# NATURE-BASED INCOME GENERATING ACTIVITIES AS LIVELIHOOD COPING AND BIODIVERSITY CONSERVATION STRATEGIES IN THE ULUGURU MOUNTAINS IN TANZANIA

**WILLICKISTER REUBEN KADIGI**

**A DISSERTATION SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE IN ENVIRONMENTAL AND NATURAL RESOURCES ECONOMICS OF SOKOINE UNIVERSITY OF AGRICULTURE.**

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## EXTENDED ABSTRACT

A study was conducted in Uluguru Mountains, Tanzania to investigate to what extent Nature-based Income Generating Activities (NIGAs) have served as effective livelihood and biodiversity conservation strategies in the study area. The specific objectives were to: a) assess the perceptions of local communities regarding the role of different NIGAs as livelihood coping and biodiversity conservation strategies, b) evaluate the economic viability of two highly ranked NIGAs, and c) evaluate factors influencing the adoption of NIGAs in the study area. The Kendall‘s Coefficient of Concordance (*W*) - Kendall‘s tau, the Spearman correlation - Spearman‘s rho, and Likert scale methods were used as metrics of perception. Viability of NIGAs was evaluated using the Costs and Benefits Analysis (CBA) approach with NPVs, BCRs, and IRR applied as decision criteria. The factors influencing NIGA adoption were evaluated using the Generalized Linear Binary Probit (GLBP) model - Multivariate Analysis of Variance (MANOVA), and Discriminant Function Analysis (DFA). The Kendall‘s, *W* statistic suggested that to some extent, the respondents agreed with each other about the rankings of NIGAs though not at a super high extent. The null hypothesis that the respondents did not agree among themselves about the NIGAs that are potential as livelihood and biodiversity conservation strategies was therefore rejected. Based on the Spearman‘s rho and Kendall‘s tau statistics, the study failed to reject the null hypothesis that the NIGAs adopted by smallholder farmers in the study area were interrelated. The results of both Likert-type and Likert scale data analyses yielded similar results suggesting that the communities in the study area moderately reduced their reliance on timber products from the UFR. The hypothesis of improved biodiversity conservation was therefore accepted. The viability analysis yielded positive NPVs for both agroforestry and beekeeping projects at discount rates not higher that 8.2% and 8.5% respectively. In terms of IRR however, beekeeping was slightly more efficient than agroforestry. Overall, agroforestry was more profitable than beekeeping in terms of NPV and BCR criteria. The results of GLBP model, MANOVA, and DFA revealed that farmland location (whether close or far from homestead), major source of capital (whether sale of farm products and assets or other sources), and type of household based on the sex of household head (whether female or male –headed household) exerted the most influence over smallholder farmers' decision to adopt NIGAs. Based on the study findings, the following recommendations are drawn: a) policy makers and development partners should understand the real needs and priorities of target communities prior to the implementation of NIGA projects to enhance livelihoods and biodiversity conservation; b) smallholder farmers need support from the government and other development partners through training and they need to be inspired to shift from orthodox farming to sustainable NIGAs, such as, agroforestry and beekeeping; and c) policy directions to benefit smallholder farmers in mountain areas should establish a strong linkage between gender equality and pro-nature agendas. Future research is recommended on: a) viability of NIGAs using a combination of empirical models and judgment to predict future discount rates and evaluate correlation of results; and b) using time series data to investigate the determinants of NIGA adoption as this facilitates the capacity to model and predict related processes. This study used cross-sectional data.

## DECLARATION

I **Willickister Reuben Kadigi**, do hereby declare to the Senate of Sokoine University of Agriculture that this dissertation is my own original work done within the period of registration and that it has neither been submitted nor being concurrently submitted for degree award in any other institution.

Willickister Reuben Kadigi Date

(MSc. Candidate)

The above declaration is confirmed by;

Prof. Yonika M. Ngaga Date

(Supervisor)

## COPYRIGHT

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## ACRONYMS AND ABBREVIATIONS

| | |
|---|---|
| $\chi^2$ | Chi Square |
| AIC | Akaike Information Criterion |
| AICC | Consistent Akaike Information Criterion |
| ANOVA | Analysis of Variance |
| BCR | Benefit Cost Ratio |
| BIC | Bayesian Information Criterion |
| BoT | Bank of Tanzania |
| BT | Benefit Transfer |
| CA | Conservation Agriculture |
| CBA | Cost-Benefit Analysis |
| CBD | Convention for Biological Diversity |
| CDA | Canonical Discriminant Analysis |
| CI | Confidence Intervals |
| CSA | Climate-Smart Agricultural |
| CVM | Contingent Valuation Method |
| DAI-PESA | Development Alternative Inc. - Private Enterprise Support Activities |
| DANIDA | Danish International Development Agency |
| DFA | Discriminant Function Analysis |
| DFID | Department For International Development |
| DIDCSC | Department for International Development Civil Society Challenge |
| DOF | Danish Ornithological Foundation |
| EAMCEF | Easter Arc Mountains Conservation Endowment Fund |

| | |
|---|---|
| EAMs | Eastern Arc Mountains |
| ETE | Economic Theory of Entrepreneurship |
| FAO | Food and Agriculture Organization |
| FDR | Financial Discount Rate |
| FGDs | Focus Group Discussions |
| GAPs | Good Agricultural Practices |
| GLBP | Generalized Linear Binary Probit |
| GLM | Generalized Linear Model |
| $H_1$ | Alternative hypothesis |
| $H_o$ | Null hypothesis |
| HQC | Hannan-Quinn Criterion |
| IBM | International Business Machines Corporation |
| IIA | Integrated Investment Appraisal |
| IPM | Integrated Pest Management |
| IPMS | Integrated Pest Management Strategy |
| IQR | Inter-Quartile Range |
| JAED | Journal of Development and Agricultural Economics |
| JEMA | Joint Environmental Management Action |
| KIIs | Key Informant Interviews |
| K-S | Kolmogorov-Smirnov |
| m.a.s.l | metre above sea level |
| MANOVA | Multivariate Analysis of Variance |
| MJUMITA | Mitandao ya Jamii ya Usimamizi wa Misitu Tanzania |
| MNP | Multimomial Probit |
| MVIWATA | Mtandao wa Vikundi vya Wakulima Tanzania |
| NAP | National Action Programme to Combat Desertification |

| | |
|---|---|
| NAPA | National Adaptation Programme of Action |
| NBSAP | National Biodiversity Strategy and Action Plan |
| NEAP | National Environmental Action Plan |
| NGOs | Non-Governmental Organizations |
| NIGA | Nature-based Income Generating Activities |
| NPV | Net Present Value |
| NSGPR | National Strategy for Growth and Poverty Reduction |
| OJF | Open Journal of Forestry |
| P-P | Probability-Plot |
| Q-Q | Quantile-Quantile |
| $R^2$ | R-Squared |
| RSPB | Royal Society for the Protection of Birds |
| SACCOS | Savings and Credit Cooperatives |
| SDGs | Sustainable Development Goals |
| SDR | Social Discount Rate |
| SFTR | Sustainable Futures |
| SLF | Sustainable Livelihood Framework |
| SOFO | State of the World's Forests |
| SPSS | Statistical Package for Social Sciences |
| SSA | Sub Saharan Africa |
| Std. Dev | Standard Deviation |
| SUA | Sokoine University of Agriculture |
| S-W | Shapiro-Wilk |
| SWC | Soil and Water Conservation |
| TAFORI | Tanzania Forestry Research Institute |
| TFCG | Tanzania Forest Conservation Group |

| | |
|---|---|
| TZS | Tanzanian Shillings |
| UFRs | Uluguru Forest Reserves |
| UMADEP | Uluguru Mountains Agricultural Development Project |
| UMBCP | Uluguru Mountains Biodiversity Conservation Project |
| UMNR | Uluguru Mountains Nature Reserve |
| UMPWSP | Uluguru Mountains Payment for Watershed Services Project |
| UMs | Uluguru Mountains |
| UNDP | United Nations Development Programme |
| URT | United Republic of Tanzania |
| VICOBA | Village Community Banking |
| VIFs | Variance Inflating Factors |
| *W* | Kendall’s coefficient of concordance |
| WCST | Wildlife Conservation Society of Tanzania |
| WTAC | Willingness To Accept Compensation |
| WTP | Willingness to Pay |

## STRUCTURE OF DISSERTATION

This thesis consists of five chapters. The first chapter consists of general introduction which provides background information on conservation of natural ecosystem and the role of nature-based income generating activities (NIGA) in promoting conservation and hence sustainable livelihoods. The chapter also presents the problem statement and justification, objectives of the study and hypotheses. Chapter two consists of paper one. The paper explores the perceptions of smallholder farmers on NIGAs as potential livelihood and biodiversity conservation strategies in Uluguru Mountains. The paper has been published by the Journal of Development and Agricultural Economics (JAED). Chapter three consists of paper two which evaluates the economic viability of smallholder agroforestry and beekeeping projects in Uluguru Mountains. The paper has been published by the Open Journal of Forestry (OJF). Chapter four consists of paper three which evaluates factors influencing the adoption of NIGAs in the study area. The paper has been published by Sustainable Futures (SFTR). Chapter four presents the key contributions the present study has made to the body of existing knowledge. It also presents some concluding remarks, policy recommendations, and outlines the areas that need further studies.

# CHAPTER ONE

## 1.0 GENERAL INTRODUCTION

### 1.1 Background

Globally, the conservation of natural ecosystems and simultaneously enhancement of livelihoods of rural communities is increasingly viewed as an important pathway to sustainable development (Sunderlin *et al*., 2005). This has in turn necessitated many governments, development partners and researchers to design programmes and initiatives that aim to effectively balance conservation goals with livelihood needs (Musinguzi *et al*., 2018; Sunderlin *et al*., 2005). Most of these programmes and initiatives focus on implementation of sustainable livelihood activities that promote nature conservation. The income generating activities which promote conservation are commonly known as Nature-based Income Generating Activities (NIGAs). This study viewed them as activities focused on creating opportunities for communities to productively use locally available resources to develop less state dependent, more self-reliant households and communities able to care for themselves. The major driver for introduction of NIGAs has been their potential to address conservation issues through the use of productive and locally available resources to the benefit of the entire community. NIGAs have a great role in biodiversity and environmental conservation as they entail actions to protect, sustainably manage, and restore natural or modified ecosystems (*ibid*).

The Uluguru Mountains are among the areas attracting NIGA programmes in Tanzania (Bhatia and Buckley, 1998). The Uluguru Mountains are part of the Eastern Arc Mountains (EAMs) providing both ecological and economic services to adjacent communities (*ibid*). The Uluguru Mountains Agricultural Development Project (UMADEP) is among the NIGA initiatives supporting sustainable agricultural practices and income generation schemes in villages located adjacent to the Uluguru Forest Reserves (UFRs). The introduction of these activities in selected villages aimed at increasing productivity per area hence reducing pressure on forest resources, while at the same time increasing income levels (*ibid*). The NIGA introduced in Uluguru Mountains include beekeeping, aquaculture, tree planting, agroforestry (intercropping of trees and/or shrubs with crops), contour farming, natural fallow, soil and stone bunds, terraces, use of composite manure and crop rotation just to mention few. However, agricultural production in the study area is currently not diversified enough dominated by bananas and livestock due to land scarcity.

## 1.2 Problem Statement and Justification

The introduction and adoption of NIGAs in highly degrading and sensitive ecosystems, like the Uluguru Mountains, can enhance livelihood coping and biodiversity conservation strategies of the communities residing adjacent to these systems (FAO, 2000; Coche, 1991). Agroforestry and beekeeping, for example, can provide outputs for home consumption as well as for sale to earn income and thus enhance food security and the welfare of the rural farmers.

Despite the high potential of NIGAs as reliable livelihoods enhancement and biodiversity conservation strategies, the rate of adoption of these activities is still low (Ayubu, 2017; Bhatia and Buckley, 1998). The factors causing this low rate of adoption are not well documented in the literature, at least in the context of Uluguru Mountains. Previous NIGA – related studies in the study area have focused mainly on the analysis of institutional and policy issues (Hartley and Kaare, 2001), as well as the contribution of good agricultural practises to socioeconomic and nutritional status (Mhina, 2015), but did not assess the perceptions of local communities regarding the role of NIGAs and their long-term economic viability. This study was therefore an endeavour to fill this knowledge gap and inform policies and strategies for sustainable livelihoods and environmental conservation in Uluguru Mountains. Specifically, the study used the sustainable livelihood framework (SLF) - a people centred framework to investigate the potential of NIGAs. The framework can be used in both planning new development activities and assessing the contribution to livelihood sustainability made by existing activities. In particular, the framework provides a checklist of important issues and sketches out the way these link to each other; draws attention to core influences and processes; and emphasises the multiple interactions between the various factors which affect livelihoods.

The study is in line with the Tanzania Development Vision 2025 which envisions a society of Tanzanians living with a high-quality livelihood. The vision aims to eradicate abject poverty and transform the economy from a low productivity agricultural economy to a semi-industrialized economy led by modernized and highly productive agricultural activities. The study is also in line with the current management plan for Uluguru Nature Reserve which promotes the adoption of Nature-based Income Generating Activities (NIGAs) such as, agroforestry, tree planting, and beekeeping, just to mention few (MNRT, 2017).

The findings of this study are therefore intended to complement the efforts of other institutions that are active in the study area, such as the Tanzania Forestry Research Institute (TAFORI), *Mitandao ya Jamii ya Usimamizi wa Misitu* Tanzania (MJUMITA), the Joint Environmental Management Action (JEMA), Mtandao wa Vikundi vya Wakulima Tanzania (MVIWATA), and others by providing an understanding of how the target population perceives these efforts, what practices are worth undertaking and what factors hinder or facilitate the adoption of these NIGAs.

## 1.3 Objectives of the Study

### 1.3.1 General objective

The general objective of the study was to investigate the extent to which Nature-based Income Generating Activities (NIGAs) introduced in the Uluguru Mountains have served as effective livelihood and biodiversity conservation strategies.

### 1.3.2 Specific objectives

The specific objectives of the study were to:

a) Assess the perceptions of local communities in the study area regarding the role of different NIGAs as livelihood coping and biodiversity conservation strategies,

b) Evaluate the economic viability of two highly ranked NIGAs, and

c) Evaluate factors influencing the adoption of NIGAs in the study area.

## 1.4 Hypotheses

The following hypotheses were put forward for the study:

a) Farmers in Uluguru Mountains do not agree among themselves about NIGAs that are most effective in enhancing livelihood and biodiversity conservation.

$H_0$: the Coefficient of concordance (the Kendall's W) is less than 0.4

$H_1$: the Coefficient of concordance (the Kendall's W) is not less than 0.4

b) The NPVs and BCRs of the first two highly ranked NIGAs are not significantly different. The null hypotheses ($H_o$) and alternative hypotheses ($H_1$) were:

$H_0$: $NPV_1 = NPV_2$ (the NPVs of the first two highly ranked NIGAs are equal)

$H_0$: $BCR_1 = BCR_2$ (the BCRs of the first two highly ranked NIGAs are equal)

$H_1$: $NPV_1 \neq NPV_2$ (the NPVs of the first two highly ranked NIGAs are not equal)

$H_1$: $BCR_1 \neq BCR_2$ (the BCRs of the first two highly ranked NIGAs are not equal)

c) There are no significant differences in **population means** of socioeconomic variables between NIGA adopters and non-adopters. The null hypothesis ($H_o$) and alternative hypothesis ($H_1$) were:

$H_o$: $\mu_1 = \mu_2$ (the two population means of socioeconomic variables are equal)

$H_1$: $\mu_1 \neq \mu_2$ (the two population means of socioeconomic variables are not equal)

OR

$H_o$: $\mu_1 - \mu_2 = 0$ (the two population means of socioeconomic variables are equal)

$H_1$: $\mu_1 - \mu_2 \neq 0$ (the two population means of socioeconomic variables are not equal)

d) There are no significant differences in population variances of socioeconomic conditions between NIGA adopters and non-adopters: The null hypothesis ($H_o$) and alternative hypothesis ($H_1$) are:

$H_0: \sigma_1^2 - \sigma_2^2 = 0$ (the population variances of socioeconomic variables for NIGA adopters and non-adopters are equal)

$H_1: \sigma_1^2 - \sigma_2^2 \neq 0$ (the population variances of socioeconomic variables for NIGA adopters and non-adopters are not equal)

## 1.5 Theoretical Framework

### 1.5.1 Assessment of perceptions of local communities regarding the role of NIGAs

The assessment of the perceptions of local communities in the study area regarding the role of different NIGAs as livelihood coping and biodiversity conservation strategies was based on the Expected Utility Maximization Theory which suggests that an individual farmer *i* will adopt a specific NIGA on his or her farm plot if the expected utility from adoption $U_{ij}^{¿}$ is greater than the expected utility from any other alternative activities or projects, here the business as usual (i.e. not adopting NIGA) $U_{ij}$, i.e. $y_{ij}^{¿}=U_{ij}^{¿}-U_{ij}>0;$ where, $y_{ij}^{¿}$, is the net benefit (latent variable) that the farmer can receive from adopting the *j*th measure.

In this regard, farmers' preferences towards the adoption of NIGAs or Good Agricultural Practices (GAPs) in the study area were assumed to be linked to the characteristics (or traits) of the practices. As argued by Roussy *et al*. (2014), farmers will choose an activity or combination of practices for which they obtain the highest expected utility of profit and the components of farmers' profit are subjectively perceived and specific to each production context based on their perceptions and preferences.

### 1.5.2 Evaluation of economic viability of NIGAs

The evaluation of economic viability of two highly ranked NIGAs was grounded on the Economic Theory of Entrepreneurship (ETE) which suggests that an entrepreneur executes all activities due to economic incentives. The theory views "profit motive" as the prime driving force that changes an individual into an entrepreneur (Pananek, 1962). In the context of of the study, the ETE implies an existence of an inner-drive for a rational farmer to decide to practice a certain NIGA rather than its alternative options. This drive can be associated with the perceived economic gains, which make the farmer to allocate his or her available scarce resources into the implementation of a specific NIGA or combination of NIGAs. The incentives for farmers to practice NIGAs may come in different forms, including availability of information and knowledge, affordability of the NIGAs in terms of investment and operating costs, as well as access to extension and lucrative output markets, just to mention few.

### 1.5.3 Evaluation of factors influencing the adoption of NIGAs

The evaluation of factors influencing the adoption of NIGAs also borrowed from the expected utility maximization theory. The theory is renowned as the best developed formal theory of rationality, which forms the core of neoclassical economics. It postulates a utility function, which measures the degree to which an individual's aggregate goals are achieved as a result of their actions. The expected utility maximization theory considers the concept of satisfaction as synonymous with consumption utility in economic psychology. As such, the adoption of NIGAs in the current study was considered to depend on expected utility of farmers which in turn is influenced by other constraining and facilitating factors.

## 1.6 Empirical Framework

Several studies have investigated the adoption of NIGAs and Good Agricultural Practices (GAPs) in developing countries (Ochieng *et al*., 2019; Asfaw and Neka, 2017; Tesfaye *et al*., 2016; Teshome *et al*., 2016; Barungi *et al*., 2013; Kahimba *et al*., 2014). Ochieng *et al*. (2019) for example, have evaluated the adoption of improved amaranth and GAPs in East Africa. In Ethiopia, Asfaw and Neka (2017), Tesfaye *et al*. (2016) and Teshome *et al*. (2016) have evaluated factors influencing the adoption of Soil and Water Conservation

(SWC) practices. A similar study was also conducted by Barungi *et al*. (2013) who evaluated the factors that influenced the adoption of soil erosion control technologies along the slopes of Mountain Elgon in Eastern Uganda. In Tanzania, Kahimba *et al*. (2014) have evaluated the adoption and scaling-up of conservation agriculture in Arusha and Dodoma regions.

These studies have used different economic models to evaluate factors which influence the adoption of GAPs and have generally come up with different results and conclusions. Abdulai and Huffman (2014), for example, have used the Endogenous Switching Regression Model to evaluate the adoption and impact of SWC technology in Africa. They identify the factors that affect farmers' decisions to adopt SWC technology as including farmers' education, capital and labour constraints, social networks and extension contacts, and soil conditions. Barungi *et al*. (2013) and Asfaw and Neka (2017) found the adoption of GAPs to be affected by socio-economic factors, like sex, age and education of head of household, household assets, income, size of land and livestock holdings, engagement in off-farm activities, as well as access to credits. Other studies found contact with extension agents (Asfaw and Neka 2017; Fentie *et al*., 2013) and perceptions of farmers regarding the farm characteristics and extent of environmental degradation (Teshome *et al*., 2016) to be influencing the decision of farmers to adopt GAPs.

In Nepal, Adhikari *et al*. (2019) used the probit model to determine the extent of technology adoption between improved and local seed users of Arghakhanchi district of Nepal. They found that the extent of technology adoption and benefit cost ratio were significantly higher for improved seed users than local seed users. The probability of adoption of recommended technology (improved seed) for maize farming was found to be higher for those with access to extensive service.

However, studies which have attempted to evaluate the perception of farmers were generally limited in scope. Most did not evaluate the perception of farmers on the role of NIGAs in enhancing livelihoods and conservation of biodiversity and the environment and their economic feasibility. Tenge *et al*. (2011), for example, evaluated the perception and effectiveness of SWC measures in East African Highlands but did not consider the long-term economic viability or time value of money for the introduced conservation measures. Most of these studies have assumed the adoption of GAPs as mutually exclusive with little or no interdependency among the various influential factors. This assumption is inaccurate because it implies that a farmer can only choose one GAP (or NIGA in this case) to practice on his/her single farming plot from several mutually exclusive (independent) options. The analysis based on this assumption ignores the possibility for GAPs or NIGAs to complement or substitute each other (the likelihood of having either positive or negative correlations respectively). This is imperative because several other studies (e.g. that of Amare *et al*., 2014; Tenge *et al*., 2011) have already observed that farmers can adopt more than one GAPs measures on an individual plot.

This study recognized the fact that NIGAs are not necessarily mutually exclusive and that farmers may implement more than one NIGA simultaneously on a single plot. The study used the case of smallholder farmers in Uluguru Mountains to assess the factors that jointly act to impede or facilitate the adoption of different NIGAs. Based on the results of evaluation of farmers’ perceptions, a Cost-Benefit Analysis (CBA) was conducted to compare the relative worthiness or economic viability of two highly ranked NIGAs in terms of their effectiveness as livelihood coping and biodiversity as well as environmental conservation strategies.

The analysis and comparison of profitability and viability between adopters and non-adopter of good agricultural practices has of recent received a particular attention among scholars. Muriithi *et al*. (2020) for example, have compared the potential adoption of Integrated Pest Management Strategy (IPMS) for suppression of Mango Fruit Flies in East Africa using the case of Ethiopia and Kenya. Specifically, they used a multinomial logit model to assess and compare the potential adoption of the fruit fly IPM technology and the determinants of fruit fly IPM adoption behaviour among mango farmers in the two countries. Their results revealed that this technology has a relatively high adoption rate and high prospects for adoption growth in Kenya compared to Ethiopia in the near future.

Elsewhere, Adhikari *et al*. (2019) did a CBA to compare categories of farming households (i.e. farmers using improved seed and farmers using local seed for maize production) to assess profitability. Specifically, they used the Benefit Cost Ratio (BCR) or the benefit per unit cost.

However, these previous studies have used undiscounted methods of CBA disregarding the potential disparities in the value of money over the lifespan of the project (the value of money today is not the same as the value of money tomorrow). To address this drawback the streams of costs and benefits were discounted at different interest rates to estimate the respective NPVs and BCRs and these were compared between two highly ranked projects using an ex post econometric CBA approach. Where the data were not readily available or reliable the analysis was complemented by information and data transferred from similar studies conducted elsewhere in Tanzania. In this regard the study by Kuboja *et al*. (2017)

provided very useful information and data especially for the CBA in the beekeeping project though their study also did not use discounted values.

### 1.7 Description of the Study Area

The study was conducted in fourteen hamlets (Table 11.) located near or along the Uluguru Mountains Nature Reserve in the wards of Mlimani and Luhungo (Morogoro Municipality), and Mzumbe (Mvomero district).

**Table 1.1: Location of the study hamlets**

| Village/Hamlet | Ward | Division | District | Altitude (masl) | Position | |
|---|---|---|---|---|---|---|
| | | | | | Eastings | Northings |
| Tangeni/Kikoya | Mzumbe | Mlali | Mvomero | 656 | 345874 | 9234196 |
| Tangeni/Chalinze | Mzumbe | Mlali | Mvomero | 860 | 347046 | 9233084 |
| Tangeni/Simbo | Mzumbe | Mlali | Mvomero | 737 | 346759 | 9232891 |
| Tangeni/Mng'hongo | Mzumbe | Mlali | Mvomero | 737 | 346466 | 9233799 |
| Tangeni/Mihubulu | Mzumbe | Mlali | Mvomero | 883 | 347563 | 9234125 |
| Kilala | Luhungo | Morogoro | Morogoro | 731 | 349501 | 9236858 |
| Mundu | Luhungo | Morogoro | Morogoro | 847 | 350263 | 9236314 |
| Mambani | Luhungo | Morogoro | Morogoro | 975 | 350490 | 9237492 |
| Kivaza | Luhungo | Morogoro | Morogoro | 722 | 348904 | 9236453 |
| Mbete | Mlimani | Morogoro | Morogoro | 808 | 353746 | 9241263 |
| Ruvuma | Mlimani | Morogoro | Morogoro | 1041 | 352694 | 9240058 |
| Choma | Mlimani | Morogoro | Morogoro | 1212 | 354139 | 9239703 |
| Kisosa | Mlimani | Morogoro | Morogoro | 1341 | 353599 | 9239560 |
| Tulo | Mlimani | Morogoro | Morogoro | 1192 | 352716 | 9239617 |

The study area has been selected because of existing challenge of increasing human activities that threaten biodiversity and the environment at large. There are different land uses in the study area (Figures 1.2 and 1.2), especially in the hamlets that border the Uluguru Mountains which constitute a biodiversity hotspot and home to hundreds of species found nowhere else on earth. The area also serves as a water catchment and water source for populations living downstream in Morogoro rural and Municipality as well as other residents in the Dar es Salaam City and the Ruvu/Wami River Catchments. Land degradation in the study area is reported to be rampant caused by unsustainable anthropologic activities (Massawe *et al.*, 2020; Massawe *et al.*, 2019; Harrison and Mdee, 2017; William, 2010; Yanda and Munishi, 2007; Lyamuya *et al.*, 1994). The study focus was to investigate whether the NIGAs introduced by different projects in the study sites have helped to overcome the challenge of environmental degradation and biodiversity loss. Put differently the idea was to evaluate whether these NIGAs have serve as effective livelihood and biodiversity conservation strategies.

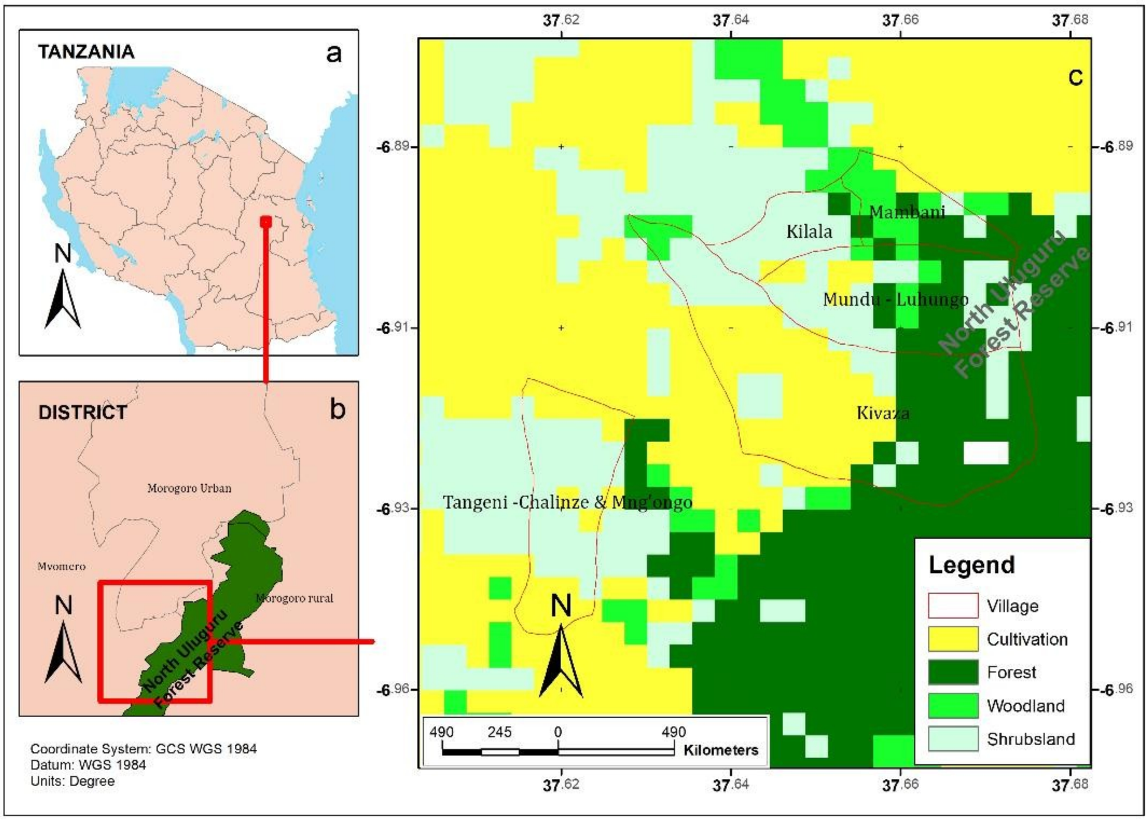



**Figure 1.1: Map showing the location of study sites and existing land uses**

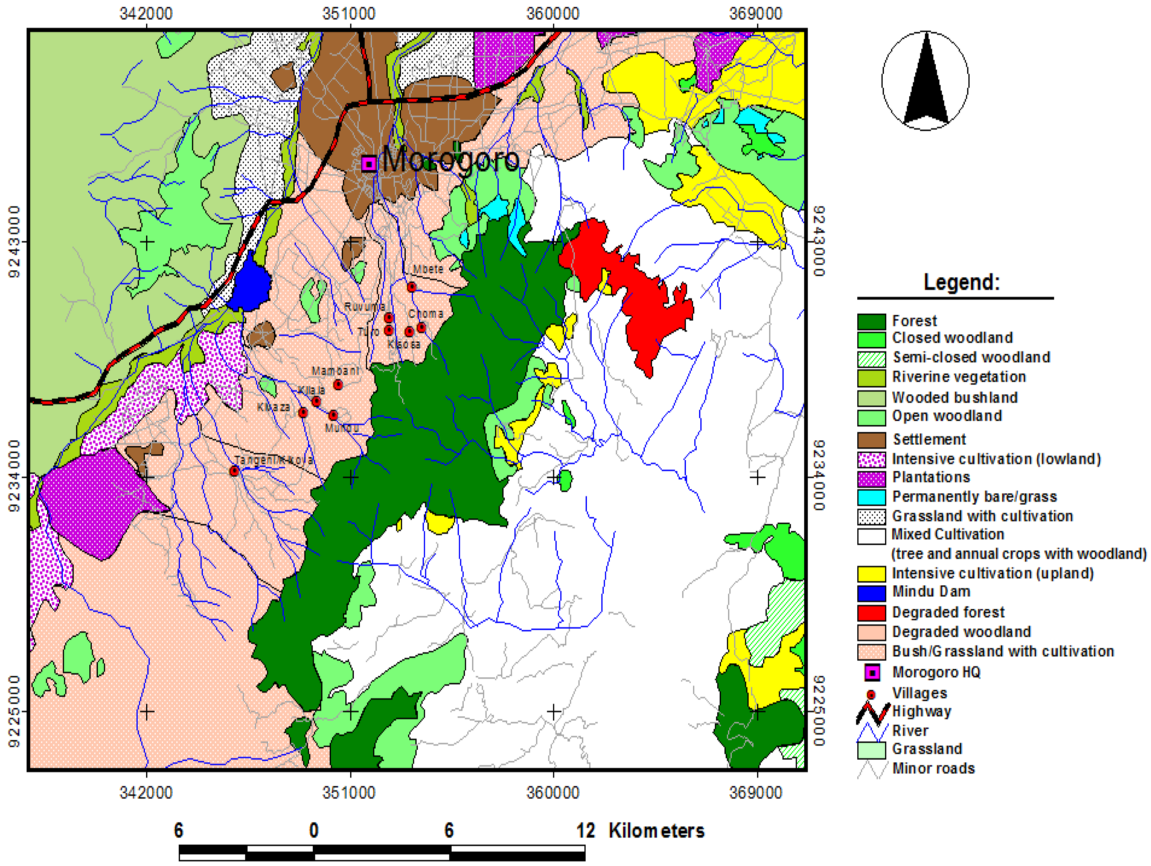



**Figure 1.2: Geographic land use map of the study area (Source: WCST, 2010)**

## 1.8 Research Design

The study employed a non-experimental research design using the cross-sectional research technique whereby data were collected at a single point in time from selected sample of respondents to represent the population. This design allows determination of relationship between variables while requiring little resources and providing useful information and data for simple statistical analysis and interpretation (Levin, 2016; Kothari, 2004).

## 1.9 Sampling Procedure

The study used the multi-stage sampling procedure to select the study villages and sample households. In the first stage, fourteen hamlets were selected purposely based on their participation in the previous NIGA projects, notably the Uluguru Mountains Payment for Watershed Services Project (UMPWSP), funded by the Department for International Development Civil Society Challenge and supported by the Royal Society for the Protection of Birds (RSPB) in partnership with the Wildlife Conservation Society of Tanzania (WCST) and others.

In the second stage, households were stratified into strata according to wealth ranks assigned by UMPWSP. The third stage entailed the selection of sample households from each stratum using the proportionate probability sampling procedure. The actual sample size for each stratum was established using the formula suggested by Bartlett *et al.* (2001) as shown in Equation 1.

$$n=\frac{n_0}{1+\frac{(n_0-1)}{N}} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (1)$$

where: $n$ is the require sample size, $N$ is the population size, $n_o$ is the sample size (equal to 223 households for the all hamlets). The study of NIGA adoption in the study hamlets involved only 2 009 households. The sample size that would be necessary was therefore calculated as follows:

$$n=\frac{223}{1+\frac{(223-1)}{2009}}=201$$

The distribution of samples by hamlets is provided in Table 1.2.

**Table 1.2: Distribution of sample sizes by sample hamlets**

| **Hamlets** | **Households** | **Sample size*** | **%** |
|---|---|---|---|
| Tangeni village (5 hamlets) | 1 030 | 66 | 32.8 |
| Kilala** | 85 | 12 | 6.0 |
| Mundu | 145 | 15 | 7.5 |
| Mambani | 152 | 21 | 10.4 |
| Kivaza | 167 | 21 | 10.4 |
| Mbete | 22 | 9 | 4.5 |
| Ruvuma | 72 | 15 | 7.5 |
| Choma | 210 | 21 | 10.4 |
| Kisosa | 84 | 12 | 6.0 |
| Tulo | 42 | 9 | 4.5 |
| **Total** | **2 009** | **201** | **100** |

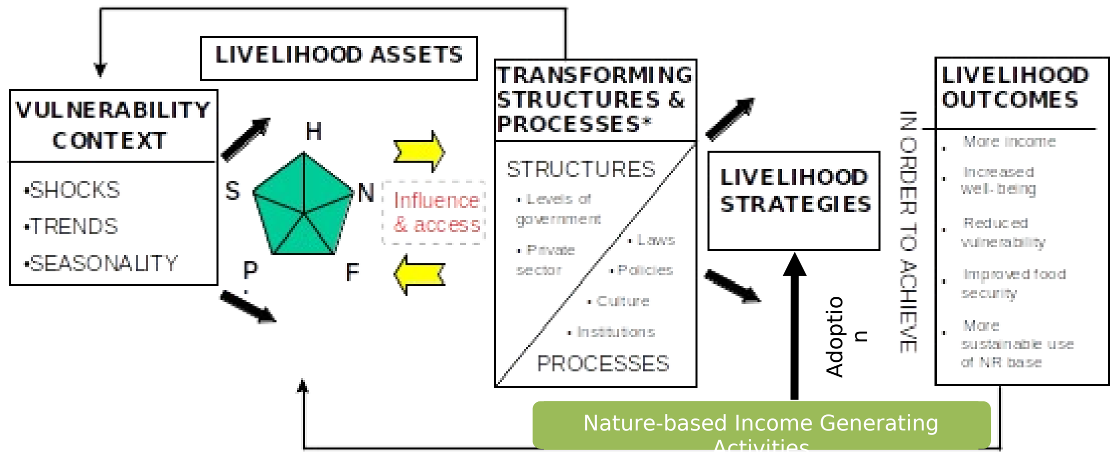
*The total sample size used in the final analysis (after data cleaning) was 154 households.
**The number of households in Kilala hamlet excludes the households in the Military base of Mzinga. If these households were considered the total number of households for Kilala hamlet would be 750.

As argued by Nachimias and Nachimias (1996) sample size is one of the most important determinants of survey estimates gauged by precision yardsticks (i.e. the amount of sampling error that can be tolerated) and the confidence level or the level of certainty that the true value of the variable being studied is captured within the standard error or sampling error. According to Nachimias and Nachimias (1996) the greater the precision of estimate and confidence in the results, the larger the sample size that is required. Elsewhere in the literature, Gay and Diehl (1992) also affirm that the number of respondents for a study often depends on the type of the research (i.e. if descriptive, correlational, or experimental). For descriptive research, for example, the sample should be 10% of the population. But if the population is small, then 20% of the population may be required. For correlational research at least 30 subjects are required to establish the relationship. For experimental research, 30 subjects per group are often cited as the minimum. As such, the sample size of 201 households in this study is considered adequate as it was equal to 10% of the total households. Given the scope of the study and available resources for fieldwork (time, fund and personnel) the sample size of 10% was reasonable.

## 1.10 Conceptual Framework

To investigate the NIGAs practiced along the Uluguru Mountains and the factors influencing their adoption in the study area, the DFID's Sustainable Livelihood Framework (SLF) was adopted. The framework was slightly modified to encompass NIGAs as livelihood and biodiversity conservation strategies and pathways for "sustainable livelihood outcomes" measured using the yardsticks of economic viability (increased net present income and wellbeing), reduced vulnerability and sustainable use of natural resources (Error: Reference source not found).

According to Carney (1998) a livelihood, which comprises the capabilities, assets (including both material and social resources) and activities required for a means of living, is sustainable when it can cope with and recover from stresses and shocks and maintain or enhance its capabilities and assets both now and in the future, while not undermining the natural resource base. In the conceptual framework livelihood outcomes are considered to be determined by the portfolio of livelihood strategies practiced by communities. Of these, the adoption of NIGAs is considered to strengthen the portfolio and hence enhance livelihoods while ensuring sustainable use of natural resource base. The adoption of these strategies is considered to be determined by the existing transforming structures (e.g. levels of government and private sector's involvement) and processes (e.g. laws, policies, culture, institutions and livelihood assets) as well as the livelihood assets at the exposure of the people or communities.




Key: H = Human Capital; N = Natural Capital; F = Financial Capital; S = Social Capital; P = Physical Capital

**Figure 1.3: The DFID's sustainable livelihood framework (modified from Carney and Ashley, 2000)**

The capital upon which people build their livelihoods includes a portfolio of five different types of assets namely:

(i) *Natural capital (N)* such as land, water, forests, marine resources, air quality, erosion protection, and biodiversity.

(ii) *Physical capital (P)* including transportation, roads, buildings, shelter, water supply and sanitation, energy, technology, or communications.

(iii) *Financial capital (F)* including savings (cash as well as liquid assets), credit (formal and informal), as well as inflows (state transfers and remittances).

(iv) *Human capital (H)* including education, skills, knowledge, health, nutrition, and labour power.

(v) *Social capital (S)* which includes any networks that increase trust, ability to work together, access to opportunities, reciprocity, informal safety nets, and membership in organizations.

Given the interaction of livelihood assets with the vulnerability context and institutions, various livelihood strategies may take the lead in singular or in combination. These strategies refer to the choices people employ in pursuit of income, security, well-being, and other productive as well as reproductive goals. They are the patterns of behaviour adopted by the household as a result of the mediation processes on the household assets and have been classified according to different criteria. Scoones (1998) and Swift (1998), for example, classify rural livelihood strategies into three broad types according to the nature of activities undertaken: agricultural intensification and extensification, livelihood diversification, and migration.

Ellis (2000) classifies livelihood strategies based on the observation that for the majority of rural households in Sub Saharan Africa (SSA), farming alone does not provide a sufficient means of survival. Most rural households increasingly rely on constructing a diverse portfolio of activities and income sources in order to survive and to improve their standard of living. This includes both on - and off - farm activities undertaken to generate income (i.e. monetary and non-monetary contributions to household consumption) additional to that from the main household agricultural activities. Ellis (2000) divides these activities into natural resource and non-natural resource based activities. He identifies seasonality, risk, labour markets, credit substitution, and asset strategies (investment to enhance future livelihood prospects e.g. developing networks, education) as factors which might induce voluntary motives for the adoption of diverse livelihoods.

Davies (1996) amongst others has made the distinction between survival, coping, adaptive and accumulative strategies. Accumulative strategies are those which increase consumption outcomes and stocks of assets in response to opportunity. Adaptive strategies are those that seek to spread risk of consumption failure in response to anticipated adverse trends. This may be through the intensification of existing livelihood strategies or by diversification into new activities. Coping strategies are those that absorb the impact of an adverse shock by drawing down assets and reducing consumption. When there is no respite coping may lead to survival strategies. With survival strategies not only is consumption drastically reduced, but household assets are extensively, most often irreversibly eroded, in an attempt to ward off destitution and death.

Siegel and Alwang (1999) classify household livelihood strategies on the basis of how they manage risk, differentiating between ex-ante strategies which seek to reduce or mitigate risks, and ex-post strategies which are ad-hoc responses to unforeseen events and outcomes. Such strategies are typically part of a sequential planning process, in which a combination of risk prevention, risk mitigation and coping are practised in anticipation of, and in response to, risky events and outcomes

Livelihood outcomes encompass many of the types of impact of interest. Potential outcomes include conventional indicators such as income, food security, and sustainable use of natural resources. Outcomes can also include a strengthened asset base, reduced vulnerability, and improvements in other aspects of well-being such as health, self-esteem, sense of control, and even maintenance of cultural assets, and thus have a feedback effect on the vulnerability status and asset base.

## 1.11 Data Collection, Processing and Analysis

### 1.11.1 Data collection

The study used both primary and secondary data. Prior to commencement of fieldwork, the researcher hired six enumerators to assist her during data collection. These were trained on how to administer questionnaires and use other research tools (checklists and guidelines). They were also reminded about the research ethics they should comply with.

The actual fieldwork started with a reconnaissance survey to get an overview and understanding of the study area and applicability of the questionnaire. During the reconnaissance survey the household questionnaire was pre-test to a small number of respondents before the actual fieldwork to check for their relevance to the study area and objectives. This was followed by the main survey which used different research tools and techniques, including structured questionnaires and checklists for interviews with key informants (selected based on their involvement in NIGA initiatives) and Focus Group Discussions (FGDs).

The FGDs were attended by about 10 participants per hamlet representing different socioeconomic groups that existed in the area, including the rich, poor, youth and women, men, abled and disabled people. In addition, direct observation served as a complementary tool. In selecting the key informants for interview the snowball technique was used. The technique is particularly suitable when the population of interest is hard to reach and compiling a list of the population poses difficulties for the researcher (Etikan *et al*., 2016). It begins with a convenience number of initial subject which serves as “seeds,” through which wave 1 subject is identified; wave 1 subject, in turn, identifies wave 2 subjects; and the number of interviewees consequently expands wave by wave-like a snowball growing in size as it rolls down a hill (Heckathorn, 2015).

### 1.11.2 Data cleaning and statistical tests

Before data analysis, the collected data were cleaned and tested for different statistical hypotheses, including the assumption of normality, and the outliers were removed. To test for normality, the Explore procedure in SPSS was used to produce univariate descriptive, as well as Confidence Intervals (CIs) for the mean, normality tests, and plots. The output of the test in this case included univariate descriptive statistics for each of the continuous variables, including skewness and kurtosis. It should be noted that the standard normal distribution has a skeweness and kurtosis of zero. However, the skewness numbers alone should not be taken for granted as very good indicators of disparities from normality, but they can supplement the graphs and the normality tests. The tests of normality entail the Kolmogorov-Smirnov (K-S) and Shapiro-Wilk (S-W) tests, in which the null hypothesis is rejected when the *p*-values are smaller than the chosen significance level ($\alpha = 0.05$ in this study), suggesting non-normality. However, the two tests (K-S and S-W can also show contradictory conclusions.

This disparity can be resolved by looking at the graph output, such as the boxplot showing the direction of skewness (left tail, media or central line, right tail, and the outliers if any). In statistical analyses, outliers are extreme values that do not seem to fit with the majority of a data set (Kent State University Libraries, 2017). If not removed, these extreme values can have a large effect on any conclusions that might be drawn from the data in question, because they can slant the correlation coefficients and lines of best fit in the wrong direction. In this study outlying values were identified and removed from the data set using the SPSS software programme. Specifically, the normal Q-Q and detrended Q-Q plots were used to ascertain the presence of systematic deviances from normality (Appendix 2).

The detrended normal Q-Q plot acts as a magnifying glass for normal Q-Q allowing the analyst to see just how strong the existing deviances (the y –axis of this plot shows the range of deviances from normality). Note that the cleaning of data (removal of erroneous observations and extreme values) in this study reduced the original sample size from 201 to 154.

In the Q-Q plot approach, the observed value and expected value are plotted on a graph. If the plotted values vary more from a straight line, then the data is not normally distributed. Otherwise data will be normally distributed (Schreiber-Gregory and Jackson Foundation, 2018). The detrended normal Q-Q plot shows a horizontal line representing what would be expected for that value if the data were normally distributed. Any values below or above represent what how much lower or higher the value is, respectively, than what would be expected if the data were normally distributed (*ibid*).

The dataset was also tested for heteroskedasticity which refers to the state of systematic changes in the spread of residuals or the error term of the model. The presence of residual variance in a model would show that the scattering of the model is dependent on at least one independent variable. Heteroskedasticity was tested using graphical or visual tests and statistical tests. Specifically, the graphical tests included the scatter plots, P-P normal plots, and histograms. Where the presence of heterosckedasticity in the model was detected the causal predictor variables were excluded in the regression analysis.

The predictor variables were also correlated to check for multicollinearity and some variables were found to have *r* value equal to or greater than 0.8 (shaded cell in Table 1.3), which meant that there was a problem of multicollinearity for these predictor variables. Consequently, the variables were removed from the regression analysis (Field, 2019). This test was also complemented by computing the Variance Inflating Factors (VIFs) and tolerances of independent variables (Table 1.4). The VIFs were found to be less than 1.9 and tolerance values were greater than 0.1, which was not enough to overlay concerns about presence of multicollinearity. VIFs greater than 10 and tolerances less than 0.1 would imply the presence of muticollinearity problem (Landau and Everitt, 2004).

**Table 1.3: Results of Pearson correlation analysis, cells with r values equal to or greater than 0.8 are shaded**

| Variables | Income from crops and TPs (TZS) | Income from farm TPs (TZS) | Income from crops (TZS) | Annual operating costs (TZS) | WTAC (TZS) | Revenue per acre (TZS) | Total household income (TZ) | Farm operation cost per acre (TZS) |
|---|---|---|---|---|---|---|---|---|
| Income from crops and TPs (TZS) | 1 | 0.941 | 0.998 | 0.992 | 0.917 | 0.725 | 0.986 | 0.650 |
| Income from farm TPs (TZS) | 0.941 | 1 | 0.918 | 0.955 | 0.972 | 0.703 | 0.919 | 0.643 |
| Income from crops (TZS) | 0.998 | 0.918 | 1 | 0.986 | 0.894 | 0.720 | 0.986 | 0.643 |
| Annual operating costs (TZS) | 0.992 | 0.955 | 0.986 | 1 | 0.933 | 0.710 | 0.975 | 0.651 |
| WTAC (TZS) | 0.917 | 0.972 | 0.894 | 0.933 | 1 | 0.647 | 0.899 | 0.592 |
| Revenue per acre (TZS) | 0.725 | 0.703 | 0.720 | 0.710 | 0.647 | 1 | 0.696 | 0.970 |
| Total household income (TZ) | 0.986 | 0.919 | 0.986 | 0.975 | 0.899 | 0.696 | 1 | 0.625 |
| Farm operation cost per acre (TZS) | 0.650 | 0.643 | 0.643 | 0.651 | 0.592 | 0.970 | 0.625 | 1 |

**Table 1.4: Results of multicollinearity test**

| Model | Unstandardized Coefficients | | Standardized Coefficients | T | Sig. | Collinearity Statistics | |
|---|---|---|---|---|---|---|---|
| | B | Std. Error | Beta | | | Tolerance | VIF |
| Dependent Variable: Age of household head | | | | | | | |
| (Constant) | 31.688 | 2.102 | | 15.073 | 0.000 | | |
| Household size | 3.403 | 0.337 | 0.635 | 10.087 | 0.000 | 0.885 | 1.129 |
| Size of farmed land (acres) | -0.582 | 0.468 | -0.089 | -1.245 | 0.215 | 0.684 | 1.463 |
| Value of household assets (TZS) | 2.412E-07 | 0.000 | 0.155 | 2.052 | 0.042 | 0.619 | 1.616 |
| Dependent Variable: Size of farmed land | | | | | | | |
| (Constant) | 3.069 | 0.522 | | 5.880 | 0.000 | | |
| Household size | -0.033 | 0.076 | -0.040 | -0.429 | 0.669 | 0.528 | 1.893 |
| Value of household assets (TZS) | 1.434E-07 | 0.000 | 0.600 | 8.399 | 0.000 | 0.885 | 1.130 |
| Age of household head | -0.018 | 0.014 | -0.115 | -1.245 | 0.215 | 0.532 | 1.880 |
| Dependent Variable: Value of household assets | | | | | | | |
| (Constant) | -6 819 169.398 | 2 214 554.639 | | -3.079 | 0.002 | | |
| Household size | 540 605.455 | 296 090.482 | 0.157 | 1.826 | 0.070 | 0.539 | 1.854 |
| Age of household head | 113 163.965 | 55 157.729 | 0.177 | 2.052 | 0.042 | 0.541 | 1.848 |
| Size of farmed land (acres) | 2 230 752.032 | 265 594.847 | 0.533 | 8.399 | 0.000 | 0.995 | 1.005 |
| Dependent Variable: household size | | | | | | | |
| (Constant) | -1.201 | 0.615 | | -1.953 | 0.053 | | |
| Age of household head | 0.119 | 0.012 | 0.636 | 10.087 | 0.000 | 0.883 | 1.132 |
| Size of farmed land (acres) | -0.038 | 0.088 | -0.031 | -0.429 | 0.669 | 0.677 | 1.476 |
| Value of household | 4.022E-08 | 0.000 | 0.138 | 1.826 | 0.070 | 0.615 | 1.625 |

| |
|---|
| assets (TZS) |

### 1.11.3 Perceptions of local communities regarding the role of NIGAs

This objective is discussed in detail in Chapter two "perceptions of smallholder farmers on nature-based income generating activities as potential livelihood and biodiversity conservation strategies in Uluguru mountains, Tanzania." Data were collated using different tools including household questionnaire, FGDs, KIIs, direct observation approaches, review of government and project document as well as office records. During the household survey the respondents were asked to rank the identified NIGAs according to their importance in terms of enhancing livelihoods and biodiversity or environmental conservation. The information was then combined, coded and used in the analysis.

The assessment of perceptions of local communities in the study area regarding the role of introduced NIGAs in enhancing livelihoods and sustainable use of natural resources applied the approach described by Legendre (2010) which entails the computation of Kendall's coefficient of concordance (*W*). The coefficient (*W*) is used to measure the agreement among several quantitative or semi-quantitative variables that assess a set of objects of interest. It was calculated using the IBM SPSS 20 software. Specifically, the Kendall's Coefficient of Concordance (*W*)/Kendall's tau, the Spearman correlation/Spearman's (rho), and the Likert scale methods were used to identify the highly ranked NIGAs and test the hypotheses that: (a) the smallholder farmers in the study area did not agree among themselves about the ranking of potential livelihood and biodiversity-enhancing NIGAs, (b) the promotion of agroforestry has reduced the communities' reliance on firewood, building poles and wood from the Uluguru Forest Reserve (UFR). The latter was used as an indicator of improved biodiversity conservation.

### 1.11.4 Evaluation of economic viability of two highly ranked NIGAs

This objective is addressed and discussed in Chapter three which entails the analysis of economic viability involved two highly ranked NIGAs as identified in the foregoing section (agroforestry with tree planting and beekeeping in this case). The analysis benefited from the information and data gathered during FGDs, KII and questionnaire survey, complemented by information gathered through deskwork review of relevant documents. The information and data gathered during the fieldwork and through literature review helped the generation of streams of costs and benefits of the two NIGAs over their life spans. Both the short and long term costs and benefits were taken into consideration to ensure that the projections are based on realistic lifespan of the respective NIGAs, looking at how both costs and benefits evolve over time. The identification of physical amounts and expected value of costs and benefits (i.e. the financial receipts and outlays as measured by market prices) entailed the specification of when they occur in time.

The types of benefit and cost information gathered included: a) the direct benefits and costs associated with the production of a cost object, like product, service, or activity; b) indirect benefits and costs, which are usually fixed in nature, and may come from overhead of the NIGAs; c) tangible benefits and costs, which usually related to an identifiable source or asset, like purchasing tools; and d) real benefits and costs or expenses associated with producing an offering (product or service).

In addition, information and data on interest rates were gathered to inform the selection of discount rate for future benefits and costs to obtain the present value (the equivalent value that one is receiving or giving up today when the decision to adopt a certain NIGA is made). NPV, in this case, refers to the present value of the NIGA’s net benefit stream, obtained by discounting the stream of net benefits produced by the NIGA over its lifetime, back to its value in the chosen base period, usually the present. The market rate of interest and social interest rate were used for discounting the annual net-benefit stream of NIGAs. The individual worthiness or economic viability of the two highly ranked NIGAs was evaluated and compared using the CBA approach. In particular, the costs and benefits of the two NIGAs were projected and compared using the Net Present Values (NPVs) and Benefit-Cost Ratios (BCRs) as measures of economic viability. (Fudge, 2011).

### 1.11.5 Evaluation of factors influencing adoption of NIGAs

This objective is addressed and discussed in Chapter four. The evaluation of factors influencing adoption of NIGAs benefited from information and data which were gathered using mainly the household questionnaire which included a wide range of questions intended to identify the factors that influence the adoption of NIGAs in the study area. Specifically, the questionnaire was used to solicit information on demographics, socio-economics characteristics (e.g. household asset endowment), existing transforming structures and processes/institutional contexts of the sample households, as well as, plot specific characteristics, and types of NIGA adopted.

The study applied the Multimomial Probit (MNP) model to evaluate the factors influencing adoption of NIGAs. The MNP model was preferred for its flexibility which allows random test variation and can represent any substitution pattern, avoiding the restrictive substitution pattern assumptions in other models (Willis, 2014). The model assumes a normal distribution for all unobserved components of utility. Other models, such as the Probit models simply use the cumulative Gaussian normal distribution rather than the logistic function for calculating the probability of being in one category or not (*ibid*).

The maximum likelihood method was used to fit the set of statistical NIGA adoption models on sets of simulated data. The best relationships were compared and selected using the Akaike information criterion (AIC); Bayesian information criterion (BIC) methods (Heo *et al*., 2011; Heo, 2020), and the Finite Sample Corrected AIC (AICC). The AIC and BIC have the advantage of testing the significance of the difference between the functions of different model specifications. AIC evaluates how well a model fits the data it was generated from. It is used to compare different possible models and determine which one is the best fit for the data. It is calculated from the number of independent variables used to build the model and the maximum likelihood estimate of the model (how well the model reproduces the data).

## 1.12 Possible Limitations of the Study

While the findings of the study are generally viewed as fairly robust, detailed and empirical, there are some limitations which are worth acknowledging. Firstly, the primary data collection process relied primarily on the responses of interviewees. As such the precision of information they provided, in the absence of recording keeping, might have been influenced by their ability to recall past events. In this regard the use of information triangulation using different approaches, such as KII and FGDs was very useful in verifying the information.

Secondly, due to the diverse but interconnected and complex nature of mountain agro-ecologies, like that of Uluguru Mountains, modelling of the factors which influence adoption of NIGAs in these areas can be cumbersome. For example, the statistics in our final stage of analysis show that our model was able to describe only 26.4% of all the causal-effect relationships.

Thirdly, the model used cross-sectional instead of time series data. This can also be misleading unless the year under study precisely represents the long-term scenario of the phenomena under study. The use of time series data is preferred because it has the advantage of enabling natural ordering which makes it distinct from cross-sectional studies, in which there is no natural ordering of observations. Most standard data analysis methods used in adoption studies, such as, ANOVA and OLS regression assume linear association between variables of interest. Time series analysis has an additional advantage of modelling both linear and nonlinear relationships between variables over time. In fact, nonlinear functions are reported to provide better approximation of the true relationship between adoption-related variables.

Despite these limitations the study still offers some very useful insights to inform agricultural policy reforms for balancing the existing trade-offs between economic gains and sustainable nature conservation in fragile agro-ecologies of mountain areas. The study identifies some of the key determinants of NIGA adoption upon which the policy reforms should focus on, notably, the issues related to access to land and financial resources.

## 1.13 Organization of the Dissertation

This dissertation is organized into five chapters. The next three chapters present journal papers which were published using the findings from this study. The first paper is presented in Chapter 2 and was published by the Journal of Development and Agricultural Economics (JAED). The paper investigated the perceptions of smallholder farmers on NIGAs as potential livelihood and biodiversity conservation strategies in the study area. The second paper was published by the Open Journal of Forestry (OJF) and is presented in Chapter 3. It investigated the economic viability of smallholder agroforestry and beekeeping projects in the study area. The third paper is presented in Chapter 4 and was published by Sustainable Futures (SFTR). It evaluated the determinants for adoption of NIGAs in the study area. Finally, a conclusion of the major findings and recommendations are presented in Chapter 5.

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# CHAPTER TWO

## 2.0 PERCEPTIONS OF SMALLHOLDER FARMERS ON NATURE-BASED INCOME GENERATING ACTIVITIES AS POTENTIAL LIVELIHOOD AND BIODIVERSITY CONSERVATION STRATEGIES IN ULUGURU MOUNTAINS, TANZANIA

Paper 1

Willickister R. Kadigi[1], Yonika Ngaga[1] and Reuben M. J. Kadigi[2]

[1]Department of Forest and Environmental Economics, College of Forestry, Wildlife and Tourism
Sokoine University of Agriculture, P.O. Box 3011, Morogoro, Tanzania.

[1]Department of Forest and Environmental Economics, College of Forestry, Wildlife and Tourism
Sokoine University of Agriculture, P.O. Box 3011, Morogoro, Tanzania.

[2]Department of Food and Resource Economics, School of Agricultural Economics and Business Studies.
Sokoine University of Agriculture, P.O. Box 3007, Morogoro, Tanzania.

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## 2.1 Abstract

Nature-based Income Generating Activities (NIGAs) can enhance livelihoods of smallholder farmers and biodiversity conservation in highly degrading ecosystems. These practices are promoted by various development and conservation partners worldwide to combat land degradation and biodiversity loss. However, their adoption remains low for reasons not well understood by their promoters. This can largely be attributed to the failure of the promoters to recognise and acknowledge the perceptions and priorities of target communities. We use the case of Uluguru Mountains to investigate the perceptions of farmers regarding the NIGAs that have potential to enhance both livelihoods and biodiversity conservation. Specifically, we use the Kendall's Coefficient of Concordance (*W*)/Kendall's tau, the Spearman correlation/Spearman's (rho), and the Likert scale methods to identify the highly ranked NIGAs and test the hypotheses that: (a) the smallholder farmers in the study area did not agree among themselves about the ranking of potential livelihood and biodiversity-enhancing NIGAs, (b) the promotion of agroforestry has reduced the communities' reliance on firewood, building poles and wood from the Uluguru Forest Reserve (UFR). We used the latter as an indicator of improved biodiversity conservation. We found that agroforestry and beekeeping were the highly ranked NIGAs and the communities in the study area had moderately reduced their reliance on timber products from UFR. We conclude that NIGAs can significantly enhance livelihoods and conserve biodiversity in mountain areas. However, future efforts to promote them should be guided by a thorough understanding and recognition of the real needs and priorities of target beneficiaries. This is imperative for winning their support and for designing the right outreach package.

**Key words:** Uluguru Mountains, Uluguru Forestry Reserve, Kendall's coefficient of concordance, Likert scale analysis, nature-based income generating activities.

## 2.2 Introduction

Globally, the management of natural ecosystems while simultaneously enhancing livelihoods of rural communities who rely on these ecosystems, is increasingly viewed as an important pathway to sustainable development (Sunderlin and Huynh, 2005; Tole, 2010; Surkin, 2011; Sutherland *et al.*, 2014; Chevallier, 2016). Using the case of community-based approach in Southern Africa, for example, Chevallier (2016) provides a historical overview of natural resource management by examining to what extent this approach has been successful in achieving the objective of enhancing rural livelihoods through benefit sharing, income generation, as well as, biodiversity conservation and sustainable resource use. Chevallier (2016) concluded that the development of innovative income generating activities from natural resources is critical for fostering economic growth and sustainable natural resource management. She recommends a new thinking that includes integrated landscape-level natural resource management and the use of ecosystem service accounting to justify land-use choices about conservation. In their paper, Sutherland *et al.* (2014) identified several topics of special focus, including unsustainable cultivation practices that may increasingly affect conservation of biodiversity. Similarly, the publication by Surkin (2011) indicates that natural resource governance improvement can lead to positive impacts for livelihoods and biodiversity conservation. Tole (2010) identified the key institutional and incentives that appear to significantly affect the success or failure of rural forestry management initiatives as including, among others, the consideration of institutional and socio-economic factors along with personal characteristics of key stakeholders, such as, perceptions, attitudes, and availability of financial resources. It is important to note that, farmers' decisions to adopt 'new' practices depend on many complex factors. One such factor is their perception of characteristics of the practices (Negatu and Parikh, 1999; Bagheri et al., 2008; Emmanuel, 2014), and the successful promotion of these practices is likely to be more influenced by farmers' perception and attitudes than any other factors (Smathers, 1982). Therefore, a thorough understanding of these factors and their impact on livelihoods and biodiversity conservation provides valuable information to promoters of these practices (Bhatia and Buckley, 1998; Ruheza *et al.*, 2012; Ayubu, 2017; Thompson *et al.*, 2019). We attribute the current low rate of NIGA adoption to the lack of this understanding, though this would vary from one farmer to another due to different interactive factors (Moges and Taye, 2017). In fact, farmers' perception is generally renowned as the best predictor of the adoption of Good Agricultural Practicers (GAPs) (Alonge and Martin, 1995; Rogers, 2003).

The literature provides some useful case studies to illustrate this. Musinguzi *et al.* (2018), for example, provide the case of a community-based initiative that used a cooperative-driven organic certification of honey producers in Mwingi, Eastern Kenya to achieve the goal of improving livelihoods and acacia woodland management in the study area. This initiative performed poorly because of the failure to take into consideration the issue of long-term project sustainability as perceived by the project farmers. According to Musinguzi *et al.* (2018), this initiative registered minimal to no significant impacts of certification on household‘s incomes, honey quantity, and sales prices. Just as important, many governments, development partners and researchers have designed and launched programmes and initiatives that aim to effectively balance conservation goals and livelihood needs but the outcomes have been disappointing (Bhatia and Buckley, 1998; Sunderlin and Huynh, 2005; Ruheza *et al*., 2012; Ayubu, 2017), for reasons not very well known by their proponents. Most of these previous initiatives have focused on the implementation of sustainable income generating activities that concurrently promote livelihoods and nature conservation. We dub these activities as NIGAs. These have the potential to create opportunities for communities to productively use locally available resources to generate income without endangering biodiversity (Coche, 1991; FAO, 2000).

As for many other mountain areas in the tropics, the Uluguru Mountains in Tanzania have also attracted several NIGA initiatives (Bhatia and Buckley, 1998). Examples of these initiatives include the Uluguru Mountains Agricultural Development Project (UMADEP), Uluguru Mountains Biodiversity Conservation Project (UMBCP), and the Uluguru Mountains Payment for Watershed Services Project (UMPWSP), just to mention few. UMADEP was initiated in 1993 as a research and extension project based in the Department of Agricultural Education and Extension, Faculty of Agriculture of Sokoine University of Agriculture (SUA). It was a community-based research and extension project which worked in partnership with government extension officers and farmers using the multidisciplinary approach. UMBCP was implemented starting from 1999 to 2002 under financial support from DANIDA through the Danish Ornithological Foundation (DOF) of Denmark in partnership with the Wildlife Conservation Society of Tanzania (WCST). UMPWSP was funded by the Department for International Development Civil Society Challenge and supported by the Royal Society for the Protection of Birds (RSPB) in partnership with the Wildlife Conservation Society of Tanzania (WCST).

Most of the introduced NIGAs in Uluguru Mountains aimed at increasing productivity per area, hence reducing pressure on forest resources, while at the same time increasing farmers' income (Malisa *et al.,* 2016; TFCG, 2017). Examples of these NIGAs include beekeeping, aquaculture, tree planting, agroforestry (intercropping of trees and/or shrubs with crops), contour farming, natural fallow, soil and stone bunds, terraces, use of composite manure and crop rotation, just to mention few. If adopted, the benefits of these

NIGAs can be enormous. Agroforestry and beekeeping, for example, can provide outputs for home consumption as well as for sale to earn income and thus enhance food security and livelihoods of smallholder farmers. NIGAs can significantly improve income and capacity of smallholders to conserve ecosystems, especially in mountain areas where land degradation is renowned as a major cause of biodiversity loss. The complex nature and interrelated relationships between humans and ecologies in these areas needs a systematic and simultaneous understanding, especially with regard to sustainability, constraints for adoption of NIGAs, and scaling-up them to better guide agricultural strategy and policy interventions (Jha *et al.,* 2020). This implies understanding of local settings through the eyes and perceptions of the farmers themselves, who are the primary actors in the uptake process of agricultural technologies (Baccar et al., 2020). This understanding is currently lacking. The previous studies in mountain areas have focused mainly on other aspects, such as, the institutional, policy studies (Hartley and Kaare, 2001), and evaluation of the contribution of GAPs to socioeconomic and nutritional status (Mhina, 2015). The studies which assess the perceptions of local communities regarding the role of NIGAs are limited. This study was therefore an endeavour to fill this knowledge gap and inform policies and strategies to achieve sustainable livelihoods and biodiversity conservation in mountain areas.

## 2.3 Methodology

### 2.3.1 Theoretical framework

The study is based on the expected utility maximization theory which suggests that an individual farmer *i* will perceive a specific NIGA as a potential livelihood and biodiversity enhancing strategy if the expected utility from implementing it, $U_{ij}^{¿}$ is greater than the expected utility from any other alternative activities or projects, $U_{ij}$, i.e.

$y_{ij}^{*} = U_{ij}^{*} - U_{ij} > 0;$ where, $y_{ij}^{*}$, is the net benefit (latent variable) that the farmer can receive from practising the *j*th NIGA. This utility will in turn have an influence on the farmer's attitudinal behaviour. In this regard, perception is considered to relate to famer's own view or interpretation of utility. Perception (attitude) and behaviour are viewed to be mutually influencing each other (Reibstein *et al.*, 1980).

Having the utility theory in mind, we assessed the perception of farmers on the role of introduced NIGAs in the study area as livelihoods and biodiversity strategies using the approach described by Legendre (2010) which requires the computation of Kendall's coefficient of concordance (*W*). In the context of NIGAs, perceiption is defined as an understanding of the characteristics of these activities specified to include relative advantages, compatibility, complexity, trialability, and observability (Oo and Usami, 2020). These characteristics are considered to play a crucial role in farmers' decision making on adopting a new farming practice (ibid).

Kendall's *W* ranges from 0 (i.e., no overall trend of agreement among the respondents) to 1 (perfect or complete agreement, i.e., all the judges or survey respondents have been unanimous). Intermediate values of *W* indicate a greater or lesser degree of unanimity among the various judges or respondents.

Specifically, the Kendall's *W* statistic was calculated using the IBM SPSS software (versions 20 and 26). The first step entailed the calculation of sum-of-squares (*S*) over the low sums of rank ($R_i$), and the mean of $R_i$ values ( $\bar{R}$ ) as in Equation 2.1.

$$S = \sum_{i=1}^{n} (R_i - \bar{R})^2 \; or \; S' = \sum_{i=1}^{n} R_i^2 = SSR \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2.1)$$

The second step was the computation of Kendall's *W* statistic using the formula shown in Equation 2.2.

$$W = \frac{12\,S}{m^2(n^3 - n) - mT} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(2.2)$$

where *n* represents the number of objects; *m* is the number of variables and *T* is a correction factor for tied ranks which was calculated as shown in Equation 2.3.

$$T == \sum_{k=1}^{g} (t_k^3 - t_k) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(2.3)$$

in which $t_k$ is the number of tied ranks in each (*k*) of *g* groups of ties. The sum was computed from the overall groups of ties found in all *m* variables of the data worksheet. *T* equalled zero when there were no tied values. Kendall's *W* is used as an estimate of the variance of the row sums of ranks $R_i$ divided by the maximum possible value the variance can take; this occurs when all variables are in total agreement. Hence, $0 \leq W \leq 1$ whereas (1 represents perfect concordance). We used the Friedman's chi-square statistic (Equation 2.4) to test the significance of Kendall's *W*.

$$\chi^2 = m(n-1)W \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(2.4)$$

The overall aim of the analysis was to identify variables that agree in the estimation of the common property of the objects in terms of preferences, profitability and acceptability of NIGAs by farmers. We calculated the Spearman correlation among all judges from Kendall's *W* using the formula presented in Equation 2.5.

$$\bar{R}_s = \frac{kW - 1}{k - 1} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(2.5)$$

where $\bar{R}_s$ denotes the average Spearman correlation and $k$ the number of judges or rankers. The Spearman's rank coefficient can be denoted by $r_s$ and symbolically presented as in Equation 2.6.

$$r_s = \frac{1-\left(\partial \sum d_i^2\right)}{\left(n\left(n^2-1\right)\right)} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (2.6)$$

where, $d_i$ represents the difference in the ranks given to the values of the variable for each item of the particular data. This formula is applied in cases when there are no tied ranks. However, in case of fewer numbers of tied ranks, this approximation of Spearman's rank correlation coefficient provides sufficiently good approximations. If there are no repeated data values, a perfect Spearman correlation of +1 or -1 occurs when each of the variables is a perfect monotone function of the other. Intuitively, the Spearman correlation between two variables will be high when observations have a similar (or identical for a correlation of 1) rank (i.e. relative position label of the observations within the variable: 1st, 2nd, 3rd, etc.) between the two variables, and low when observations have a dissimilar (or fully opposed for a correlation of −1) rank between the two variables. Spearman's and Kendall's *W* can be formulated as special cases of a more general correlation coefficient.

The analysis of farmers' perceptions of the role of NIGAs in biodiversity conservation was complemented by the application of some forms of standard scaling techniques. These techniques are broadly debated in the literature with the mainstream of the debate subscribing to the summative construction of Likert scale (Likert, 1932) dubbed by Krosnick *et al.* (2018) and Cooper *et al.* (2016) as the "Likert's method of summated ratings." The method uses a standard scaling procedure or method that attributes numerical values to responses (Pollard et al., 2007) and requires that the scoring, scaling, and the response format for items are consistent. For example, if a Likert scaling technique is used then all items will confirm to a Likertr scale (e.g. 5 points with “disagree” and “agree” response stems) as well as the use an additive scoring method (Krosnick *et al.*, 2018).

However, the “Likert’s method of summated ratings” is also criticized for the problem of inconsistency between the scoring method (additive) and the scaling method (Pollard and Johnston, 2001; Pollard *et al.*, 2007), as well as the lack of a simple scale of reference to assure consistency across disciplines (Perscaroli *et al.*, 2020). Instead, a method for selecting items which is broad enough to sample the full range and not restricted to just one source or domain (Pollard *et al.*, 2007) and a simple-to-use rating tool that can be used for benchmarking responses in questionnaires (Pescaroli *et al.*, 2020) are recommended, especially where the target groups, for cultural, social, or political reasons may be improper for in-depth analyses (e.g. scales of up to 7 or 10). The output of the tool is a replicable scale from 0 to 3 presented in a tabular form that includes category labels with qualitative attributes and descriptive equivalents which are used in the formulation of model answers (Pescaroli *et al.*, 2020). The advantage of the Likert scale based response model is that it can be applied in a wide variety of disciplines (ibid).

The “Likert’s method of summated ratings” is also criticized for misrepresenting and losing information due to the closed-form scaling and the ordinal nature of this measure (Goeb *et al.*, 2007; Li, 2013). According to Goeb *et al.* (2007), perception or attitude data are often evaluated with techniques designed for cardinal measurements, despite the problem of attitude which suggests an ordinal interpretation of Likert scales. To overcome these problems, Goeb *et al.* (2007) present the interpretation of scales for perception or attitude measuring and suggest data analysis techniques under the proper ordinal understanding. Likewise, Li (2013) proposes a novel fuzzy Likert scale which was developed based on the fuzzy sets theory. According to Li (2013), the main strength of the fuzzy Likert approach is that it allows partial agreement of a scale point enabling the capture of lost information and regulation of distorted information. The fuzzy sets theory offers scholars with a better "language that is half-verbal-conceptual and half-mathematical-analytical" (Ragin, 2000; cited in Li, 2020). It allows the conversion of a discrete ordinal variable into a continuous variable while maintaining the sematic meaning and capturing the interval details of ordinal variables in an open response format (ibid). This is advantageous because it helps to moderate the problem of information misinterpretation and attenuation in the conventional "Likert's method of summated ratings."

In Myanmar, Oo and Usami (2020) applied the characteristics defining the concept of perception (i.e. relative advantages, compatibility, complexity, trialability, and observability) to measure farmers' perception of GAPs in rice production. They included different statements for measuring these characteristics. Specifically, they used a Likert-scale five-point continum starting from 1 (strongly disagree) to 5 (strongly agree) and categorised respondents into two groups using a cut-off point of 4 (i.e. "did not perceive" if the score was less than 4; and "perceived" if the score was equal to or greater than 4. They then calculated the Cronbach's alpha to examine the reliability of data collected on farmers' perception of GAPs in rice production. They found that the different components of GPAs in rice production were perceived as relatively difficult to apply by farmers.

Although it is considered a good index for stability, the Cronbach's alpha has some disadvantages: it is affected by duration (time) and dimensionality of adoption (Al-Osail *et al.,* 2015). As the time increases, reliability will increase (Streiner, 2003; Tavakol and

Dennick, 2011). Therefore, the index measures stability but not the internal consistency (which decscribes the extent to which all the items in a test measure the same concept or constructs). Hence, the Cronbach's alpha is not sufficient for measuring reliability (Agbo, 2014; Al-Osail *et al.*, 2015). Adding other indices of internal consistency such as the Kendall's coefficient of concordance (Kendall and Babington, 1939), Spearman's rank correlation, and $R^2$ coefficient is recommended because it gives more accurate and reliable results (ibid). As non-parametric methods, the Kendall's *W* and Spearman's rank-order are generally suggested for non-normal data.

The Kendall's coefficient of concordance and Spearman's rank correlation coefficient are non-parametric statistics. The Kendall's coefficient of concordance is a normalisation of the statistic of the Friedman test (Legendre, 2005; Voshaar *et al*., 2021). It has a close relationship with the Milton Friedman's two-way analysis of variance without replication by ranks (Kraemer, 1976; Legendre, 2005). They both address hypotheses concerning the same data table and they use the same $\chi^2$ statistic for testing. The Spearman's rank correlation coefficient assesses how well the relationship between variables can be described using a monotonic function. It is important to note that the Spearman correlation between two variables is actually equal to the Pearson correlation between the rank values of those two variables. The Pearson's correlation assesses linear relationships, but the Spearman correlation assesses monotonic relationships (whether linear or not). It should be noted here that in most situations, the interpretations of the variant of Kendall's *W* (i.e. the Kendall's tau) and Spearman's rank correlation coefficient are very similar and thus, invariably lead to the same inferences. However, the former is more preferable to the Spearman's rank correlation coefficient and Pearson's correlation for a number of reasons. Firstly, it is insensitive to errors and its *p*-values are more accurate with small sample sizes whereas, the Spearman’s correlation is much more sensitive to error and discrepancies in data and it has usually larger values than the Kendall’s *W* (Chok, 2010). Secondly, the distribution of Kendall’s tau has generally better statistical properties (Kraemer, 1976; Legendre, 2005). Thirdly, the interpretation of Kendall’s tau results, in terms of the probabilities of observing the agreeable (concordant) and non-agreeable (discordant) pairs is very direct (LeDonne *et al.*, 2011). It is worth noting here the difference between the Kendall's *W* and Kendall's tau. The former is calculated for more than two variables, while the latter (Kendall's tau) is calculated for two variables as any other correlation coefficient.

The Pearson correlation is the most frequently used coefficient for normal distributed data but it has a disadvantage of being sensitive to outliers (Abdullah, 1990; Balakrishnan, 2009). The Kendall’s *W* is even less sensitive to outliers and is often preferred due to its simplicity and ease of interpretation (ibid). Originally, the Kendall’s correlation coefficient was proposed to be tested with the exact permutation test (Kendal, 1938). This non-parametric approach can help comparing the ability of the correlation coefficients to reflect a given monotone association, aside from the possible differences caused by discrepancies in the statistical testing procedures.

As compared with Spearman’s and Kendall’s correlation, the Pearson’s correlation approach escalates the possibility of outliers, and results in increasingly poorer performance of the correlation (Chok, 2010). This is more evident for large sample sizes where the probability of obtaining datasets with the outliers is higher. Thus, if the data contains outliers, the Kendall’s *W* and Spearman’s rank-order correlation coefficient are considered more appropriate (Chok, 2010). The Pearson correlation coefficient is appropriate only for interval data while the Spearman’s and Kendall’s correlation coefficients could be used for either ordinal or interval data (McKillup, 2005). The available literature also suggests the Spearman's correlation to be more appropriate for data that involves several types of variables (Hurbert, 2009; Armstrong, 2019). For data that have at least one ordinal variable, the Kendall's *W* is more appropriate (Hurbert, 2009). Other scholars (e.g. Schober, 2018), suggest Spearman's correlation coefficients for the same scenarios. The Pearson correlation is a natural parameter of association for a bivariate normal distribution (it assumes zero value if and only if the two variables are independent). Thus, a statistical test based on the Pearson's correlation coefficient is likely to be the most powerful for this type of data than similar tests on the other correlation coefficients (Armstrong, 2019). However, for non-normal data, the sensitivity of the Pearson correlation coefficient has led to recommendations of other correlation coefficients (ibid). The standard procedure for testing significance of the estimates for the Pearson's correlation coefficient is sensitive to the deviations of bivariate normality (Chok, 2010). Due to the proximity of Spearman's to Pearson's correlation coefficient in bivariate normal data, and the appropriateness of Spearman's statistical test for any type of interval data the Spearman's correlation coefficient is more preferable than the Pearson's correlation and Cronbach's alpha (McKillup, 2005; Chok, 2010).

In our study, we used the Likert-scale analysis, Kendall's coefficient of concordance, *W*, and the Spearman correlation to assess agreement among respondents (judges or rankers) regarding their perceptions of the importance of NIGAs in Uluguru Mountains. The analysis was complemented by the use of Spearman's rho and Kendall's tau statistics to test the null hypothesis that the NIGAs adopted by smallholder farmers in the study area are interrelated or associated. Our focus on mountain areas makes the study more imperative recognising that mountain ecosystems are generally fragile and very sensitive to anthropogenic changes and indirect alterations in the environment (Houet *et al.,* 2010; Wang *et al*., 2018; Mengist *et al.,* 2020). Just as important, the occurrence of climate change and anthropogenic factors alter the potential for provision of mountain ecosystem services and goods which calls for a special attention to achieve sustainable land management and utilisation in these areas (Chaudhary *et al.*, 2017; Mengist *et al.*, 2020).

### 2.3.2 Conceptual framework for the study

As indicated in our conceptual framework (Figure 2.1), farmer's decision to adopt NIGAs is influenced by both internal and external factors, coupled with the farmer's perception of expected outcomes as conceptualized by the expected utility maximization theory. The internal factors include the personal as well as farming and economic characteristics. Farmers' perceptions of NIGAs are associated with farmers' characteristics, such as the age of the farmer, gender, marital status, education, size of household and farming experience (Bagheri *et al.*, 2008; Benmeke and Ajayi, 2008; Pinthukas, 2015; Abdul-Gafar *et al.,* 2016; Sasima *et al.,* 2016; Mugula and Mkuna, 2016). Farming characteristics, such as, size farmland area, farmland location (if located far or close to homestead), and availability of active labour have a positive influence on farmers' perception (Meseret, 2014; Pongvinyoo *et al.,* 2014; Sasima *et al.,* 2016; Maswadi and Suharyani, 2018). Famer's perception of NIGAs is therefore influenced by many factors, including the household's economic characteristics, such as, access to credits and the value of assets owned by the farmer (Ndambiri *et al.,* 2013). In Colombia, for example, the adoption decision of agroforestry practices was influenced by the access and use of credit and location, among others (Jara-Rojas *et al.*, 2020).

The external factors influencing farmers' perception of NIGAs include the existing transforming structures and processes, such as, the public and private institutions supporting and promoting the adoption of NIGAs, laws, policies, culture, access to extension services, access to information, and training (Abdul-Gafar *et al.,* 2016; Arslan *et al.,* 2020). The expected outcomes are then mirrored from the actual outcomes which include increased income, improved food security, improved wellbeing, reduced vulnerability, reduced land degradation and enhanced ecosystem resilience, as well as improved biodiversity conservation and more sustainable use of natural resource base.

The literature on the influence of both internal and external factors on the perception and adoption of NIGAs and GAPs by smallholder farmers is enormous. For example, in the Oyo State of Nigeria, Banmeke and Ajayi (2008) assessed farmers' perception of the agricultural information resource centre at Ago-Are as a source of information for improving agricultural productivity. They found a significant relationship between the type of information sought and respondents’ perception of the resource centre and they recommended organizing frequent training for farmers. Their recommendation accentuates the role of transforming structures and processes in influencing perception and adoption of NIGAs to enhance livelihoods and biodiversity conservation. They furthermore view this as providing a basis for discussing targeted agricultural and policy interventions in the Sub Saharan Africa (SSA) region, including the mountain areas. Elsewhere, in Haraz catchment area of Mazandaran province in Iran, Bagheri *et al.* (2008) investigated the perception of paddy farmers towards sustainable agricultural technologies. They found that education level of household head (personal household characteristics), contact with agricultural experts and extension participation (transforming structures and processes) were the best predictors of farmers’ perceptions.

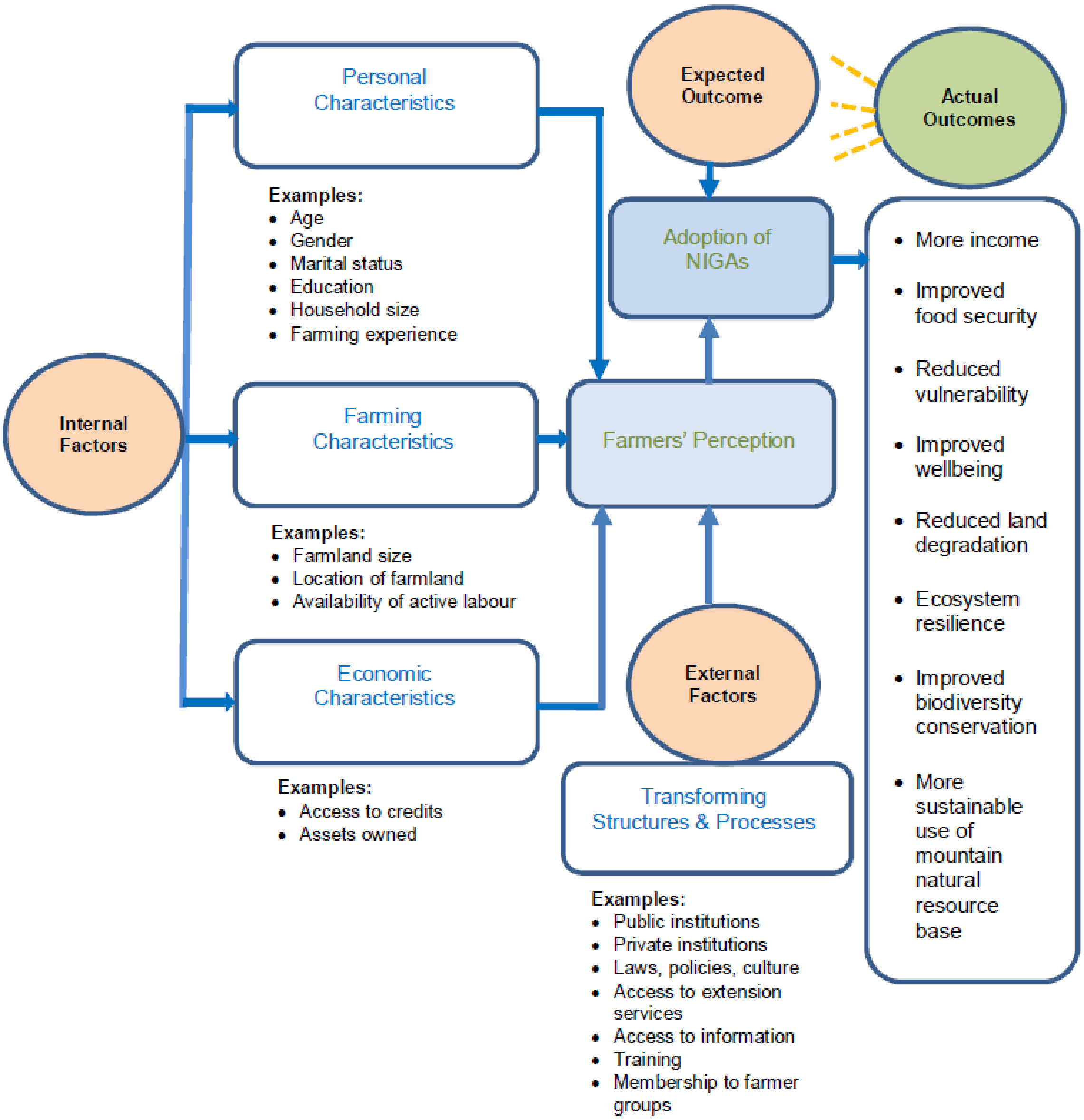


**Figure 2.1: Conceptual framework for the study**

Arslan *et al.* (2020) who present a synthesis of micro-economic literature on the analysis of drivers of agricultural technology adoption in Africa using a meta-data set built from the results of different recently published papers identify eleven determinants that were positively influencing the perception and adoption of technology in the continent. Four of these related to transforming structures and processes (access to extension, access to information, farmer group participation, and access to credit); five related to economic characteristics (land size, livestock assets, off-farm income, overall income and wealth index); one was the exposure to high temperatures (a location specific factor); and the final one was secure land tenure (a mixture of farm characteristics, transforming structures and processes).

### 2.3.3 The study area

The study was conducted in Uluguru Mountains covering fourteen hamlets (Table 2.1) in the wards of Mlimani and Luhungo (Morogoro Municipality), and Mzumbe (Mvomero district) in Morogoro, Tanzania. The mountains run approximately north-south with altitudes of up to 2 630 metres above sea level at their highest point (EAMCEF website, undated) and their range contains a nature reserve which constitutes the Uluguru North, Uluguru Soutn and Bunduki Forest Reserves. About fifty villages border the Uruguru Forestry Reserve with population of over 151 000 found within the mountain area (ibid). The vegetation of the area is extremely variable (Figure 2.2) ranging from drier lowland coastal forest to transitional rainforests, sub-montane, montane and upper montane forest types, as well as the afromontane grasslands on the Lukwangule plateau. All these ecosystems are rich in endemic species making them of high conservation priority. However, land degradation in the area is rampant due to existence of unsustainable anthropologic activities (Yanda and Munishi, 2007; William, 2010; Harrison and Mdee, 2017; Massawe *et al.*, 2020). The mountains also serve as a water catchment and water source for populations living downstream in Morogoro rural and Municipal districts, as well as other residents in the Dar es Salaam City and the Ruvu/Wami River Catchments. Thus, the study area was purposefully selected based on, not only its importance as a water catchment, but also as a biodiversity hotspot encountered by the challenge of increasing human activities that threaten biodiversity and environmental integrity at large.

**Table 2.1: Location of the study sites**

| Village/Hamlet | Ward | Division | District | Altitude (masl) | Position | |
|---|---|---|---|---|---|---|
| | | | | | Eastings | Northings |
| Tangeni/Kikoya | Mzumbe | Mlali | Mvomero | 656 | 345874 | 9234196 |
| Tangeni/Chalinze | Mzumbe | Mlali | Mvomero | 860 | 347046 | 9233084 |
| Tangeni/Simbo | Mzumbe | Mlali | Mvomero | 737 | 346759 | 9232891 |
| Tangeni/Mng'hongo | Mzumbe | Mlali | Mvomero | 737 | 346466 | 9233799 |
| Tangeni/Mihubulu | Mzumbe | Mlali | Mvomero | 883 | 347563 | 9234125 |
| Kilala | Luhungo | Morogoro | Morogoro | 731 | 349501 | 9236858 |
| Mundu | Luhungo | Morogoro | Morogoro | 847 | 350263 | 9236314 |
| Mambani | Luhungo | Morogoro | Morogoro | 975 | 350490 | 9237492 |
| Kivaza | Luhungo | Morogoro | Morogoro | 722 | 348904 | 9236453 |
| Mbete | Mlimani | Morogoro | Morogoro | 808 | 353746 | 9241263 |
| Ruvuma | Mlimani | Morogoro | Morogoro | 1041 | 352694 | 9240058 |
| Choma | Mlimani | Morogoro | Morogoro | 1212 | 354139 | 9239703 |
| Kisosa | Mlimani | Morogoro | Morogoro | 1341 | 353599 | 9239560 |
| Tulo | Mlimani | Morogoro | Morogoro | 1192 | 352716 | 9239617 |

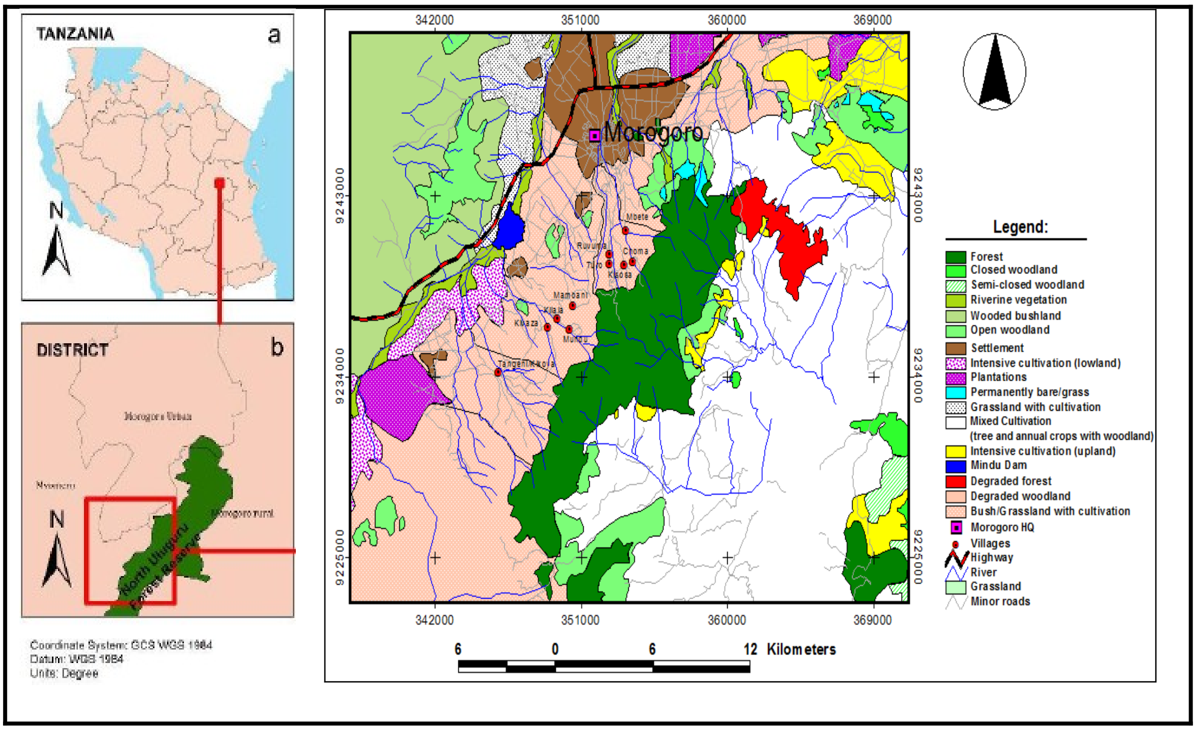


**Figure 2.2: Map showing the location of the study area and major land uses**

### 2.3.4 Sampling and data collection

The study used the multi-stage sampling procedure to select the study villages and sample households. In the first stage, fourteen hamlets were selected purposely based on their participation in the previous NIGA projects. In the second stage, households were stratified into strata according to the wealth ranks assigned by UMPWSP and more recent government initiatives in the study area (WCST, 2010). The third stage entailed the selection of sample households from each stratum using the proportionate probability sampling procedure. The distribution of sample households by study sites is shown in Table 2.2.

**Table 2.2: Distribution of sample sizes by sample hamlets**

| Hamlets | Households | Sample size* | % |
|---|---|---|---|
| Tangeni village (5 hamlets) | 1,030 | 66 | 32.8 |
| Kilala | 85 | 12 | 6.0 |
| Mundu | 145 | 15 | 7.5 |
| Mambani | 152 | 21 | 10.4 |
| Kivaza | 167 | 21 | 10.4 |
| Mbete | 22 | 9 | 4.5 |
| Ruvuma | 72 | 15 | 7.5 |
| Choma | 210 | 21 | 10.4 |
| Kisosa | 84 | 12 | 6.0 |
| Tulo | 42 | 9 | 4.5 |
| TOTAL | 2,009 | 201 | 100 |

*The total sample size used in the final analysis (after data cleaning and removal of outliers) was 154 households.

The study used both primary and secondary data. Prior to commencement of fieldwork, the researchers hired six enumerators to assist them during data collection. These were trained on how to administer questionnaires and use other research tools, such as the checklists and guidelines. They were also reminded about the research ethics they should comply with. The actual fieldwork started with a reconnaissance survey to get an overview and understanding of the study area and applicability of the questionnaire.

During the reconnaissance survey, the household questionnaire was pre-test to a small sample before the actual fieldwork to check for its relevance to the study area and objectives. This was followed by the main survey which used different research tools and techniques, including structured questionnaires, interviews with key informants (selected based on their involvement in NIGA initiatives) and Focus Group Discussions (FGDs).

The FGDs were attended by at least 10 participants per village representing different socioeconomic groups that existed in the area, including the rich, poor, youth and women, men, abled and disabled people. In addition, direct observation served as a complementary tool. In selecting the key informants for interview the snowball technique was used. The technique is particularly suitable when the population of interest is hard to reach and compiling a list of the population poses difficulties for the researcher (Etikan et al., 2016). It begins with a convenience number of initial subject which serves as “seeds,” through which wave 1 subject is identified; wave 1 subject, in turn, identifies wave 2 subjects; and the number of interviewees consequently expands wave by wave-like a snowball growing in size as it rolls down a hill (Heckathorn, 2015).

### 2.3.5 Data processing and analysis

We identified the different NIGAs which were introduced in the study area using the household questionnaire, FGDs, KIIs, direct observation approaches, review of government and project documents, as well as office records from relevant government and non-government organizations. During the questionnaire survey the respondents were asked to rank the identified NIGAs according to their potential in enhancing livelihoods and biodiversity conservation. The rankings were coded as: lowest rank (1), low rank (2), moderately low rank (3), moderately high rank (4), high rank (5), and highest rank (6). The codes were then used in the computation of the Kendall’s coefficient of concordance, *W*. To identify the best NIGAs, we used the visualisation (percentage chart) and the Friedman test as appropriate analytical tools because the rankings involved mainly ordinal variables. The Friedman was used to test the null hypothesis that the respondents or farmers in the study area did not agree among themselves about NIGAs that are potential as livelihood and biodiversity conservation strategies [i.e., the null hypothesis ($H_0$) that the Kendall's *W* was less than 0.4] versus the alternative hypothesis ($H_1$) that the Kendall's *W* was not less than 0.4]. In this case, the coefficient (*W*) values of 0.4 and above were used to ascertain if the rankings of respondents agreed with each other. Additionally, we calculated the Spearman correlation among all judges or rankers from the Kendall's *W* and complemented our analysis by employing the Spearman's rho and Kendall's tau statistics.

Specifically, we used the reduced household reliance on, and frequency of, using timber products from the Uluguru Forest Reserve (UFR) as a proxy for biodiversity conservation. We asked farmers to indicate the extent to which they agree or disagree with the assertion that agroforestry reduced dependence on and frequency of using firewood, building poles and timber products from UFR. In particular, we designed three Likert questions, one for each of these three forest products, to study the perception and attitude of respondents on the extent to which agroforestry has enhanced biodiversity conservation. During the coding we realised that none of the respondents reported to be neutral, we therefore recoded our five scale Likert data into the following four response alternatives: strongly disagree (1), Disagree (2), Agree (3), and strongly agree (4). It is important to note that the use of 4-point Likert alternatives is not new in the literature. Behnke and Kelly (2011) for example, used the 4-point Likert alternatives to investigate the influence of Latino parent involvement in the programmes to help Latino youth thrive at school. Elsewhere, Robinson and Shepard (2011) also used the same technique to investigate outreach, applied research, and management needs for the Wisconsin's great lakes freshwater estuaries.

For comparison reason, we generated two scenarios for Likert analysis by treating the three questions as both Likert-type and Likert scale questions (Clason and Dormody, 1994; Boone and Boone, 2012). The main idea was to find out if the results from the two scenarios were different or the same. The Likert-type items can be described as single questions which apply some facets of the novel Likert response alternatives but the researcher does not combine the responses from the item into a composite scale (Clason and Dormody, 1994).

In the second scenario we combined the responses from the three questions (the Likert scale questions) to create a perception or attitude measurement scale. According to Boone and Boone (2012), the Likert scale data are generated by computing a composite score (sum or mean) from the Likert-type items. The mean for central tendency and standard deviations for variability are the most recommended statistics. Since Likert scales produce ordinal data one may also use the Inter-Quartile Range (IQR) of each item (Garth, 2008). Alternative procedures would entail the use of Pearson's r, *t*-test, ANOVA and regression analysis (ibid). The arithmetic mean measures the distribution of agreement scores that are collected on an ordinal scale (Goeb *et al.*, 2007; Rubaish, 2010). The median, the number found exactly in the middle of the distribution, is a measure of central tendency which shows what the "average" respondent might think, or the "likeliest" response whereas the IQR is a measure of spread which shows whether the responses are clustered together or scattered across the range of possible responses (Maheta and Patel NR/SPSS Inc., 1996; Garth, 2008).

However, the median, quartiles, and cumulative percentage measures are preferred to the mean when distributions are skewed Rubaish (2010). Therefore, the mean would not be an appropriate measure in cases where distributions are skewed; instead one would use cumulative percentage. The latter, cumulative percentage is preferred because it is a straightforward, easy to comprehend, and apply method (Rubaish, 2010). In our study, we used five grading criteria to interpret the results of analysis (Table 2.3) namely; composite (sum and mean), media, quartiles, and cumulative percentages of scores 3 and 4 (i.e. the sum of "agree" and "strongly agree" responses respectively).

**Table 2.3: Likert grading criteria for reduced reliance on products from forest reserve and enhanced biodiversity conservation**

| Grading | Criteria | | | | |
|---|---|---|---|---|---|
| | Composite (sum) | Mean | Median | Quartiles | Cumulative % |
| Low or poor | < or = 7 | < or = 2.6 | 1 and 2 | 1 and 2 | < or = 60% |
| Moderate | 7 – 10 | 2.6 - 3.6 | 3 | 3 | 60 – 80 |
| High | > or = 10 | > or = 3.6 | 3 and 4 | 3 and 4 | > or = 50% |

Source: Modified from Rubaish (2010)

## 2.4 Results and Discussion

### 2.4.1 Ranking of NIGAs and results of Kendall's *W* test

The summary of ranking of NIGAs according to their potential to enhance livelihoods and biodiversity conservation is presented in Figure 2.3. The proportions of households that practiced NIGAs are provide in Table 2.3 for each NIGA. When the "highest" and "high" ranks are summed together, agroforestry was ranked as the most important NIGA in enhancing livelihoods and biodiversity conservation (with cumulative percentage of more than 60%), followed by beekeeping (50%), terraces (about 35%), and contour farming (about 30%).

As the recent study by Yamane and Ito (2020) indicates, the common agroforestry systems in the study area include the homegardens (where several crops are grown mainly for commercial purposes, including banana and an array of tree varieties, such as the jackfruit, mango, cinnamon, cardamom, breadfruit, coco palm and eucalyptus), and the hillside agroforestry systems (where food crops like maize and cassava, mixed with yams and common beans, dominate). Besides the direct use values of agroforestry products, such as firewood, building poles, fodder, fruits and timbers (Van Donge, 1992; Tiisekwa, 2002; Ruheza *et al*., 2012; Mkonda and He, 2017), agroforestry also provides several ecosystem services range from its contribution to control of soil erosion, conservation of soil fertility through nutrient recycling and enhancement of biodiversity conservation). Thus, it was important to understand the perceptions and attitudes of respondents in this study regarding the role of different NIGAs in enhancing livelihoods and biodiversity conservation and level of agreement in their perception and attitude.

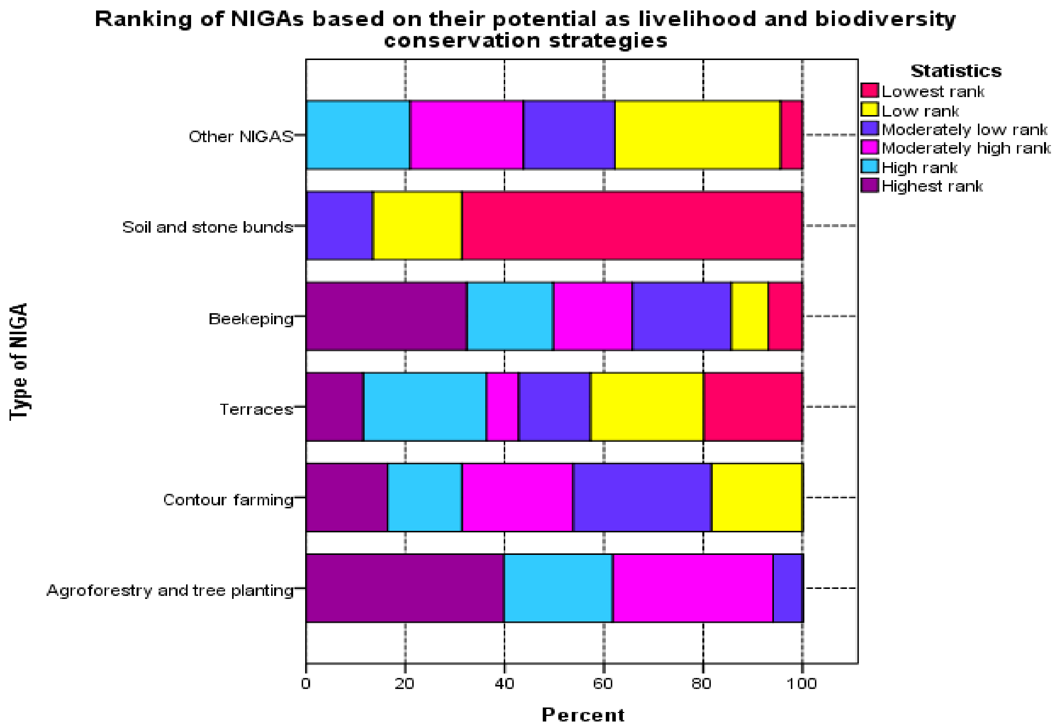

**Figure 2.3: A bar chart showing the results of NIGA ranking based on their importance as livelihoods and biodiversity conservation strategies**

**Table 2.4: Proportion of households who practised NIGAs by type of NIGA**

| Type of NIGA/Response | Frequency | % | Cumulative % |
|---|---|---|---|
| **Agroforestry** | | | |
| No = 0 | 43 | 27.9 | 27.9 |
| Yes = 1 | 111 | 72.1 | 100.0 |
| **Total** | **154** | **100.0** | |
| **Terraces/contour farming** | | | |
| No = 0 | 98 | 63.6 | 63.6 |
| Yes = 1 | 56 | 36.4 | 100.0 |
| **Total** | **154** | **100.0** | |
| **Soil/stone bunds** | | | |
| No = 0 | 138 | 89.6 | 89.6 |
| Yes = 1 | 16 | 10.4 | 100.0 |
| **Total** | **154** | **100.0** | |
| **Beekeeping** | | | |
| No = 0 | 141 | 91.6 | 91.6 |
| Yes = 1 | 13 | 8.4 | 100.0 |
| **Total** | **154** | **100.0** | |
| **Other NIGAs*** | | | |
| No = 0 | 138 | 89.6 | 89.6 |
| Yes = 1 | 16 | 10.4 | 100.0 |
| **Total** | **154** | **100.0** | |

*Other NIGAs include the remainder of NIGAs which were rarely practised by farmers in the study area, such as natural fallow, the use of composite manure, and crop rotation.

The results of analysis of the Kendall's *W* test, Friedman test and the estimate of coefficient of concordance are presented in Table 2.5. The point estimate of the coefficient of concordance was 0.40 which was about the same value as the average over all possible Spearman correlation. This test statistic suggests that the farmers agreed with each others to a reasonable though not super high extent ( $\chi^2$ (4) = 241.527, $p$ = 0.000). In fact, the asymptotic *p* – value of 0.000 strongly suggests that the coefficient of concordance was not zero, meaning that there was some agreement among judges in terms of how they ranked the NIGAs. Accordingly, the null hypothesis that the Kendall's *W* was zero (i.e. there was perfect disagreement among the judges or respondents) is rejected. However, the fact that the Kendall's *W* was not equal to 1 (i.e. the judges/respondents did not perfectly agree amongst themselves) does not imply that they did not rank the NIGAs in the same order but each NIGA faired well at the hands of some judges or rankers (respondents) and poorly at the hands of others (see Meheta and Patel/SPSS Inc., 1996). Under perfect disagreement, each NIGA would fare the same overall and would thereby produce identical values for equal total rankings for all NIGAs, consequently, the Kendall's *W* would be equal to zero. It should also be noted that, the test-statistic, Chi-square ( $\chi^2$ ) is synonymous to variance over the mean ranks: it is zero when the mean ranks are exactly equal and becomes larger as they lie further apart. The asymptotic significance (our $p$ – value) is less than 0.05 confirming that the rankings were statistically significantly different for all the five categories of NIGA. Agroforestry and terraces/contour farming were rated most favourably with mean ranks of 4.11 and 3.22 respectively, followed by soil/stone bunds and other NIGAs, such as natural fallow, use of composite manure, crop rotation, and others rarely adopted NIGAs combined together (both categories with a mean rank of 2.57). Unexpectedly, beekeeping in this case was ranked the fifth with a mean rank of 2.52.

Our results of Kendall's tau and Spearman rank correlations are presented in Table 2.6. We used these statistics to evaluate the extent to which the five categories of NIGAs were interrelated or associated. Our data contained five NIGA categories (adoption of agroforestry, terraces/contour farming, beekeeping and other NIGAs) which were ordinal variables making it reasonable to use either of the two rank correlations. We used both test statistics and they yielded similar correlation coefficients.

**Table 2.5: Results of Kendall's *W* test, Friedman test and average Spearman correlation**

| Type of NIGA | Mean Rank | Std. Deviation | Test Statistics |
|---|---|---|---|
| **a) Kendall's *W* test** | | | |
| Agroforestry | 4.11 | 0.450 | |
| Terraces/contour farming | 3.22 | 0.483 | |
| Soil/stone bunds | 2.57 | 0.306 | |
| Beekeeping | 2.52 | 0.279 | |
| Other NIGAS* | 2.57 | 0.306 | |
| Kendall's W[a] | | | 0.400 |
| Chi-Square | | | 241.527 |
| Df | | | 4 |
| Asymp. Sig. | | | 0 |
| **b) Friedman Test** | | | |
| Agroforestry | 4.11 | 0.450 | |
| Terraces/contour farming | 3.22 | 0.483 | |
| Soil/stone bunds | 2.57 | 0.306 | |
| Beekeeping | 2.52 | 0.279 | |
| Other NIGAS* | 2.57 | 0.306 | |
| Chi-Square | | | 241.527 |
| Df | | | 4 |
| Asymp. Sig. | | | 0 |
| c) Average Spearman correlation | | | 0.405 |

*Other NIGAs included natural fallow, use of composite manure, crop rotation, and others which were rarely practiced by farmers
[a.] Kendall's Coefficient of Concordance

The results of statistical tests using the Kendall's tau and Spearman's rho indicate that the *p* - values of correlations between the adoption of agroforestry/tree planting and soil/stone bunds were statistically significant ( $r_s$ = 0.212, $p$ = 0.009). The adoption of agroforestry was also positively associated with adoption of beekeeping ( $r_s$ = 0.189, $p$ = 0.019), and other NIGAs ( $r_s$ = 0.212, $p$ = 0.009). The adoption of terraces and contour farming was positively interrelated with soil/stone bunds ( $r_s$ = 0.273, $p$ = 0.001). The *p* - value of correlation between the adoption of soil/stone bunds and beekeeping were statistically significant ( $r_s$ = 0.356, $p$ = 0.000). It was also statistically significant between the adoption of soil/stone bunds and other NIGAs ( $r_s$ = 0.512, $p$ = 0.000). Consequently, we failed to reject the null hypothesis that the NIGAs adopted by smallholder farmers in the study area are interrelated.

**Table 2.6: Correlation coefficients (n = 154)**

| | Adoption of agroforestry | Adoption of terraces/contour farming | Adoption of soil/stone bunds | Adoption of beekeeping | Adoption of other NIGAs |
|---|---|---|---|---|---|
| **Kendall's tau b** | | | | | |
| Adoption of agroforestry | 1.000 | -0.101 | 0.212** | 0.189* | 0.212** |
| Adoption of terraces/contour farming | -0.101 | 1.000 | 0.273** | 0.110 | 0.008 |
| Adoption of soil/stone bunds | 0.212** | 0.273** | 1.000 | 0.356** | 0.512** |
| Adoption of beekeeping | 0.189* | 0.110 | 0.356** | 1.000 | 0.356** |
| Adoption of other NIGAs | 0.212** | 0.008 | 0.512** | 0.356** | 1.000 |
| **Spearman's rho** | | | | | |
| Adoption of agroforestry | 1.000 | -0.101 | 0.212** | 0.189* | 0.212** |
| Adoption of terraces/contour farming | -0.101 | 1.000 | 0.273** | 0.110 | 0.008 |
| Adoption of soil/stone bunds | 0.212** | 0.273** | 1.000 | 0.356** | 0.512** |
| Adoption of beekeeping | 0.189* | 0.110 | 0.356** | 1.000 | 0.356** |
| Adoption of other NIGAs | 0.212** | 0.008 | 0.512** | 0.356** | 1.000 |

** Correlation is significant at the 0.01 level (2-tailed)
* Correlation is significant at the 0.05 level (2-tailed)

These results are interesting and have important implication for policy making and promotion of NIGAs in mountain areas. From the test statistics presented in Table 2.6, it is reasonable to argue that the association between adoption of soil/stone bunds and other NIGAs (such as natural fallow, use of composite manure, and crop rotation) was the strongest amongst all associations. This implies that farmers who adopt soil/stone bunds in mountain areas are also more likely to invest in other NIGAs. More interesting is the finding that farmers who adopted agroforestry were also willing to invest in soil and stone bunds, beekeeping and other NIGAs. We therefore affirm that, if well informed by the perception of target farmers, appropriately packaged and supported by transforming structures and processes, NIGAs have the potential to enhance livelihoods and biodiversity conservation in mountain areas. Similar arguments are given by Rajendran *et al.* (2016) who underscore the need for provision of adequate farmer training by non-governmental organizations and rural institutions to complement change agents, such as, public extension officers.

### 2.4.2 Perceptions of farmers about the role of agroforestry in biodiversity conservation

We compared the results of analysis of the respondents' perceptions about the potential of agroforestry as effective biodiversity conservation strategy using Likert-type and Likert scale data. Figure 2.4, Table 2.7 and Table 2.8 present the results of analysis for the Likert-type data. The cumulative scores (sum of scores 3 and 4) for reduced reliance on firewood and building poles were 76% and 61% respectively (Figure 2.4 and Table 2.7). The mean (average) scores were 3.1 and 2.6 for reduced reliance on firewood and building poles (Table 2.7 and Table 2.8). These results suggest that communities in the study area have moderately reduced reliance on firewood and building poles from UFR. However, there was no evidence to statistically conclude that the communities have reduced reliance on wood products because the cumulative score and mean score for wood products were 44.2% and 2.2% respectively, which according to the grading criteria presented in Table 2.3, these scores fall under the "low" or "poor" category.

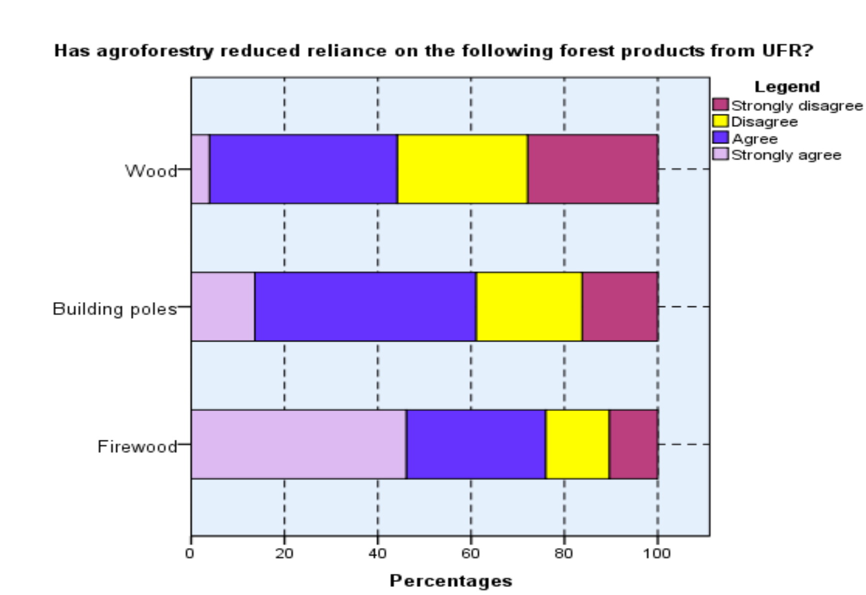


**Figure 2.4: A bar chart summarizing the responses of three Likert-type questions**

**Table 2.7: Summary results of Likert-type analysis for reduced reliance on products from forest reserve**

| Responses by products | Frequency | % | Cumulative % |
|---|---|---|---|
| Firewood | | | |
| Strongly disagree (1) | 16 | 10.4 | 10.4 |
| Disagree (2) | 21 | 13.6 | 24.0 |
| Agree (3) | 46 | 29.9 | 53.9 |
| Strongly agree (4) | 71 | 46.1 | 100.0 |
| **Total** | **154** | **100.0** | |
| **Cumulative scores 3 & 4** | | | **76.0** |
| **Minimum score** | | | **1** |
| **Maximum score** | | | **4** |
| **Average score** | | | **3.12** |
| Building poles | | | |
| Strongly disagree (1) | 25 | 16.2 | 16.2 |
| Disagree (2) | 35 | 22.7 | 39.0 |
| Agree (3) | 73 | 47.4 | 86.4 |
| Strongly agree (4) | 21 | 13.6 | 100.0 |
| Total | 154 | 100.0 | |
| Cumulative scores 3 & 4 | | | 61.0 |
| Minimum score | | | 1 |
| Maximum score | | | 4 |
| Average score | | | 2.58 |
| Wood | | | |
| Strongly disagree (1) | 43 | 27.9 | 27.9 |
| Disagree (2) | 43 | 27.9 | 55.8 |
| Agree (3) | 62 | 40.3 | 96.1 |
| Strongly agree (4) | 6 | 3.9 | 100 |
| Total | 154 | 100 | |
| Cumulative scores 3 & 4 | | | 44.2 |
| Minimum score | | | 1 |
| Maximum score | | | 4 |
| Average score | | | 2.2 |

**Table 2.8: Summary of results for median Likert-type analysis**

| Scores | Frequency | Percent | Cumulative % |
|---|---|---|---|
| 1 | 21 | 13.6 | 13.6 |
| 2 | 39 | 25.3 | 39.0 |
| 3 | 69 | 44.8 | 83.8 |
| 4 | 25 | 16.2 | 100.0 |
| **Total** | **154** | **100.0** | |
| **Mean** | | | **2.6364** |

| | |
|---|---|
| **Median** | **3** |

The analysis of Likert scale data resulted in conclusions similar to that of Likert-type data (Tables 2.9 and 2.10). The mean Likert scale score was 2.6 and the cumulative mean score was about 7.9 both supporting the assertion that communities in the study area moderately reduced their reliance on timber products from the reserve (firewood, building poles and wood considered together) and hence it is sensible to argue that biodiversity conservation has reasonably improved in the study area. This implies that agroforestry has performed relatively better than the other NIGAs which were introduced by different programmes and initiatives in the study area.

**Table 2.9: Summary of results for mean Likert scale analysis**

| Mean score | Frequency | Percent | Cumulative % |
|---|---|---|---|
| 1.0 | 11 | 7.1 | 7.1 |
| 1.3 | 10 | 6.5 | 13.6 |
| 1.7 | 14 | 9.1 | 22.7 |
| 2.0 | 17 | 11 | 33.8 |
| 2.3 | 7 | 4.5 | 38.3 |
| 2.7 | 11 | 7.1 | 45.5 |
| 3.0 | 32 | 20.8 | 66.2 |
| 3.3 | 27 | 17.5 | 83.8 |
| 3.7 | 23 | 14.9 | 98.7 |
| 4.0 | 2 | 1.3 | 100 |
| **Total** | **154** | **100** | |
| **Minimum score** | | | **1** |
| **Maximum score** | | | **4** |
| **Mean score** | | | **2.6342** |
| **Std. Dev** | | | **0.85793** |

**Table 2.10: Summary of results for composite Likert scale analysis**

| Total score | Frequency | % | Cumulative % |
|---|---|---|---|
| 3 | 17 | 11 | 7.1 |
| 4 | 13 | 10 | 13.6 |
| 5 | 21 | 14 | 22.7 |
| 6 | 23 | 17 | 33.8 |
| 7 | 8 | 7 | 38.3 |
| 8 | 12 | 11 | 45.5 |
| 9 | 38 | 32 | 66.2 |
| 10 | 37 | 27 | 83.8 |
| 11 | 29 | 23 | 98.7 |
| 12 | 3 | 2 | 100 |
| **Total** | **154** | **100** | |
| **Minimum cumulative score** | | | **3** |
| **Maximum cumulative score** | | | **12** |
| **Mean score** | | | **7.9026** |
| **Std. Dev** | | | **2.5738** |

Unfortunately the results were a bit different for beekeeping. Though it was ranked as the second important NIGA that has the potential to enhance livelihoods, beekeeping was practiced by very few farmers, only 8.4% of all farmers (Table 2.4). The low adoption of beekeeping was attributed to many factors, including the lack of suitable land at the proximity of farmer's homestead, inadequate access to extension services and lack of capital. Previous studies have also reported different reasons for the low rate of adoption (Vyamana, 2009; Mahonge, 2015). Taking a cultural perspective, Mahonge (2015), for example, attributed the low rate of beekeeping adoption in the study area to the persistence of a norm locally dubbed "*Kazopata*" which is considered to hinder cooperative agreements in the implementation of beekeeping projects. This draws some particular allurements since many programmes and initiatives that promoted beekeeping in the study area have mostly entailed the use of farmer groups as a framework for sharing knowledge, skills and capacity. Yet, farmer groups have mostly existed just notionally rather than materially due to the "*Kazopata*" norm (Mahonge, 2015). According to

Mahonge, the norm expressed an inclination of some individuals in the communities to have a covetous character over someone else's ownership, accomplishments and rewards. To showcase this, Mahonge (2015) provides a few cases where farmer groups in the study area were given beehives expecting that the hives would be managed communally but the group members ended up dividing the beehives amongst themselves and practicing beekeeping on an independent basis.

Vyamana (2009) attributed the low rate of beekeeping adoption in Uluguru Mountains to high investment costs. He argued further that beekeeping in this area only benefited a very small number of elite village members who could afford initial investment costs. He added that, as part of the investment in beekeeping, the farmer was required to either make his/her own beehives or purchase beehives from commercial dealers. In essence, Vyamana (2009) viewed beekeeping projects as less inclusive, at least in the context of poor farmers in Uluguru Mountains, who could not only afford to invest in these projects but also to provide their labour for beekeeping and wait for several months before accruing benefits. The reason seems modest and coherent: poor farmers need immediate money to meet their immediate daily subsistence needs first before they consider partaking expensive projects.

Elsewhere within the EAMs, in Udzungwa Mountains, Katani and Ndelolia (2020) attributed the low rate of practicing beekeeping to lack of suitable equipment and inadequate extension services. They indicated that the costs of modern beekeeping equipment were too high to be afforded by smallholder farmers who would wish to practice beekeeping. Consequently, the beekeepers in Udzungwa Mountains opted to use traditional beehives which offered them relatively lower income than when they could use modern beehives. In fact, Katani and Ndelolia (2020) indicated furthermore that productivity could even double if the farmers were able to use modern beehives. In fact, the information we gathered during FGDs and KIIs conducted in the study area indicated that, honey production using the traditional (locally made) beehives was as low as merely 5 litres per year, whereas that from a modern beehive would range from 15 to 20 litres per annum.

## 2.5 Conclusion and Policy Implications

This study was conducted in Uluguru Mountains, Tanzania to assess the perceptions of local communities about the role of different NIGAs as livelihood coping and biodiversity conservation strategies. Specifically, the Kendall‘s Coefficient of Concordance (*W*)/Kendall‘s tau, the Spearman correlation/Spearman‘s rho), and the Likert scale methods were used. Our Kendall‘s, *W* statistic suggested that to some extent, the respondents (judges or rankers) agreed with each other about the rankings of NIGAs though not at a super high extent. Based on this result, the null hypothesis that the respondents or farmers in the study area did not agree among themselves about the NIGAs that are potential as livelihood and biodiversity conservation strategies or the hypothesis that the Kendall‘s *W* was zero (that is, there was perfect disagreement among the judges or respondents) was rejected in favour of the alternative hypothesis. Based on the Spearman‘s rho and Kendall‘s tau statistics, we also failed to reject the null hypothesis that the NIGAs adopted by smallholder farmers in the study area were interrelated.

The extent to which the adoption of agroforestry helped to reduce the reliance of communities in the study sites and frequency of using timber products from UFR were also examined. Literally, we assumed that the adoption of agroforestry would help reducing the demand of woody products from the reserve. We therefore used this as an indicator of improved biodiversity conservation and evaluated it using the Likert-type and Likert scale data. The analysis in both cases yielded similar results suggesting that the communities in the study area moderately reduced their reliance on timber products from the UFR. The hypothesis of improved biodiversity conservation was therefore accepted.

Overall, the study findings suggest an important policy implication regarding the necessity for policy makers and development partners to understand the real needs and priorities of target communities prior to the implementation of projects and initiatives that aim at enhancing the livelihood and biodiversity conservation. This is imperative not only for winning the support of beneficiaries but also for designing the right outreach package, out-scaling and diffusion strategies. Therefore, it was concluded that the understanding of specific attitudes and perceptions of target farmers is a prerequisite for developing the relevant transforming structures and processes to promote NIGAs.

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**Conflicts of Interest**

The authors declare no conflict of interest.

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# CHAPTER THREE

## 3.0 ECONOMIC VIABILITY OF SMALLHOLDER AGROFORESTRY AND BEEKEEEPING PROJECTS IN ULUGURU MOUNTAINS, TANZANIA: A COST BENEFIT ANALYSIS

Paper 2

Willickister R. Kadigi[1], Yonika Ngaga[1] and Reuben M. J. Kadigi[2]

[1]Department of Forest and Environmental Economics, College of Forestry, Wildlife and Tourism

Sokoine University of Agriculture, P.O. Box 3011, Morogoro, Tanzania.

[1]Department of Forest and Environmental Economics, College of Forestry, Wildlife and Tourism

Sokoine University of Agriculture, P.O. Box 3011, Morogoro, Tanzania.

[2]Department of Food and Resource Economics, School of Agricultural Economics and Business Studies.

Sokoine University of Agriculture, P.O. Box 3007, Morogoro, Tanzania.

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## 3.1 Abstract

Agroforestry and beekeeping are widely promoted as prospective Nature-based Income Generating Activities (NIGAs) to improve livelihoods while at the same time enhancing biodiversity conservation in degrading agro-ecologies. These activities can diversify and increase famers' incomes and support instinctive biota and fauna resilience. However, evidence to showcase and compare their long term benefits is scant. We use the case of Uluguru Mountains in Tanzania to evaluate and compare viability of agroforestry and beekeeping projects using the Cost Benefit Analysis (CBA) approach. The results of analysis yielded positive NPVs for both agroforestry and beekeeping projects at discount rates not higher that 8.2% and 8.5% respectively. Overall, the comparison of economic viability between agroforestry and beekeeping projects revealed that the former was relatively more profitable than the later in terms of both the NPV and Benefit Cost Ratio (BCR) criteria. However, the Internal Rate of Return (IRR) for beekeeping was slightly higher than that of agroforestry. Yet, we underscore the fact that these two projects can jointly be implemented to enhance livelihoods of farmers and support biodiversity conservation in the study and other parts with similar agro-ecologies in developing countries. However, farmers in these agro-ecologies need to be supported by governments and non-government development partners in terms of training and inspiration to shift from orthodox farming to sustainable NIGAs.

**Keywords**: Uluguru Mountains, Uluguru Forestry Reserve, Cost Benefit Analysis, Net Present Values, Benefit Cost Ratios, Nature-based Income Generating Activities

## 3.2 Introduction

Concerns over habitat losses, fragmentation of forests and misuse of natural ecosystems caused by unsustainable agriculture and other income generating activities are extensively reported in the literature as causing threats of extinction for some fauna and flora species (FAO, 2020a; FAO, 2020b; Vogt *et al*., 2019; Alroy, 2017; Giama, 2017; Venter *et al*., 2014; Laurance *et al*., 2012; Krauss *et al*., 2010; Tscharntke *et al*., 2008; Ewers and Didham 2006; Fahrig 2003; Tilman and Clark, 2014; Tilman *et al*., 1994). The recent UN Food and Agriculture Organization (FAO)'s global forest resources assessment report, for example, indicates that about 178 million hectares of forest has been lost worldwide over the past three decades (FAO, 2020a) and agriculture, is pointed out as the major cause of deforestation affecting a wide range of ecosystem services, including carbon sequestration, water quality, pollination, nutrient cycling, and soil retention just to mention few (Dale and Polasky, 2007). In line with this understanding, the State of the World's Forests (SOFO) report on the status of forests identifies actions that can be taken to combat deforestation and increase the contribution of forests and trees that are necessary to accelerate progress towards the 17 Sustainable Development Goals (SDGs) which is the central framework for guiding development policies throughout the world (FAO, 2020b). In this regard, the global community is urged to promote the adoption of policy and technological innovations that enhance efficiency in agricultural production, biodiversity conservation and sustainable forest value chains.

The need to conserve biodiversity has even received an extra courtesy since 2010 following the Aichi-Nagoya Declaration (Target 7 of the Convention for Biological Diversity) which requires that farmlands and forests be managed sustainably to conserve biodiversity (CBD, 2010). On 12$^{th}$ June 1992 Tanzania signed the CBD and ratified it on 1st March 1996. The country has subsequently mainstreamed biodiversity conservation into her sector policies, plans and programmes and has continued to implement various measures to ensure sustainable biodiversity conservation. It developed and implement her first National Biodiversity Strategy and Action Plan (NBSAP) in 2001 (URT, 2001), followed by the NBSAP (2015-2020). The NBSAP was developed in line with the national development vision of 2025 which articulates the need for building a society that values biodiversity richness, using it sustainably and equitably, without jeopardizing the opportunity of future generations to benefit from it. Among others, the specific objectives of NBSAP (2015-2020) are to: a) ensure sustainable use of biodiversity through strengthened knowledge, awareness raising, support to scientific research and innovations; b) protect and rehabilitate degraded biomes and threatened species to reduce the rate of habitat loss and genetic erosion; and c) promote economic valuation for biodiversity and payments for ecosystem services.

Similar efforts have included the development and implementation of the National Climate Change Strategy (URT, 2012); Strategy on Urgent Actions on Land degradation and Water Catchments (2006); Strategy on Urgent Actions for the Conservation of Marine and Coastal Environment, Lakes, Rivers and Dams (2008); and Development of National Environmental and Action Plan (2013-2018). Other efforts include the development and implementation of the National Strategy for Growth and Poverty Reduction (NSGPR), National Environmental Action Plan (NEAP), National Action Programme to Combat Desertification (NAP), National Adaptation Programme of Action (NAPA) (URT, 2007), just to mention few.

To combat deforestation and biodiversity loss in fragile agro-ecologies, Tanzania has promoted the implementation of a number of Nature-based Income Generating Activities (NIGAs) supported by various public agencies, NGOs, and international donors. NIGAs have many socioeconomic and conservation benefits. Agroforestry and tree planting, for example, enhances biodiversity through the lessening of pressure of deforestation on additional land and provision of new habitats and resources for local biota and fauna that partly depend on the forest for existence, and could not persist in a more or less exclusive agricultural landscape (Zinngrebe *et al*., 2020; Sagastuy and Krause, 2019; Atangana *et al*., 2014). Beekeeping facilitates the maintenance and promotion of biodiversity and has enormous potential for income generation and sustainable use of forest resources. It supports the diversification of rural livelihoods and the process of artificial pollination for virtually all flowering plants that provide humans with food (Winfree, 2020).

Agroforestry and beekeeping are therefore widely recognised as farming practices which enhance both rural livelihoods and biodiversity conservation (Degu and Megerssa, 2020). The lack of profit motive is broadly considered as one of the major causes of failure for most of the previous NIGA projects (Tschinkel, 1987; Murray, 1991) but their economic viability is currently poorly documented, at least in the context of developing countries. Most of the previous studies have focused on the physical and biological aspects of NIGAs, neglecting the systematic analysis of their economic contribution at the farm level (Swinkels and Scherr, 1991). Studies which compare viability between NIGAs and their influence on farmers' adoption are limited (Vergara and MacDicken, 1990). Where carried out, the analysis was narrowly based on short term costs and benefits using mostly non-discounted measures of project worth. Hence, some key questions remain, including the interrogation of which NIGAs are more profitable for smallholder farmers, recognizing their economic portfolios? What types of support and policy action are needed to facilitate the adoption of these NIGAs?

To answer these questions, we compare viability of agroforestry and beekeeping at farm level using the case of Uluguru Mountains in Tanzania. The selection of these two NIGAs was informed by the results of farmers' ranking based on the potential of individual NIGAs to enhance livelihoods and biodiversity conservation. Agroforestry and beekeeping were ranked as first and second potential NIGAs respectively. Based on the Economic Theory of Entrepreneurship (ETE) developed by Pananek (1962), we considered viability as a crucial incentive for adoption of NIGAs by farmers. Specifically, we evaluated and compared the economic viability of agroforestry and beekeeping projects using the CBA approach.

Our paper is arranged in six sections. The next section (Section 2) presents the theoretical framework for the study, followed by Section 3 which presents the empirical framework. Section 4 describes the study area and methodology. The study findings are presented and discussed in Section 5 and concluding remarks given in Section 6.

## 3.3 Theoretical Framework

### 3.3.1 The economic theory of entrepreneurship (ETE)

Our paper is grounded on the Economic Theory of Entrepreneurship (ETE) which suggests that an entrepreneur executes all activities due to economic incentives. The theory views "profit motive" as the prime driving force that changes an individual into an entrepreneur (Pananek, 1962). The literature on ETE is rich with the mainstream of it considering ownership of capital and ability to supervise the execution of production plan as key prerequisites for ensuring that the project is carried out in an economic manner (Parker, 2018; McFarlane, 2016; Smith and Chimucheka, 2014; Śledzik, 2013; Kirzner, 2011; Braguinsky *et al.*, 2011; Femandez, 2009; Langlois, 2002). In the context of agriculture, the ETE would imply an existence of an inner-drive for a rational farmer to decide to practice a certain NIGA rather than its alternative options. This drive can be associated with the perceived economic gains, which make the farmer to allocate his or her available scarce resources into the implementation of a specific NIGA or combination of NIGAs. In fact, the incentives for farmers to practice NIGAs come in different forms, including availability of information and knowledge, affordability of the NIGAs in terms of investment and operating costs, as well as access to extension and lucrative output markets, just to mention few. Thus, policy makers and promoters of NIGAs have to realise these motives which spontaneously develop the readiness of farmers to practise the introduced NIGAs to diversify their incomes and livelihood portfolios. In fact, NIGA programmes that consider the characteristics of the target population, and the associated trade-offs between economic, environmental and social outcomes are more likely to be effective than the counterpart programmes and initiatives which do not consider (Piñeiro *et al*., 2020).

### 3.3.2 Cost benefit analysis (CBA)

Cost Benefit Analysis (CBA) is defined differently by different scholars. David *et al*. (2013) for example, define CBA as “a systematic approach to estimating the strengths and weaknesses of alternatives used to determine options which provide the best approach to achieving benefits while preserving savings; for example, in transactions, activities, and functional business requirements.” The analysis helps to gauge if a project or decision is worthwhile undertaking by establishing if and by how much, its benefits outweigh its costs (*ibid*). The Economic Times (2020) defines CBA as “a procedure for estimating all costs involved and possible profits to be derived from a business opportunity or proposal …” that "takes into account both quantitative and qualitative factors for analysis of the value of money for a particular project or investment opportunity.” In this subsection, we survey theories and practices for conducting CBA and present the procedure for undertaking CBA as summarised in Figure 3.1.

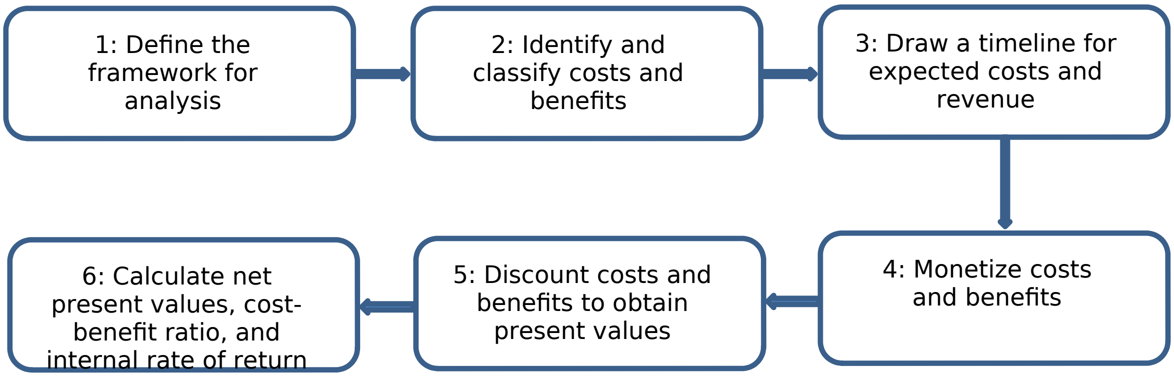



**Figure 3.1: Steps of cost benefit analysis**

As shown in Figure 2.1, the first step entails the identification of existing options, including the status quo or "without" NIGA scenario and the "with" NIGA or promoted scenario. It is important first to gauge the profit of taking up the NIGA investment option instead of continuing with the conventional practices. The second step is to identify and classify costs and benefits and ensure that the effects of each cost and benefit are understood. In the third step the analyst should sketch the timing of projects or map the activities to be done, indicate when the costs and benefits will occur, and choose the life span or time horizon of the projects in question. It is worth noting here that the choice of time horizon (maximum number of years for which forecasts are provided) requires consistency with the economic life of the main assets in the project as well as, in the general inflation and relative price changes (EC, 2008). It is therefore recommended to establish a point in the future when all the assets and all the liabilities are assumed to be virtually liquidated simultaneously. The choice of appropriate time horizon is important in the determination of the NPV of a project (CREO, 2020).

The fourth step entails the placing of all costs and benefits identified in the previous step in the same monetary *numeraire* and the fifth steps requires the analyst to make a choice of discount rate that will be used to convert future costs and benefits into present values. A discount rate refers to “a rate of return used to discount future cash flows back to their present value” (Cooperate Finance Institute Website, n.d). Different discount rates are proposed in the literature. The European Commission - EC (2008) for example, suggests a benchmark real Financial Discount Rate (FDR) of 5% which is widely accepted as the opportunity cost of capital or sacrificed return on another project or an implicit cost or sink capital invested into a project. In economic analysis, the social discount rate (SDR) is recommended (EC, 2008). SDR mirrors the social perspective on how future benefits and costs are to be valued against the present ones and it can be established using different approaches. One of the key theoretical approaches, for example, requires that the SDR is derived from the predicted long-term growth in the economy (EC, 2008). However, the mainstream literature applauds the Social Time Preference Rate (STPR) approach (Chua and Choong, 2016; Evans, 2007; Kula, 2006) which is based on the long term rate of growth in the economy, considering the predilection for benefits over time that ponders the anticipation of higher revenue, or consumption, or expenditure. The commonly used formula for estimating STPR from the growth rate is presented in Equation 3.1:

$$r = eg + p \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3.1)$$

where $r$ is the real SDR derived using a proper currency; $g$ is the growth rate of social or government expenditure; $e$ is the elasticity of marginal social welfare with regard to government expenditure, and $p$ is a rate of pure time preference.

The analyst may also reinterpret the STRP formula in terms of consumption with *g* representing the growth rate of consumption, *e* being the elasticity of marginal utility with regard to consumption, and *p* the inter-temporal preference rate (EC, 2008). The first item of the STPR equation is a utilitarian preference and the second one (*p*) is a pure time preference. It is important to note that all the values in Equation 3.1 are country specific, especially those of consumption growth (*g*) which is directly reliant on GDP. Social and private preferences affect the marginal utility parameter (*e*). Life expectancy and other individual characteristics influence the time preference parameter (*p*). If income tax structures are assumed to be at least roughly centred on the principle of equal absolute sacrifice of satisfaction, then the extent of progressiveness in the tax structure would provide a metric for *e* as shown in Equation 3.2.

$$e=\frac{Log(1-t)}{Log\left(1-\frac{T}{Y}\right)}\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(3.2)$$

where *t* is the marginal rate of income tax; *T* is the total income tax liability and *Y* the total taxable income.

The common approach used to aggregate costs and benefits occurring in different years is by weighting them, using appropriate coefficients, decreasing with time to measure the loss of value of the *numeraire*. Such a coefficient is called a discounting factor and can arithmetically be expressed as in Equation 3.3.

$$a_t=(1+r)^{-t}\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(3.3)$$

where $t$ is the time, $r$ is the rate of discount and $a_t$ is the coefficient for discounting a value in year $t$ to obtain its present value.

The sixth step is to calculate the NPV, BCR, and IRR which are used as metrics of viability (Fudge, 2011). NPV is calculated as in Equation 3.4.

$$NPV = \sum_{t=0}^{n} \frac{(B_t - C_t)}{(1+r)^t} \dots\dots (3.4)$$

where; $B_t$ and $C_t$ represent the total benefits and total costs respectively.

A positive NPV (NPV>0) implies that the project yields a net benefit because the sum of the weighted flows of costs and benefits is positive, and therefore generally desirable. BCR is the present value of project benefits divided by the present value of project costs and is calculated as shown in Equation 3.5.

$$BCR = \frac{\sum_{t=0}^{n} \frac{(B_t)}{(1+r)^t}}{\sum_{t=0}^{n} \frac{(C_t)}{(1+r)^t}} \dots\dots (3.5)$$

If BCR >1 the project is worth undertaking because the benefits, measured by the Present Value of the total inflows, are greater than the costs, measured by the Present Value of the total outflows. IRR is defined as the discount rate that zeroes out the NPV of flows of costs and benefits of an investment (Florio *et al*., 1997). It is the discount rate at which it would be just worthwhile doing the project. So the IRR is the discount rate, $r$*, at which:

$$\sum_{t=0}^{n} \frac{(B_t - C_t)}{¿¿} ¿¿¿$$

The arithmetic rule of calculating IRR requires the use of two discount rates: one which gives a positive NPV and the other which gives a negative NPV as presented in Equation 3.6.

$$IRR = r_1 + \left[ (r_1 - r_2) * \left( \frac{NPV_1}{NPV_1 - NPV_2} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3.6) \right) \right]$$

where; $r_1$ is the lower discount rate, $r_2$ is the higher discount rate, $NPV_1$ is the NPV at the lower discount rate, and $NPV_2$ is the NPV at the higher discount rate.

## 3.4 Empirical Framework

The analysis and comparison of viability of Good Agricultural Practices (GAPs) has recently received attention among scholars (Ahmed and Sallam, 2020; Adhikari *et al*., 2019; Jenkins *et al*., 2018; Lazaro *et al*., 2017; Daujanov *et al*., 2016). In the Upper Egypt for example, Ahmed and Sallam (2020) assessed the potential for improving the livelihoods of rural communities from proposed agricultural interventions. They conducted a CBA and risk analysis using the Monte Carlo simulation method. Specifically, they evaluated agricultural interventions that convert the existing traditional farming and marketing practices to modern export or high-end market-oriented production of fresh horticultural export crops (i.e. table grapes, green beans, and green onions) via the improved use of market intelligence and logistics. They found the proposed interventions to be viable from both financial and socio-economic perspectives having low risk and probability of yielding negative returns.  In Nepal, Adhikari *et al*. (2019) conducted a CBA to compare categories of farming households (i.e. farmers using improved seed and farmers using local seed for maize production). They assessed viability using undiscounted BCR or the benefit per unit cost.

In Nigeria, Jenkins *et al*. (2018) conducted CBA of a series of agriculture production and productivity enhancing interventions in the cowpea, groundnuts, maize, and soybean value chains. Specifically, they assessed the financial and economic benefits of adopting best agricultural practices in growing these crops using an Integrated Investment Appraisal (IIA) method. They define IIA as a method of CBA that measures benefits and costs in financial and economic terms making it possible to identify, quantify and allocate costs and benefits to the appropriate parties. Their analysis covered a 10-year period from 2015 to 2025, comparing the “with-project” and “without- project” scenarios using the real financial and economic discount rates of 12%. Their model first derived nominal cash flows, which were then discounted according to price indexes (World Bank inflation and exchange rate data). Their findings indicate that the interventions improved households’ incomes across all value chains. Conversely, they argue that assistance alone for growing crops would not necessarily help the farmers to move out of poverty. Farmers needed to diversify their sources of income by undertaking other economic activities such as livestock husbandry and off-farm sources.

Daujanov *et al*. (2016) used a hypothetical situation to conduct CBA where the farm decides to switch from conventional agriculture to conservation agriculture (CA). Their study assumed a farm of 50 ha having all the necessary machinery for conventional agriculture, except a harvesting combine which is rented from the government or private companies. They assumed a cotton-winter wheat-maize rotation and a CA based on tillage and that no crop residue left on the field. The CA practices included planting on permanent beds, permanent soil cover and crop rotation. They used an SDR of 4.67%

which was considered to be equal to the marginal rate of return on private investments, adjusted for inflationary expectations. To calculate the SDR, they used the Uzbekistan interest rate on bank deposits of 12% and inflation rate of 7% in 2014. Their results suggested that the investment in CA implementation would result in positive incremental benefits if the advantages of CA were monetized. Their results also indicated that even if the net incremental benefits in a crop rotation cycle were positive, the same were not adequate to recover the investment expenses in the long-term period. However, the use of a hypothetical situation and the assumption of a farm size of 50ha ignore the realities of smallholder farming systems in mountain areas, such as that of the Eastern Arc Mountains (EAMs) in East Africa where land is often scarce and concerns about loss biodiversity conservation are rampant.

Most imperative here is the fact that CBA studies comparing long-term economic viability of NIGAs introduced in agro-ecologies of tropical mountainous areas are generally rare. Where available, they mostly focus on individual agricultural value chains (e.g., Adhikari *et al*., 2019; Jenkins *et al*., 2018) or single practice, like agroforestry (Wainaina *et al*., 2020; van Thang *et al*., 2015; Rahman, *et al*., 2007; Current, 1995) or single technology, like climate-smart agriculture (Sain *et al*., 2017). Studies which compare viability between different mountainous NIGAs are lacking.

Many studies have also applied undiscounted approaches to CBA, like the gross margin and short-term benefit per unit cost approaches (e.g., Adhikari *et al*., 2019; Kuboja *et al*., 2017; Lazaro *et al*., 2017) disregarding the potential disparities in the value of money for long-term projects (the value of money today is not the same as the value of same money tomorrow). Lazaro *et al*. (2017) for example, used the gross margin approach to measure viability of GAPs in an Integrated Maize-based Farming System. They found profit from these GAPs to be not statistically different from that of the conventional practice, at least in the short time duration. However, the reliance on undiscounted short-term measures may undermine the actual long-term viability and lead to indecisive policy recommendation and formulation.

In fact, there are many aspects of NIGAs which remain not well known by researches, government and development partners promoting them. For example, it is not known with certainty why farmers can appreciate the potential of an introduced NIGA as a livelihood and biodiversity enhancing strategy but they do not practice it. In the Uluguru Mountains for example, beekeeping was ranked as the second important NIGA but only very few farmers (8.4%). It is therefore important to investigate these aspects to inform current and future policies and initiatives for sustainable livelihoods and biodiversity conservation. Our study investigated the viability of agroforestry and beekeeping in the long-term period. We discounted the streams of costs and benefits using a time horizon of 10 years and different interest rates to estimate and compare the respective NPVs and BCRs of the two projects. Where the data were not readily available or not reliable we complemented the analysis with information and data transferred from similar studies conducted elsewhere in Tanzania. In this regard, the study by Kuboja *et al*. (2017) provided very useful price information and data, especially for the CBA of beekeeping project though their study also did not use discounted values.

## 3.5 Study Area and Methodology

### 3.5.1 The study area

The study was conducted in fourteen hamlets located near or along the Uluguru Mountains Nature Reserve (UMNR) in the wards of Mlimani and Luhungo (Morogoro Municipality), and Mzumbe (Mvomero district). Located at altitudes of between 650 and

1,400 metres above sea level (Figure 3.2), the study sites are mountain areas. Geologists classify a mountain as a landform that rises at least 300 meters or more above its surrounding (National Geographic Website, n.d). Though harbour many endemic flora and fauna species, mountain areas are generally vulnerable to many natural and anthropogenic threats, including frequent fires, land cover change and agricultural intensification, just to mention few (Secretariat of the Convention on Biological Diversity, n.d).

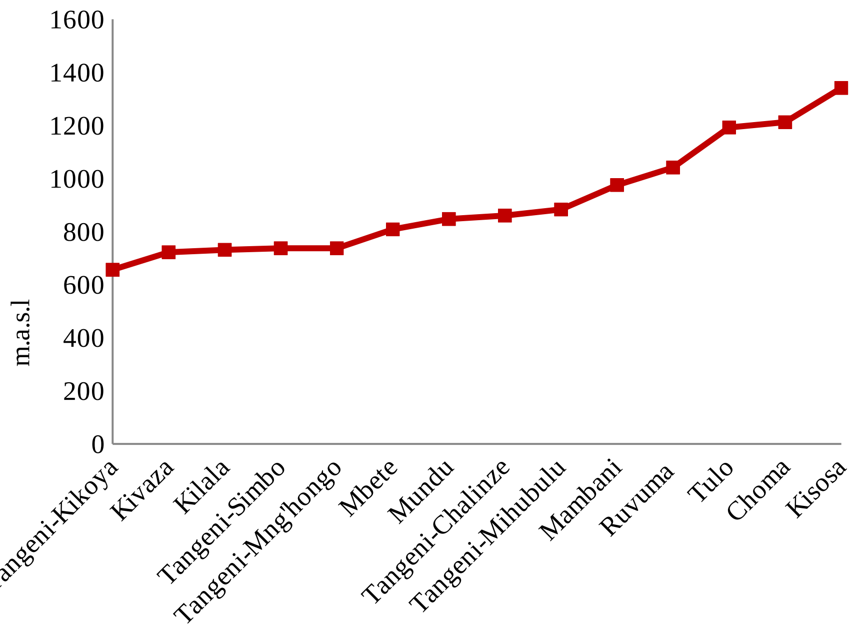



**Figure 3.2: Altitudinal locations of the study hamlets**

As in many other mountain areas, forest resources in the study area are threatened by uphill expansion of agriculture and human settlements, logging for timber and fuel wood. As such, there are different land uses in the area (Figure 3.3), especially in the hamlets that border the Uluguru Mountains Forest Reserve which constitute a biodiversity hotspot and home to hundreds of species found nowhere else on earth. The area also serves as a water catchment and water source for populations living downstream in Morogoro rural and Municipality as well as other residents in the Dar es Salaam City and the Ruvu/Wami River Catchments. Land degradation in the study area is reported to be rampant caused by unsustainable anthropologic activities (Massawe *et al*., 2020; Massawe *et al*., 2019; Harrison and Mdee, 2017; William, 2010; Yanda and Munishi, 2007; Lyamuya *et al*., 1994).

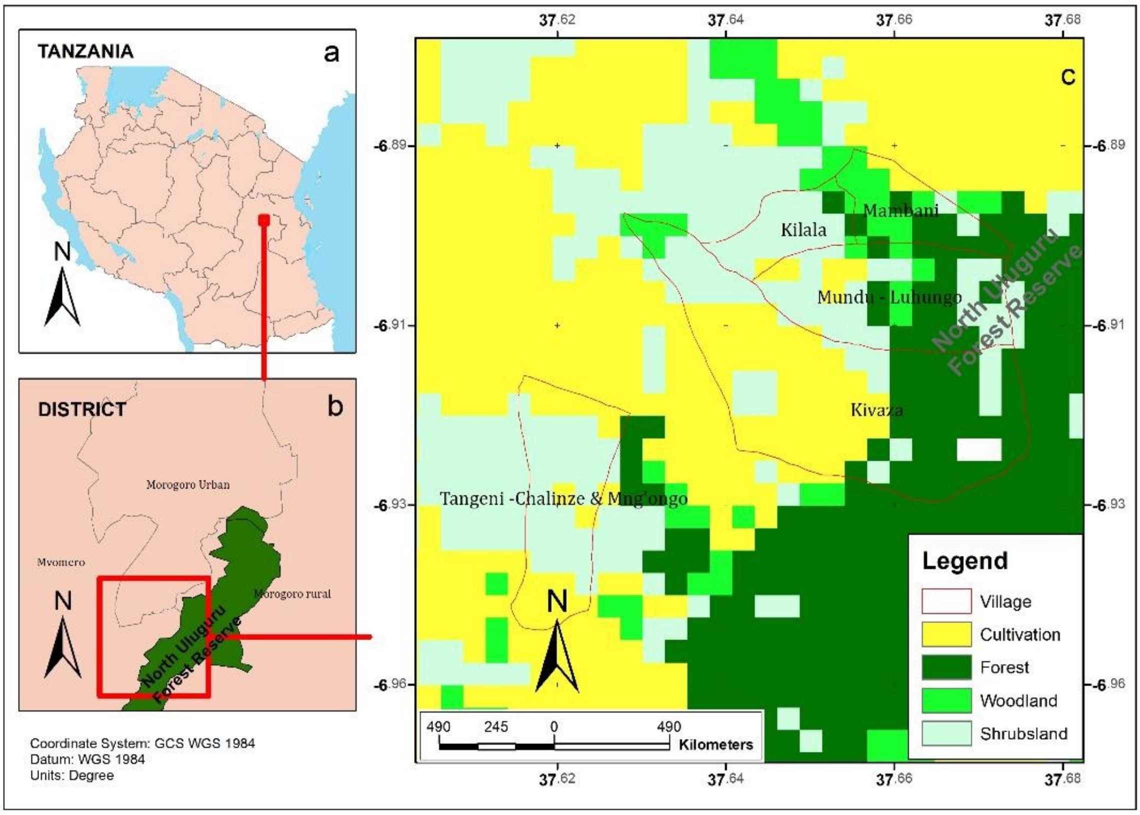



**Figure 3. 3: Map showing the location of the study sites and existing land uses**

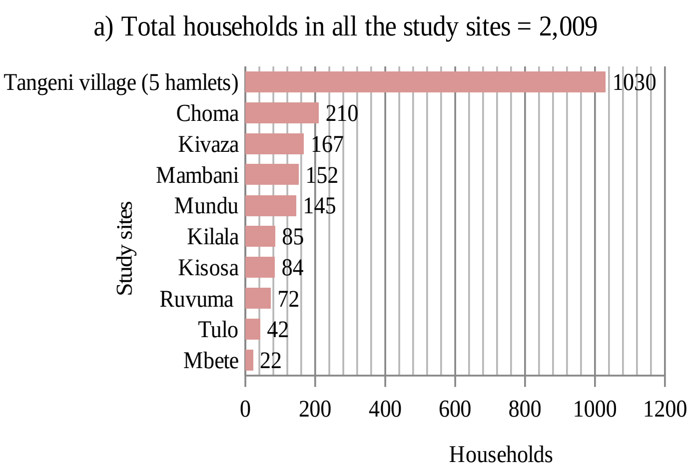
### 3.5.2 Methodology

#### 3.5.2.1 Sampling and data collection

We used the multi-stage sampling procedure to select the study villages and sample households. In the first stage, fourteen hamlets were selected purposely based on their participation in the previous NIGA projects, notably the Uluguru Mountains Payment for Watershed Services Project (UMPWSP), funded by the Department for International

Development Civil Society Challenge and supported by the Royal Society for the Protection of Birds (RSPB) in partnership with the Wildlife Conservation Society of Tanzania (WCST) and others.

In the second stage, households were stratified into strata according to wealth ranks assigned previously by UMPWSP. The third stage entailed the selection of sample households from each stratum using the proportionate probability sampling procedure. This led to a total of 201 sample households though the number dropped down to 154 households after data cleaning and removal of outliers. The distribution of sample by study site is shown in Figure 3.4.



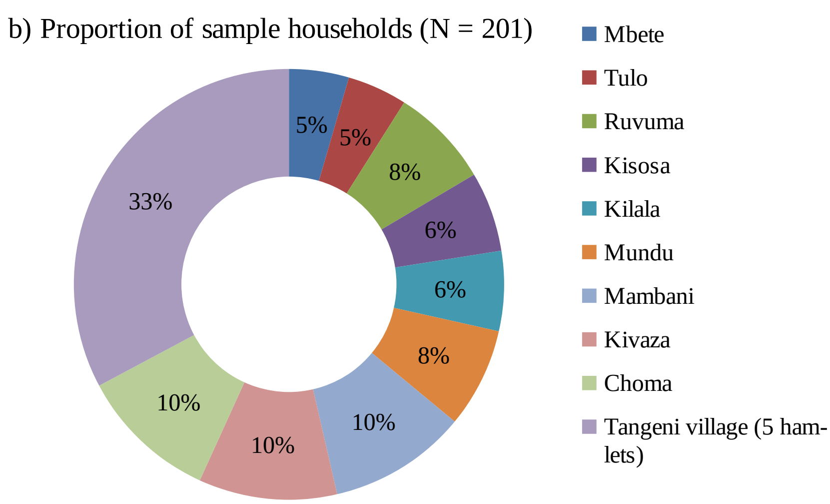



**Figure 3. 4: Total households and proportion of sample households in the study sites**

The study used both primary and secondary data. Prior to commencement of fieldwork, we hired six enumerators to assist in data collection. These were trained on how to administer questionnaires and use other research tools (checklists and guidelines). They were also reminded about the research ethics they should comply with.

The actual fieldwork started with a reconnaissance survey to get an overview and understanding of the study area and applicability of the questionnaire. During the reconnaissance survey the household questionnaire was pre-tested to a small number of respondents before the actual survey to check for its relevance to the study area and objectives. This was followed by the main survey which used different research tools and techniques, including structured questionnaires, key informant interviews (with interviewees selected based on their involvement in NIGA initiatives) and Focus Group Discussions (FGDs). The FGDs were attended by about 10 participants per hamlet representing different socioeconomic groups that existed in the area, including the rich, poor, youth and women, men, abled and disabled people. In addition, direct observation served as a complementary tool. In selecting the key informants for interview, the snowball technique was used. The technique is particularly suitable when the population of interest is hard to reach and compiling a list of the population poses difficulties for the researcher (Etikan *et al*., 2016). It begins with a convenience number of initial subject which serves as "seeds," through which wave 1 subject is identified; wave 1 subject, in turn, identifies wave 2 subjects; and the number of interviewees consequently expands wave by wave-like a snowball growing in size as it rolls down a hill (Heckathorn, 2015).

### 3.5.2.2 Data processing and analysis

The analysis and comparison of economic viability of agroforestry versus beekeeping benefited from the information and data gathered during FGDs, KII and questionnaire survey, complemented by information gathered through the deskwork review of relevant documents. The information and data gathered during the fieldwork and through literature review helped the generation of streams of costs and benefits of the two NIGAs over the life span or time horizon of 10 years. Both the short and long term costs and benefits were taken into consideration to ensure that the projections are based on realistic lifespan of the respective NIGAs, looking at how both costs and benefits evolve over time. The identification of physical amounts and expected value of costs and benefits (i.e. the financial receipts and outlays as measured by market prices) entailed the specification of when they occur in time.

The types of benefit and cost information gathered included: a) the direct benefits and costs associated with the production of a cost object, like product, service, or activity; b) indirect benefits and costs, which are usually fixed in nature, and may come from overhead of the NIGAs; c) tangible benefits and costs, which usually related to an identifiable source or asset, like purchasing tools; and d) real benefits and costs or expenses associated with producing an offering (product or service).

Moreover, information and data on interest rates were gathered to inform the selection of discount rate for future benefits and costs to obtain the present value (the equivalent value that one is receiving or giving up today when the decision to adopt a certain NIGA is made). NPV, in this case, refers to the present value of the NIGA’s net benefit stream, obtained by discounting the stream of net benefits produced by the NIGA over its lifetime, back to its value in the chosen base period, usually the present. The market rate of interest and social interest rate (SDR) were used for discounting the annual net-benefit stream of NIGAs. Recognising the difference in lives of assets between agroforestry and beekeeping projects, we constructed a scenario to maintain consistency in the time horizons of the two projects. The economic live of most assets in beekeeping (e.g. beehives) is often around 10 years whereas an agroforestry project is often complex requiring enduring capital due to large up-front capital demands and relatively longer time horizons spent to grow trees (CREO, 2020; Do *et al*., 2020). In our study, we used the same time horizon (10 years) for CBA in Agroforestry and beekeeping and established the mean current value of agroforestry land operated by farmers and used it as a proxy of investment cost. This makes sense because one may decide to invest in an already existing agroforestry project instead of investing in a new one.

The investment in the existing agroforestry was valued using the Contingent Valuation Method (CVM). Derived from neoclassical welfare economics, CVM is a stated preference approach which “explores the fundamental concept of *utility* as reflected in both use and non-use values and measured by the metrics of maximum Willingness to Pay (WTP) and minimum Willingness To Accept Compensation (WTAC)” (Hanley, 2002). It is theoretically sound because the method (CVM) explicitly incorporates respondents’ values via the level of WTP or WTAC they specify. Since our study interrogated owners and operators of agroforestry land it was deemed appropriate to use the WTAC approach rather than WTP as the latter approach would be appropriate when interviewing potential buyers. We then obtained mean values of investment and operating costs as well as annual revenues which enabled us to prepare and make projection of costs and benefit streams as well as the computation of NPVs and BCRs. NPVs, BCRs and IRR were used as key metrics of economic viability in this study. Table 3.1 presents the key parameters and assumptions we used to carry out our CBA in agroforestry.

**Table 3.1: Key assumptions used in the evaluation of economic viability of agroforestry project**

| Parameter | Value |
|---|---|
| Project lifespan | 10 |
| Investment cost (WTAC/acre) (TZS) | 2 298 944.57 |
| Operating costs/acre/year (TZS) | 107 810.42 |
| Revenue/acre/year | 463 030.37 |

For beekeeping project, we used the unit cost of investment per beehive established from Key Informant Interviews (KIIs) conducted in the study sites because farmers who practiced beekeeping were relatively few (8.4%) to justify a realistic statistical analysis based primary data generated from the questionnaire survey. We generated the costs and benefits streams of beekeeping using the Benefit Transfer (BT) method to collate secondary data and information from previous studies, notably the study by Kuboja *et al*. (2017). Benefit transfer is a procedure for taking the estimates of economic benefits (or values in general) gathered from one site and applying them to another (Plummer, 2009). In this study we used a common method that applies an estimate of value per acre assuming similar land-cover or habitat type. It should however be noted that BT is rarely the best choice for analysing the economic values of a project, but the costs of gathering primary, site-specific data have made it a common practice for studies that use natural sites (Plummer, 2009; Rosenberger and Loomis 2001). The detailed discussions of the theoretical and informational requirements for BT, as well as the steps required to implement it are provided in Johnston *et al*. (2015).

The key assumptions and respective sources of information in viability analysis of the beekeeping project are given in Table 3.2. For information and data sourced from previous studies (notably Kuboja *et al*. 2017 in this study) the major assumption was that prices have not changed significantly between 2017 and 2020.

**Table 3.2: Key assumptions in the evaluation of economic viability of beekeeping project**

| **Item** | **Value** |
|---|---|
| Unit cost of investment per beehive in TZS (own field survey) | 130 000.00 |
| Total cost of beehives investment in TZS (own field survey) | 1 430 000.00 |
| Household members full involved in beekeeping (Kuboja *et al*., 2017) | 2 |
| Total number of beehives harvested (*ibid*) | 11 |
| Labour cost per beehive in TZS (*ibid*) | 13 893.00 |
| Transport cost per beehive in TZS (*ibid*) | 10 137.00 |
| Actual profit per beehive (*ibid*) | 41 451.00 |

We then discounted the streams of benefits and costs using a discount rate of 3.2%, which was the current rate of inflation in Tanzania during the time of data collection. According to the recent report by the Bank of Tanzania – BoT (2020) this rate has almost remained constant, recording a twelve-month headline inflation of 3.3% in April 2020. CBA was repeated using different discount rates (1%, 2%, 4%, 5%, 6%, 7%, 8%, 9%, 10%, 15%, and 20%), primarily as part of sensitivity analysis to test the robustness of the CBA results to changes in inflation or interest rates.

## 3.6 Results and Discussion

### 3.6.1 Adoption of agroforestry and beekeeping

The respondents in our study ranked agroforestry and beekeeping as the first and second NIGAs that have the potential to enhance livelihoods and biodiversity conservation. The common agroforestry systems in the study area were homegardens (about 72%), where several crops are grown mainly for commercial purposes, including banana and different tree varieties, such as the jackfruit, mango, cinnamon, cardamom, breadfruit, coco palm and eucalyptus, as well as, the hillside agroforestry systems (approximately 28%) where food crops like maize and cassava, mixed with yams and common beans, dominate with relatively fewer scattered trees and shrubs. Beekeeping entailed mostly the use "tree apiaries" whereby the hives were suspended from tall shade trees so that bystanders, like domestic animals and people are safe from bee stings. Relatively however, beekeeing was practised by only few farmers (8.4%) compared to agroforestry which was practiced by more farmers (72.1%) than (Figure 3.5).

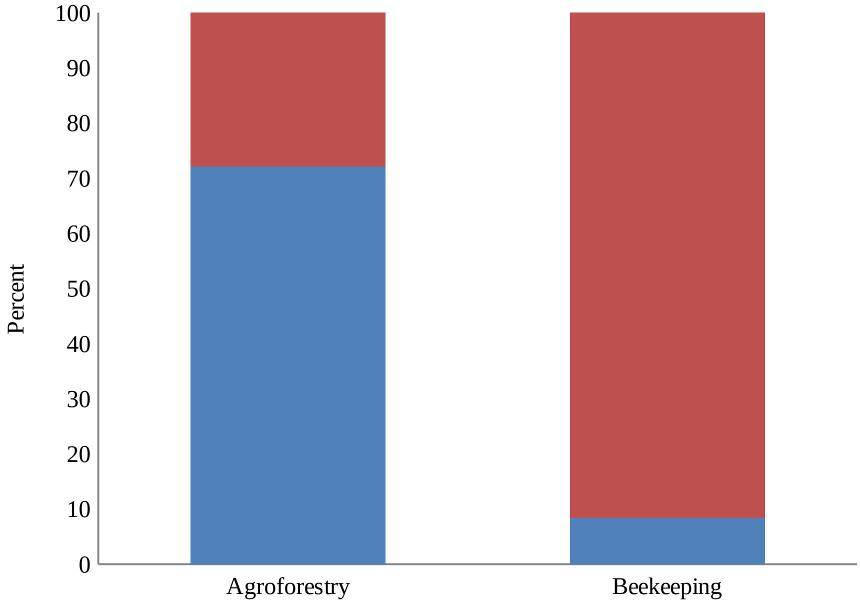



**Figure 3.5: Proportion of farmers who practised agroforestry and beekeeping versus those who did not practise (%)**

The causes of low rate of adoption of beekeeping were rigorously discussed during the FGDs and KIIs conducted in the study area. The participants attributed it largely to the lack of suitable land at the proximity of farmer’s homestead, inadequate access to extension services and lack of capital. The lack of land suitable for setting up the apiary and ensuring its safety was also reported by Tutuba and Vanhaverbeke (2018) as discouraging farmers to practise beekeeping in Mvomero District, Tanzania. The shortage of land is particularly important in mountain areas where population density is often high (de la Masselière, 2017; EAC/UNEP/GRID-Arendal, 2016). Our results of analysis of landholdings in the study area for example, indicate that on average, agroforestry farmers operated about 1.5 acres which was slightly smaller than the mean of 1.8 acres for monoculture cropping. Approximately 32% of the total farmland was located at a distance of more than a kilometre from homestead. Yet, the possession of adequate and suitable land for beekeeping cannot be generalised as a major limitation because evidence from elsewhere in the District Panchkula (Haryana), India indicates that landless farmers can install their beekeeping units on the farm of others (Monga and Manocha, 2011).

Access to adequate technical assistance and extension services was also emphasised as central to ensuring sustainable and profitable agroforestry and beekeeping. In beekeeping for example, farmers require knowledge and skills in appropriate queen rearing, colony division, apiary management, beehive product harvesting, processing, and honey handling (Tutuba and Vanhaverbeke, 2018). The lack of appropriate knowledge and skills causes inefficiencies, poor occupancy rates, and poor beekeeping quality products. Famers should be helped to own modern beehives and improve the productivity and quality of beehive products through effective extension services and technical supports (Piñeiro *et al*., 2020; Adhikari *et al*., 2019; Mujuni *et al*., 2012). They should be enabled to work within a high-quality beekeeping value chain so that they can become more productive and profitable.

The information we gathered from FGDs and KIIs also indicated that most farmers were willing to invest in beekeeping, but they were limited by their financial means and access to capital for beekeeping investment. Beekeeping was also constrained by access to quality beekeeping inputs, including the modern or commercial hives, as well as, the harvesting and processing tools or equipment. Where available, these inputs were viewed to be too expensive for smallholder farmers to afford purchasing them. Farmers who practised agroforestry incurred relatively higher costs than their counterpart farmers who did not practise it (Figure 3.6).

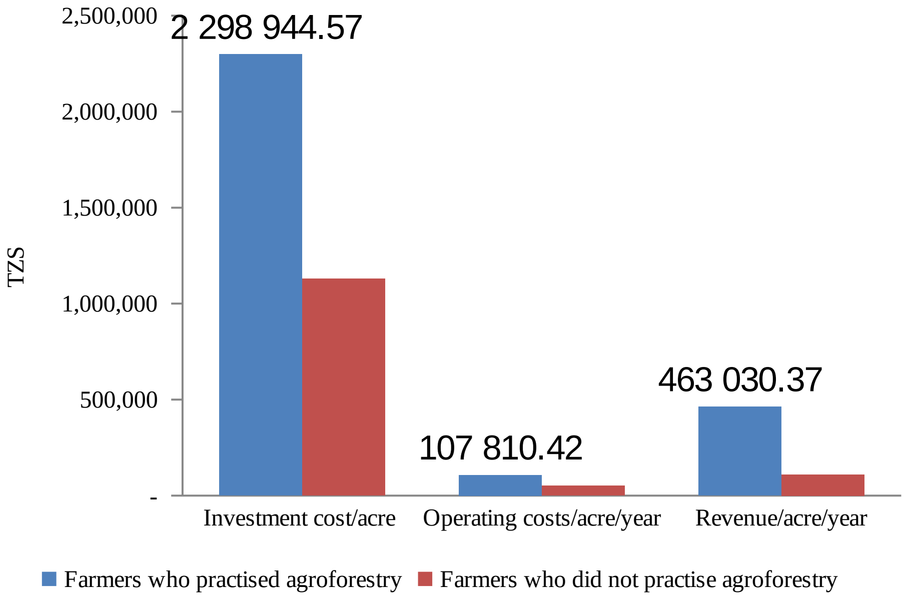



**Figure 3.6: A comparison of average costs and benefits between farmers who practiced agroforestry and those who did not practice it**

### 3.6.2 Results of viability analysis for agroforestry and beekeeping

Our results of CBA indicate that both the agroforestry and beekeeping projects were viable at the discount rate equal to the inflation rate (i.e., $r$ = 3.2%) with NPVs of TZS 700 459.40 and TZS 188 092.63 per acre respectively. In fact, the two projects were viable even at a higher discount rate of 8% yielding NPVs of TZS 84 610.21 and TZS 82 479.98 per acre respectively. For agroforestry, the BCRs at discount rates of 3.2% and 8% were 1.22 and 1.14 respectively. The BCRs for beekeeping at discount rates of 3.2% and 8% were 1.05 and 1.03 for beekeeping, respectively. Overall, the results of comparison of economic viability between agroforestry and beekeeping projects indicated that the former (agroforestry) was more profitable than the later (beekeeping) at discount rates equal or less than 8.2% and 8.5% respectively in terms of both NPVs and BCRs (Table 3.3).

**Table 3.3: Comparison of economic viability between agroforestry and beekeeping projects**

| Measure* | Discount rate | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **3.2%** | **4%** | **5%** | **6%** | **7%** | **8%** | **9%** | **10%** | **15%** | **20%** |
| **a) Agroforestry** | | | | | | | | | | |
| PVB | 3 909 732.92 | 3 755 591.07 | 3 575 397.78 | 3 407 943.83 | 3 252 131.56 | 3 106 971.47 | 2 971 570.42 | 2 845 121.18 | 2 323 842.29 | 1 941 241.90 |
| PVC | 3 209 273.51 | 3 173 383.65 | 3 131 428.06 | 3 092 438.65 | 3 056 159.85 | 3 022 361.26 | 2 990 834.94 | 2 961 392.93 | 2 840 020.12 | 2 750 936.75 |
| NPV | 700 459.40 | 582 207.42 | 443 969.73 | 315 505.18 | 195 971.71 | 84 610.21 | -19 264.52 | -116 271.75 | -516 177.83 | -809 694.85 |
| BCR | 1.22 | 1.18 | 1.14 | 1.1 | 1.06 | 1.03 | 0.99 | 0.96 | 0.82 | 0.71 |
| **b) Beekeeping** | | | | | | | | | | |
| PVB | 3 850 040.61 | 3 698 252.15 | 3 520 809.98 | 3 355 912.65 | 3 202 479.26 | 3 059 535.42 | 2 926 201.62 | 2 801 682.96 | 2 288 362.76 | 1 911 603.76 |
| PVC | 3 413 756.40 | 3 329 565.14 | 3 231 331.09 | 3 140 239.05 | 3 055 667.25 | 2 977 055.45 | 2 903 898.19 | 2 835 738.88 | 2 556 739.66 | 2 354 633.65 |
| NPV | 436 284.22 | 368 687.01 | 289 478.89 | 215 673.6 | 146 812.01 | 82 479.98 | 22 303.44 | -34 055.92 | -268 376.89 | -443 029.88 |
| BCR | 1.13 | 1.11 | 1.09 | 1.07 | 1.05 | 1.03 | 1.01 | 0.99 | 0.9 | 0.81 |

*Currency = Tanzanian Shilling (TZS)

The NPVs were negative at discount rates higher than 8.2% and 8.5% for agroforestry and beekeeping respectively implying that the projects were not viable beyond these rates. However, it is important to note that these two cut-off rates embrace the SDR of 5% recommended by EC (2008), as well as the mean savings deposit rates for Tanzania (i.e., 2.46% and 2.3% which were reported by the National Bank of Tanzania in April 2019 and March 2020 respectively) (BoT, 2020). This suggests that farmers in the study areas were relatively better off investing their money in agroforestry and/or beekeeping than depositing it in the banks. The two cut-off discount rates of 8.2% and 8.5% for agroforestry and beekeeping can also be compared with the country's growth rate in real GDP of 7.2% in 2016 - 2017, and 7.0 % in 2018, as well as, the interest rates offered on deposits, which averaged at 7.04 and 6.69% in April 2020 and April 2019, respectively (BoT, 2020). The 12- months deposit rates averaged at 7.93% and 8.01% in 2019 and 2020 respectively (*ibid*).

Using the SDR recommended by EC (2008), that is 5%, the NPVs for agroforestry and beekeeping amounted to TZS 444 969.73 and TZS 289,478.89 per acre with BCRs of 1.14 and 1.07 respectively (Table 3.3). Again, this indicates that the two projects were not only economically viable but also socially justifiable. The NPVs at discount rate of 7% (which is closely equal to the country's growth rate in real GDP) were TZS 195 971.71 and 146 812.01 per acre for agroforestry and beekeeping respectively. The BCRs were 1.06 and 1.05 respectively. In sense, our original choice of discount rate that equals the inflation rate (3.2%) was pretty reasonable for a number of reasons: firstly, lower discount rates are more preferable when analysing viability of projects that affect future generation (Arrow *et al*., 2013). At the time of survey, the country's inflation rate was relatively lower than most of the economic indicators and rates presented in the previous paragraph. Secondly, the rate 3.2% is not only economically sound but also socially justifiable at least in the perspective of Irving Fisher who called interest as “an index of a community’s preference for a dollar of present [income] over a dollar of future income.” Fisher (1930) dubbed his theory of interest as the “impatience and opportunity” theory. He theorized results from the interaction of two forces: the “time preference” individuals have for capital now, and the investment opportunity principle (that income invested now will yield greater income in the future). This proposition tortuously advocates the use of “rate of return on investment” as an appropriate discount rate. However, this works well when there are no market imperfections and distortions and the consumption rate of discount can then be considered as equal to the rate of return on investment.

Thirdly, our discount rate of choice (3.2%) was also close to the constant rate of 3% which was recommended by OMB (2003) for estimating the consumption rate of discount when evaluating projects that involve intragenerational benefits and costs. However, this requires the analyst to comply with the two-step estimation procedure by firstly using a constant rate of 3% to estimate the consumption rate of discount and, secondly by separately using a discount rate of 7% (the real, before-tax average return on private investment). For projects with important intergenerational benefits and costs, an additional lower but positive discount rate can be used (Arrow *et al*., 2013; OMB, 2003).

In addition to comparing the economic values using the yardsticks of NPV and BCR we also compared the efficiency between the two projects (agroforestry and beekeeping projects) using IRR. In principle, the IRR decision rule can be applied when the sign of net benefits (benefits minus costs), does not vary in the different years of the project. The rule ceases to offer useful information as a metric of project worthiness when the sign of net benefits changes between various years of the project lifespan (Lanctot, 2019; EC, 2008; Ley, 2007). This can easily be verified by plotting the NPVs against different discount rates to see if there are several rates which equate NPV to zero. In this regard we plotted the NPVs against various discount rates starting from 1% to 20% and both projects yielded single IRRs (see Figures 3.7 and 3.8 for agroforestry and beekeeping projects respectively).

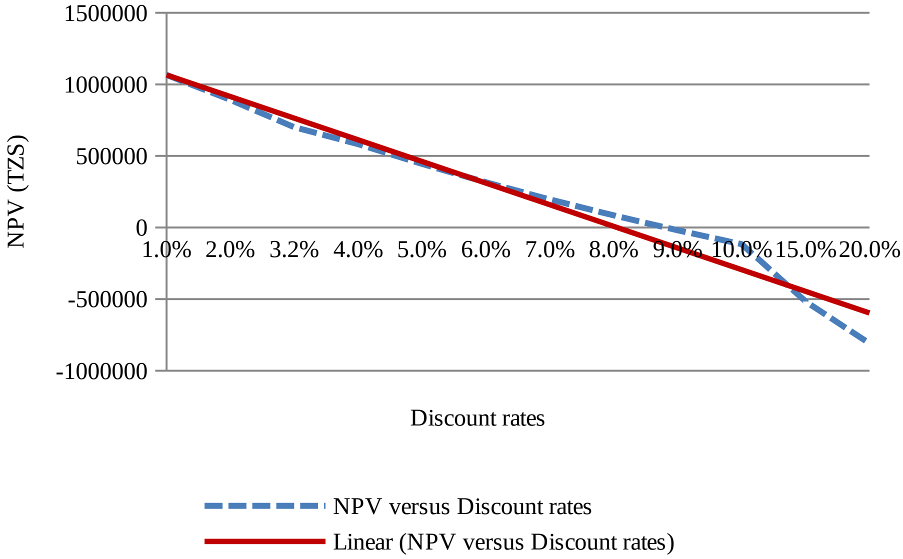



**Figure 3.7: A line plot of NPVs of agroforestry at different discount rates**

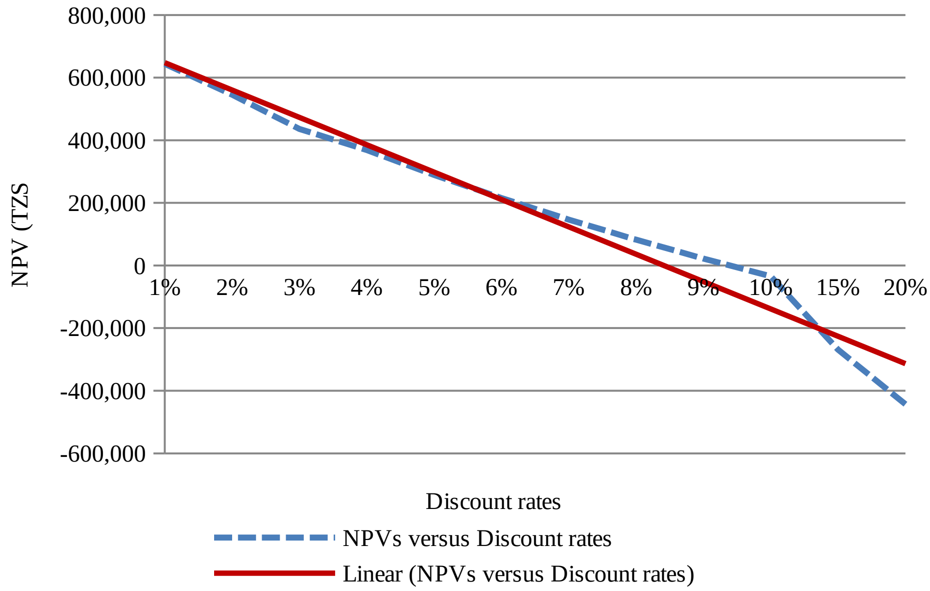



**Figure 3.8: A line plot of NPVs of beekeeping project at different discount rates**

In principle, an investment is considered acceptable if its IRR is greater than an established minimum acceptable rate of return, which in our case was either the inflation rate of 3.2% or SDR of 5%. In this regard both agroforestry and beekeeping projects were worthy undertaking though our mathematical and graphical extrapolations of IRR indicated that beekeeping was slightly more efficient (IRR = 8.5%) than agroforestry (IRR = 8.2%). However, as we have just indicated in the foregoing paragraphs the NPV and BCR of agroforestry were higher than that of beekeeping project. In fact, NPV is often considered as a much more reliable measure of project viability than IRR and a most preferable criterion when ranking investments and projects which are mutually exclusive (Cooperate Finance Institute Website, n.d). Yet, farmers could benefit more by practicing both (i.e. beekeeping as part of agroforestry) but investment was limited by the availability of funds and/or by the famer’s ability to manage a more diversified pattern of NIGAs.

## 3.7 Conclusions

A study was conducted to evaluate and compare the economic viability of agroforestry and beekeeping in the Uluguru Mountains in Tanzania using a discounted measure of costs and benefits (CBA). The results of analysis yielded positive NPVs for both agroforestry and beekeeping projects at discount rates not higher that 8.2% and 8.5% respectively. Measured in terms of IRR however, beekeeping was slightly more efficient than agroforestry. Overall, the results of comparison of economic viability between agroforestry and beekeeping projects revealed that the former was more profitable than the later in terms of both the NPV and BCR criteria. Yet, we underscore the fact that these two projects can jointly be implemented to enhance farmers’ livelihoods and support biodiversity in agro-ecologies similar to that of Uluguru Mountains. However, farmers need to be supported by the government and other development partners in terms of training and inspiration to shift from orthodox farming to sustainable NIGAs, such as, agroforestry and beekeeping. We recommend future viability studies to use a combination of empirical models and judgment to predict future discount rates and evaluate correlation of results. This is important because future discount rates are inherently uncertain due to uncertainty in the rates of growth in consumption and returns to investment.

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# CHAPTER FOUR

## 4.0 DETERMINANTS FOR ADOPTION OF NATURE-BASED INCOME GENERATING ACTIVITIES IN ULUGURU MOUNTAINS, TANZANIA

Paper 3

Willickister R. Kadigi[1], Yonika Ngaga[1] and Reuben M. J. Kadigi[2]

[1]Department of Forest and Environmental Economics, College of Forestry, Wildlife and Tourism

Sokoine University of Agriculture, P.O. Box 3011, Morogoro, Tanzania.

[1]Department of Forest and Environmental Economics, College of Forestry, Wildlife and Tourism

Sokoine University of Agriculture, P.O. Box 3011, Morogoro, Tanzania.

[2]Department of Food and Resource Economics, School of Agricultural Economics and Business Studies.

Sokoine University of Agriculture, P.O. Box 3007, Morogoro, Tanzania.

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## 4.1 Abstract

Despite the wide recognition of the potential for Nature-based Income Generating Activities (NIGAs) to enhance livelihoods and nature conservation in fragile agro-ecologies of mountain areas, certain aspects that discourage or inspire their adoption remain poorly understood. We investigated the determinants for adoption of NIGAs in Uluguru Mountains using the Generalized Linear Binary Probit model. We also used the Multivariate Analysis of Variance (MANOVA) and Discriminant Function Analysis (DFA) to find out whether our pre-selected independent variables significantly influenced the adoption of NIGAs. We underscore the need to address gender-based disparities in access to land and financial resources through the establishment of tailor-made financing schemes to promote the adoption of NIGAs.

**Keywords**: Uluguru Mountains, Generalized Linear Binary Probit, MANOVA, Discriminant Function Analysis, Nature-based Income-generation

## 4.2 Introduction

Agroforestry, beekeeping and other Nature-based Income Generating Activities (NIGAs) are widely promoted as important strategies to achieve sustainable farming, especially in fragile agro-ecologies, such as mountain areas and highlands in the tropics. Owing to their climatic and topographic diversity, mountain areas are hotspots of biodiversity, providing habitats to many fauna and flora species, some of which being endemic to these areas [1-4]. The available information for example, shows that about half of the global endemic bird areas are in mountain regions, particularly in tropical forests [5]. The Mountain Agenda 2002 shows further that in 53 countries around the globe, mountain areas cover over 50% of the national area, and in 46 others between 25% and 50% [5]. The African continent has 11% of the world's mountains, and 20% of the continent's total surface is made up of mountains [6]. In East Africa, mountain areas cover about 23% of the total land area (in Kenya and Tanzania), and 19% in Uganda [7].

Despite their importance, mountain areas face socio-economic changes triggered by both internal and external factors, such as high population densities and land use changes making their natural ecosystems being vulnerable and easily destroyed [6-8]. Anthropogenic activities, including among others, the uphill expansion of agriculture and human settlements, and logging for timber and fuel wood threaten biodiversity in these areas [1,3,9]. This has consequently called for promotion of NIGAs in mountain areas to combat the loss of habitats for wild fauna and flora species as well as halt nature degradation while at the same time enhancing the income generation potential and welfare of smallholder farmers. In fact, there are many economic and environmental benefits of doing this, particularly in fragile agro-ecologies, such as, that of mountain areas. For example, the available evidence from areas bordering the Menagesha Suba State Forest in Ethiopia shows that income from beekeeping alone contributed up to about 17% of total household income for smallholder farmers [10]. In fact, it is not just honey from beekeeping and agroforestry products that provide income to these farmers. The NIGAs they practice also contribute enormously to safeguard nature or keep ecosystem services functional through crop pollination, provision of habitat to wildlife, restoration of water and nutrients to soils and pulling carbon out of the atmosphere, just to mention few [11].

In Tanzania, the Uluguru Mountains constitute one of the important mountain areas in East Africa hosting unique biodiversity of fauna and flora species, including a number of endemic bird species, mammals, reptiles and amphibians that are found nowhere in the world. Examples of these species include the Uluguru Bush shrike (*Malconotus alius*) and

Loveridge's sunbird (*Nectarinia loveridge*); shrew mammal species, such as *Crocidura telfordi and Myosorex geata*; reptile species like *Lygodactylus williamsi*, *Cnemapsis barbouri*, *Scelotes Uluguruensis* (a skink), *Typhlops Uluguruensis* (a snake), *Prosymna ornatissima* (a snake) and *Geodipsas procterae* (a snake); as well as, the amphibian species such as *Nectophrynoides cryptus* (a toad), *Probreviceps Uluguruensis* (a microphylid frog), *Halophryne Uluguruensis* (microphylid frog), *Afrocaecilia Uluguruensis* (a caecilian) and *Scolecomrphus uluguruensis* (a caecilian) [9]. Endemism is also very high in the invertebrates, including 23 taxa of millipedes [ibid], and in plant species. The available information for example, indicates that about 108 species are identified as strict endemic plant species in Uluguru Mountains [12]. These species are under the danger of extinction if proper management strategies are not put in place. This recognition has attracted a particular attention of several programmes and initiatives, such as the Uluguru Mountains Agricultural Development Project (UMADEP) and the Uluguru Mountains Payment for Watershed Services Project (UMPWSP) to introduce and promote NIGAs. In fact, biodiversity conservation has emerged earlier as an important agenda in Tanzania since the county's independence in 1961 following the declaration of the Arusha Manifesto by the first President of Tanganyika, the Late Mwalimu Julius K. Nyerere who noted that:

> *"The survival of our wildlife is a matter of grave concern to all of us in Africa. These wild creatures amid the wild places they inhabit are not only important as a source of wonder and inspiration, but are an integral part of our natural resources and our future livelihood and wellbeing. In accepting the trusteeship of our wildlife, we solemnly declare that we will do everything in our power to make sure that our children's grand-children will be able to enjoy this rich and precious inheritance …"* [13].

To demonstrate this commitment, the United Republic of Tanzania signed the Convention of Biological Diversity (CBD) on 12th June 1992 and ratified it on 1st March 1996 [14]. The country also developed and begun to implement her first National Biodiversity Strategy and Action Plan (NBSAP) in 2001 as a requirement to Parties (Article 6 of the CBD). Other related actions have included the development and implementation of the Strategy on Urgent Actions on Land Degradation and Water Catchments (2006), the National Environmental and Action Plan (2013-2018) and the National Biodiversity Strategy and Action Plan (NBSAP) of 2015-2020. The overall objective of the latter (NBSAP) is “to reduce loss of biodiversity, promote the value of biodiversity and improve community livelihoods” [14]. In addition, a Management Plan for the Uluguru Mountains’ Nature Reserve was developed which among other things, promotes the adoption of NIGAs such as, agroforestry, tree planting, and beekeeping, just to mention few [15].

Despite all these plan and actions, the rate of adoption of NIGAs in many of the countries mountain areas remains low [16,17]. Low adoption of Good Agricultural Practices (GAPs) is not unique to mountain areas of Tanzania. It is also reported for banana farmers of Chitwan in Nepal by Joshi *et al*. [18], and in the Upper Thukela situated at the foot of the Drakensberge in South Africa by Sterve [19]. A systematic review of factors influencing the adoption of packaged or bundled sustainable agricultural practices by Rajendran *et al*. [20] also indicates limited adoption of these practices in many other countries. As such, the low adoption of GAPs would imply existence of certain factors that discourage, or rather aspire some farmers to adopt these practices. Most importantly, is perhaps the fact that studies which focus on NIGAs are lacking. Most studies have investigated factors influence adoption of GAPs [see 21-26] with little or no attention to NIGAs, especially in the context of mountain areas. Ochieng *et al*. [21] for example, evaluated the adoption of improved amaranth and GAPs in East Africa but they did not unpack the analysis into NIGAs and non-NIGAs components. In Ethiopia, studies by Asfaw *et al.*, Tesfaye *et al*., and Teshome *et al.* [22-24] evaluated factors influencing the adoption of Soil and Water Conservation (SWC) practices, again with limited specification and analysis of NIGAs. A similar study was also conducted by Barungi et al. [25] who investigated factors that influenced the adoption of soil erosion control technologies along the slopes of Mountain Elgon in Eastern Uganda.

Where the NIGAs-focused analysis was attempted, such as, in the study by Kahimba *et al*. [26] who investigated the adoption and scaling-up of conservation agriculture in Arusha and Dodoma regions in Tanzania, the focus has been mainly on a single Nature-based Income Generating Activity (NIGA). It should be noted that, focusing entirely on a single NIGA can be misleading as it ignores the fact that farm sustainability issues are diverse, interconnected and complex. In fact, studies that assume the adoption of GAPs or NIGAs as mutually exclusive with little or no interdependence among the various influential factors are bound to be inaccurate and highly misleading because they assume that a farmer can only choose one income generating activity or practice to adopt on his/her single farming plot from several mutually exclusive (independent) options. The analysis based on this assumption ignores the possibility of GAPs and NIGAs to complement or substitute each other (i.e., the likelihood of having either positive or negative correlations respectively). This is imperative because some studies [27,28] have already observed that farmers can adopt more than one practice on an individual plot. In many cases, it is reasonable to unpack the GAPs/NIGAs and re-bundle the similar ones depending on the main objective of analysis (if economic growth or nature conservation or just striking a balance between the two). It is important to underline the fact that not all GAPs can optimise the contentious benefits of economic growth and nature conservation.

For example, an initiative promoting the use of inorganic fertilizers and herbicides may increase crop yield but cause a huge cost on the environment if not properly handled.

It is also worth noting that different studies have used different economic models to evaluate factors influencing the adoption of GAPs and generally arising with different results and conclusions. Abdulai and Huffman [29], for example, have used the Endogenous Switching Regression Model to evaluate the adoption and impact of SWC technology in Africa. They identify the factors that affect farmers' decisions to adopt SWC technology as including farmers' education, capital and labour constraints, social networks and extension contacts, and soil conditions. Barungi *et al*. [25] and Asfaw & Neka [22] found the adoption of GAPs to be affected by socio-economic factors, like sex, age and education of head of household, household assets, income, size of land and livestock holdings, engagement in off-farm activities, as well as access to credits. Other studies found contact with extension agents [22,30], and perceptions of farmers regarding the farm characteristics and extent of environmental degradation [24] to be influencing the decision of farmers to adopt GAPs. In Nepal, Adhikari *et al*. [31] used the probit model to determine the extent of technology adoption between improved and local seed users in Arghakhanchi district of Nepal. They found that the extent of technology adoption was significantly higher for improved seed users than local seed users. The probability of adoption of improved seed for maize farming was found to be higher for those with access to extensive service. In this context, we define an extension agent as a public or non-state entity or individual whose main role is to set in motion a process of change after recognizing that the change is inevitable for the society, to arouse people to recognize and take an interest in their problems, to overcome these problems, to teach them how to do so, as well as, to persuade them to act on what is taught so that they ultimately achieve a transformation and egotism in their achievements. We dub the services provided by an extension agent as extension services.

In our study, we used a combination of Generalized Linear Binary Probit model/Multivariate Analysis of Variance (MANOVA) and Discriminant Function Analysis (DFA) to investigate the factors which determined the adoption of NIGAs in Uluguru Mountains and find out whether our pre-selected independent variables significantly influenced the adoption of NIGAs. We use cross-sectional data and information gathered between the end of 2019 and late 2020. Though basically based on a case study, the findings from this study are very useful for informing policy decisions. The novelty of our study derives from many aspects. Firstly, by focusing on mountain agro-ecologies, it provides some important lessons to inform policies and strategies to achieve the mutual goals of sustainable livelihoods and biodiversity conservation in mountain agro-ecologies. The study findings are relevant and will provide important implications for various change agents, including policymakers, governmental bodies, sponsorship or funding agencies, extension agents and non-governmental agencies. Secondly, through the identification of interlinked factors that consistently determine adoption of NIGAs, we hope that our study will serve as a significant knowledge base by providing information which can be used in either envisaging the reactions of potential adopters to NIGAs or to modify either the NIGAs themselves or the way in which they are introduced so as to be more harmonious with the motivational drivers of potential adaptors. Thirdly, our study recognises the reciprocal nature of the mutual objectives of ensuring sustainable livelihood and biodiversity conservation. Regarding this, we conducted a participatory ranking of all the NIGAs introduced in the study using the yardstick of their potential effects on both livelihoods and biodiversity conservation prior to the selection of NIGAs for further analysis. Fourthly, our study treated NIGAs as not necessarily mutually exclusive as farmers may implement more than one Nature-based Income Generating Activity (NIGA) simultaneously on a single plot, which is a common practice, at least in mountain areas where land resource is major limiting factor. We are, therefore, motivated to add to the knowledge base in these particular aspects.

In the next section, we start by presenting a theoretical framework that underpins our study (Section 2). We then present a brief description of the study area and methodology in Section 3. The study findings are presented and discussed in Section 4. We wind up our paper by presenting some concluding statements and policy implications from the study in Section 5.

### 4.3 Theoretical Framework

The evaluation of factors influencing the adoption of NIGAs in our study borrowed from the expected utility maximization theory. The theory is broadly applied and discussed in the literature [see 32-41]. It is renowned as the best developed formal theory of rationality, which forms the core of neoclassical economics. The expected utility maximization theory postulates a utility function, which measures the degree to which an individual’s aggregate goals are achieved as a result of their actions [37]. The theory considers the concept of satisfaction as synonymous with consumption utility in economic psychology [42]. The paper by Tan [39] provides a link between diffusion modelling and consumer diffusion research by examining the consumer’s innovation adoption decision in a utility maximization context and proposes a choice model to aid in the prediction of innovation adoption. The model incorporates multi-attribute preference, risk, and information uncertainty in an individual level expected utility framework. Abadi Ghadin & Pannell [38] also propose a model which includes the role of farmer’s personal perceptions, managerial capacity and risk preferences over time in deciding to adopt.

Their model represents the problem of adoption as a rational economic decision with the objective of profit maximization or expected utility maximization. They combine the perception expected profit with the farmer's perception of risks and their attitude to risk to define adoption as the result of maximizing expected utility of profit, which, according to Tversky & Kahneman, [41], is the form of subjective expected utility theory. In Zambia, Umar [33] found that Conservation Agriculture (CA) smallholders did not aim to maximize profit but attempted to secure household consumption from their own production, before any other considerations in risky and uncertain environment. Thus, maximization of utility was the overriding goal for these smallholder farmers.

The main assumption of expected utility theory is that the farmer acts to maximize his level of utility. Since utility is hard to measure, profit is often used by researchers as merely a substitute for this concept [35]. When risk attitude is added to the analysis, then farmers are considered as maximizers of expected utility of profit, rather than the expected profit [38]. As such, if a NIGA has a higher expected utility of profit than the conventional practices, adoption will occur. It is also important to note that people do not necessarily engage in economically optimal decision-making, but instead they may wish to optimize social, intrinsic and/or expressive goals [36]. This is more in line with some findings from the psychological approach which suggest that, instead of maximizing expected utility of profit we can also borrow from Simon's [43] satisfactory theory. This viewpoint contemplates that the theory of innovation is more concerned with "satisfying" rather than "optimising" as constructed by the classical theory of decision making.

Thus, we can argue that the expected utility maximization theory suggests that an individual farmer *i* will adopt a specific NIGA if the expected utility from practising it,

$U_{ij}^{¿}$ is greater than the expected utility from any other alternative practices, $U_{ij}$, i.e. $y_{ij}^{¿}=U_{ij}^{¿}-U_{ij}>0;$ where, $y_{ij}^{¿}$, is the net benefit that the farmer can receive from practising the *j*th activity. Farmers would therefore choose an activity or combination of practices for which they obtain the highest expected utility of profit, subject to the characteristics (or traits) of the practices [43-45]. Based on this theory, the factors influencing the adoption of NIGAs can be evaluated using the Multinomial Probit (MNP) model expressed in Equation 4.1.

$$¿_{ij}=\beta_i{}' X_{ij}+\varepsilon_{ij}\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(4.1)$$

where; $\beta_i \approx N\left(b,\Sigma_\beta\right)$, $\varepsilon_i=\left(\varepsilon_{i1},\ldots\varepsilon_{ij}\right)' \approx N\left(0,\varepsilon_\varepsilon\right)$. Thus the MNP model assumes a normal distribution for all unobserved components of utility.

It is important to note that Probit models basically apply the cumulative Gaussian normal distribution rather than the logistic function for calculating the probability of being in one category or not [45] represented in Equation 4.2.

$$p_i=\Phi\left(x_i\beta+\beta_0\right)\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(4.2)$$

$$=\int_{-\infty}^{x_1\beta+\beta_0}\phi(t)\,dt$$

where, the symbol $\Phi$ is simply the cumulative standard distribution, while the lower case symbol $\phi$ is the standard normal density function. The objective is to maximise the log-likelihood function. The partial derivatives come from the arithmetic relationship given in Equation 4.3.

$$\frac{\partial p_i}{\partial x_{i,k}}=\phi\left(x_1\beta+\beta_0\right)\beta_k\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(4.3)$$

It is important to use the maximum likelihood method to fit a set of statistical adoption models on sets of simulated data. The best relationships can be identified using the Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC) methods [46]. The AIC and BIC have the advantage of testing the significance of the difference between the functions of different model specifications. AIC evaluates how well a model fits the data it was generated from [ibid]. It is used to compare different possible models and determine which one is the best fit for the data. AIC is calculated from the number of predictor variables applied to build the model and the maximum likelihood estimate of the model (how well the model reproduces the data).

Suppose $\overset{¿}{\theta}¿$ is the value of the maximized log-likelihood objective function for a model with $k$ parameters fit to $T$ data points. The AIC for a given model is expressed as in Equation 4.4.

$$-2\log L ¿¿$$

According to AIC, the best-fit model is the one that explains the highest amount of disparity using the fewest possible independent variables. Lower AIC scores are better, and AIC punishes models that apply more parameters. So if two models explain the same amount of disparity, the one with fewer parameters will have a lower AIC score and will be the better-fit model. However, AIC lacks certain properties of asymptotic consistency [47,48].

The Bayesian Information Criterion (BIC) for a given model is expressed as in Equation 4.5.

$$-2\log L \overset{\hat{¿}+k\log(T)\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.(4.5)}{\theta \qquad ¿}$$

Although BIC takes a similar form like AIC, it is generated within the Bayesian framework, reflecting sample size and having characteristics of asymptotic consistency. For reasonable sample sizes, BIC apply a larger punishment than AIC, thus other factors being equal it tends to choice modest models than does AIC. From a Bayesian view point this persuades the use of BIC [46].

Other criteria include the Finite Sample Corrected AIC (AICC) and the Consistent AIC (CAIC). AICC is the small-sample equivalent of AIC. It imposes an additional punishment for complex models, as compared to the BIC [46,49,50]. The AICC for a given model can be expressed as in Equation 4.6.

$$AIC+\frac{2k(k+1)}{T-k-1}\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(4.6)$$

The CAIC for a given model is given as in Equation 4.7.

$$-2\log L(\theta)+2k(\log(T)+1)=BIC+k\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(4.7)$$

## 4.4 Study Area and Methodology

### 4.4.1 The study area

The study was conducted in fourteen hamlets located adjacent to the Uluguru Mountains (UMs) Nature Reserve (UMNR) in the wards of Mlimani and Luhungo (Morogoro Municipality), and Mzumbe (Mvomero district) in Tanzania. The UMs were selected as a case study area because of the challenge facing many mountain areas, notably the proliferation of anthropological activities in area which threaten biodiversity conservation [51-56]. There are different land uses in the study area (Figure 4.1). Besides its importance as biodiversity hotspot and home to hundreds of species found nowhere else on earth, the area also serves as a water catchment and water source for populations living downstream in Morogoro rural and Municipality as well as in other areas such as the Dar es Salaam City. However, land degradation in this mountain area is reported as rampant caused by unsustainable economic activities [ibid].

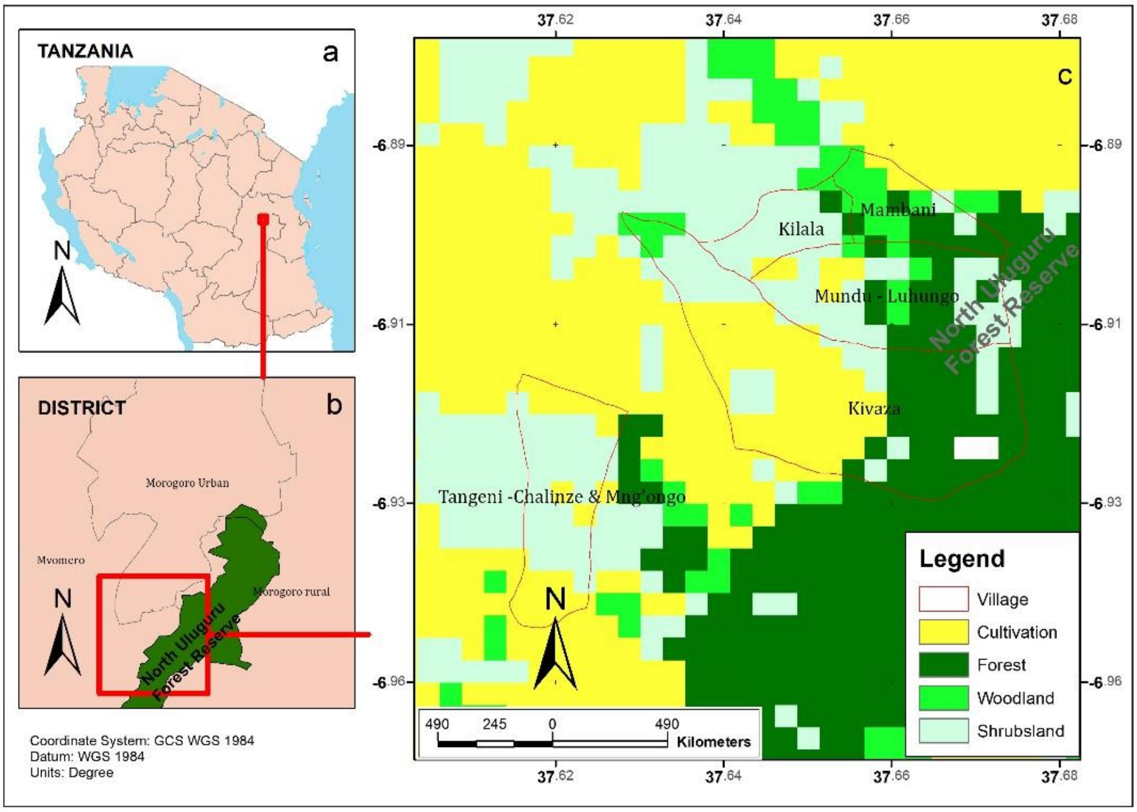


**Figure 4.1: Map showing the location of study sites and existing land uses**

### 4.4.2 Methodology

#### 4.4.2.1 Sampling and data collection

We used the multi-stage sampling procedure to select the study hamlets and sample households. In the first stage, fourteen hamlets were selected purposely based on their participation in previous NIGA projects, notably the Uluguru Mountains Payment for Watershed Services Project (UMPWSP), which was funded by the Department for International Development Civil Society Challenge, and supported by the Royal Society for the Protection of Birds (RSPB) in partnership with the Wildlife Conservation Society of Tanzania (WCST). In the second stage, households were stratified into strata according to wealth ranks assigned by UMPWSP using the indicators of wealth presented in Table 4.1. The ranking exercise eventually resulted in five types of wealth groups namely “very rich”, “rich” “medium”, “poor” and “very poor”. The “very rich” and “rich” households were relatively a small group, covering only about 13% of the total households. They were food secure all year round and had a fairly secure livelihood base. The “medium” wealth class constituted about 35% of the households, with a smaller base of assets to draw on, but the majority of the households in this class were still food secure all year round. The “poor” and “very poor” households (combined together) made up more than half of the total households (52%). The third stage entailed the selection of sample households from each stratum using the proportionate probability sampling procedure. The distribution of sample size by hamlets is given in Table 4.2.

**Table 4.1: Indicators used in the wealth ranking exercise**

| Indicator | Very rich | Rich | Medium | Poor | Very poor |
|---|---|---|---|---|---|
| Natural capital: Land owned | 4 ha or more | 3 ha | 1 - 2 ha | 0.4 – 0.9 ha | Less than 0.4 ha or do not own land at all |
| Financial capital: Livestock owned | Cattle: 5 or more, goats: 50 – 180, pigs: 10 – 20 | goats: 20 – 50, pigs: 5 – 10 | goats:3 – 20, pigs: 2 – 5 | goats:1 – 2, pigs: 1 – 2, a few chickens | A few chickens only |
| Human capital: Labour | Hire labour | Hire labour seasonally | May hire labour seasonally | May sell labour | Selling labour |
| Human capital: Education | Primary level or above | Primary level | Primary level | Many have not been to school | Many have not been to school |
| Human capital: Health services | Can always pay for health services (Hospitals, Dispensary, Clinics, traditional healers) | Can pay for health service | Can afford to pay for services from Dispensaries and traditional healers | Can afford to pay for services from traditional healers /use traditional medicines | Cannot afford paying for health service (use traditional medicines) |
| Physical and financial capital: Other assets owned | Owns a house build using block or burnt blocks, connected with reliable electricity sources; good floors and walls; Possess other valuable assets such as Vehicles, Milling machine, Sewing machine, Refrigerator, Bicycles, TV, Radio, Water pump | Owns a house built using at least mud block and roofed using corrugated iron sheets; bicycle(s), radio, and TV | Owns a house built using mud block and roofed using corrugated iron sheets, can own a bicycle, radio and/or TV | Owns a house built using mud and poles, roofed using thatch grass, Few have radios | Owns a house built using mud and poles, roofed using thatch grass |
| Food security | Affords three meals per day for all days in a year | Affords three meals per day for most of days in a year | Affords three meals per day for at least six months in a year | Affords three meals per day for less than three months in a year | Cannot afford three meals per day |
| Proportion to total households | 5% | 8% | 35% | 40% | 12% |

**Table 4.2: Distribution of sample size by study sites**

| Study sites/hamlets | Households | Sample size* | % |
|---|---|---|---|
| Tangeni village (5 hamlets) | 1 030 | 66 | 32.8 |
| Kilala | 85 | 12 | 6.0 |
| Mundu | 145 | 15 | 7.5 |
| Mambani | 152 | 21 | 10.4 |
| Kivaza | 167 | 21 | 10.4 |
| Mbete | 22 | 9 | 4.5 |
| Ruvuma | 72 | 15 | 7.5 |
| Choma | 210 | 21 | 10.4 |
| Kisosa | 84 | 12 | 6.0 |
| Tulo | 42 | 9 | 4.5 |
| **Total** | **2 009** | **201** | **100** |

*The total sample size used in the final data analysis (after data cleaning) was 154 households.

The study used both primary and secondary data. Prior to commencement of fieldwork, we hired six enumerators to assist us during data collection. These were specifically trained on how to administer questionnaires using other research tools (checklists and guidelines); how to avoid interview biases and use computer tablets (Kobo Collect) to create datasets. They were also reminded about the research ethics they should comply with. The actual fieldwork started with a reconnaissance survey to get an overview and understanding of the study area and applicability of the questionnaire. During the reconnaissance survey the household questionnaire was pre-test to a small number of respondents before the actual fieldwork to check for their relevance to the study area and objectives. This was followed by the main survey which used different research tools and techniques, including structured questionnaires, and checklists for interviews with key informants (selected based on their involvement in NIGA initiatives) and Focus Group Discussions (FGDs).

The FGDs were attended by at least 10 participants per hamlet representing different socioeconomic groups that existed in the area, including the rich, poor, youth and women, men, abled and disabled people. In selecting the key informants for interview, the snowball technique was used. The technique is particularly suitable when the population of interest is hard to reach and compiling a list of the population poses difficulties for the researcher [57]. It begins with a convenience number of initial subject which serves as "seeds," through which wave 1 subject is identified; wave 1 subject, in turn, identifies wave 2 subjects; and the number of interviewees consequently expands wave by wave-like a snowball growing in size as it rolls down a hill [58].

#### 4.4.2.2 Data processing and analysis

Different NIGAs were identified using the household questionnaire, FGDs, KIIs, direct observation approaches, review of government and project document as well as office records and questionnaire survey. The analysis of adoption of NIGAs in this study adopted the Generalized Linear Model (GLM), which is a generality of the linear model, such as the multiple regression models. Like the linear model, GLM is concerned about the conditional mean of an outcome variable $Y$, usually denoted as $\mu$. Like Logit, probit is a linear probability model for binary outcomes that allow one to elude the problems related to the linear probability model, such as non-constant error variance and the naive postulation of linearity in the parameters [59]. Logit and probit also serve as building blocks for more progressive regression models for other categorical outcomes [ibid]. Binary outcomes are dichotomous-dependent variables coded as 0 or 1 and nominal outcomes are dependent variables with three or more unordered categories.

The Multinomial Probit (MNP) model is a flexible model which permits random test variation and can embody any substitution pattern, avoiding the obstructive substitution pattern assumptions in other models [45]. In this study, the Multivariate Probit (MVP) model was preferred over other models because of its ability to allow the analysis of potential correlation between unobserved disturbances (error terms) and correlation between the adoption of each NIGA [60,61]. The means of two independent groups (adopters and non-adopters of NIGAs) were compared using the Independent Samples *t* Test (a parametric test), also known as the Uncorrelated Scores *t* Test or Unpaired *t* Test or unrelated *t* Test. The aim was to determine whether there is sufficient statistical evidence to justify that the associated population means are significantly different. Before running the Independent Samples *t* Test, we generated descriptive statistics and graphs to get an idea of what is expected from the test using the Explore procedure in IBM SPSS

Statistics 26 software to obtain comparative boxplots for each predictor and NIGA. The Independent Samples *t* Test provided the group statistics, which offered basic information about the group comparison (i.e., NIGA adopters versus non-adopters), including the sample size (*n*), mean, standard deviation, and standard error for independent variables. In addition, the Independent Samples Test displays two types of results which are most relevant to this test, that is, the Levene's Test for Equality of Variance and t-test for Equality of Means. The Levene's test is an alternative to Bartlett's test, which tests equality of variances between *k* sample populations [63]. However, the Bartlett's test is sensitive to departures from normality, and thus the Levene's test is preferred when the population samples are generally not normally distributed [63].

The null and alterative hypotheses of the Levene's test can be generally stated as follows;

$H_0$: All of the *k* sample populations have equal variances

$H_1$: At least one of the *k* sample population variances is not equal

The test statistic, *W* used in Levene's test is defined as in Equation 4.9.

$$W = \frac{(N-k)\sum_{i=1}^{k} n_i \left(Z_i - Z\ldots\right)^2}{(k-1)\sum_{i=1}^{k}\sum_{j=1}^{n_i}\left(Z_{ij} - Z_i\right)^2} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4.9)$$

where,

$k$ is the number of groups

$n_i$ is the number of samples belonging to the *i*-th group

$N$ is the total number of samples

$Y_{ij}$ is the j-th observation from i-th group

and,

$$Z_{i}=\frac{1}{n_1}\sum_{j=1}^{n_i} Z_{ij}$$

$$Z_{\ldots}=\frac{1}{N}\sum_{i=1}^{k}\sum_{j=1}^{n_i} Z_{ij}$$

are the mean of the calculated $Z_{ij}$ for group I and mean of all $Z_{ij}$, respectively.

In Levene's Test, $Z_{ij}$ can have one of the following three definitions:

$|Y_{ij}-\tilde{Y}_i|$, where $\tilde{Y}_i$ is the median of the *i*-th group

$|Y_{ij}-\bar{Y}_i|$, where $\bar{Y}_i$ is the mean of the *i*-th group

$|Y_{ij}-\bar{Y}'_i|$, where $\bar{Y}'_i$ is the trimmed mean of the *i*-th group

The null of Levene's test is rejected when $p$ is less than the chosen significance level $\alpha$ = 0.05, and can be concluded that the variance in the independent variable of interest for, say "adopters" is significantly different from that of "non-adopters." In this case, the values of "Equal variance not assumed" are used for the $t$ test (and corresponding confidence level) results. If this test gives insignificant values, that is, if the observation is $p > \alpha$ then the "Equal variances assumed" output would be used. The confidence interval (CI) output of the $t$ - test complements the significance test results. Typically, if the CI for the mean difference contains 0, the results are not significant at the selected significant level. It is important to note that the Independent Samples $t$ Test is suitable for a continuous dependent variable (i.e. interval or ratio level) and independent variables that are categorical (i.e. two or more groups). The test assumes a normal distribution (approximately) of the dependent variable for each group, as well as homogeneity of variances (i.e. variances nearly equal across groups and absence of outliers, just to mention few).

In our study, we used the maximum likelihood method to fit the set of statistical NIGA adoption models on the sets of simulated data. The best relationships were compared and selected using the Akaike information criterion (AIC); Bayesian information criterion (BIC) methods [46], and the Finite Sample Corrected AIC (AICC). In addition, we generated Q-Q plots and used them to test the assumption of normality. In this method, we plotted the observed value and expected value to check if the plotted values vary more from a straight line or not. Where they vary more from the straight line, then the data were considered to be not normally distributed, otherwise the data were considered to be normally distributed [64]. We also tested our dataset for heteroskedasticity (i.e. the state of systematic changes in the spread of residuals or the error term of the model). The presence of residual variance in a model would show that the scattering of the model is dependent on at least one independent variable [ibid]. Specifically, we tested heteroskedasticity using both graphical or visual (the P-P plot and histogram) and statistical tests (the Levene's and Breusch-Pagan tests). We then removed the variables with heteroskedasticity from our dataset before doing the final regression analysis using the robust standard method.

After data cleaning and removal of outliers, we correlated the independent variables to check for multicollinearity. For pairs of variables found to have correlation coefficient ($r$) of equal to or greater than 0.8 one or both variables were removed from the dataset [65]. The new dataset was retested by computing the Variance Inflating Factors (VIFs) and tolerances of independent variables. The VIF values were less than 1.5 and the tolerances greater than 0.1, which were not enough to overlay concerns about presence of multicollinearity. VIFs greater than 10 and tolerances less than 0.1 would imply the presence of muticollinearity problem [66].

We then applied the Multivariate Analysis of Variance (MANOVA) and Discriminant Function Analysis (DFA) to find out whether the independent variables significantly influenced the adoption of the four NIGAs (agroforestry, terraces/contour farming, soil/stone bunds and beekeeping). Specifically, we created syntax for MANOVA to uncover a meaningful underlying dependent variable which makes useful correlation amongst dependent variables and the effects of independent variables. The use of MANOVA instead of separate ANOVAs for each dependent variable is widely discussed in the literature [67-72]. By employing MANOVA, the analyst can obtain a more detailed description of the phenomenon under investigation and get a better opportunity of determining the overall impact of the treatment effect [67]. In addition, using MANOVA helps the analyst to control the overall alpha level at the desired level and increase the statistical power. Although it offers some useful advantages, MANOVA has a disadvantage of complicating the interpretation of results compared to ANOVA and losing the degree of freedom [ibid]. For that matter, if the hypotheses of interest are univariate in nature, it may be desirable to conduct separate ANOVAs. In the real world however, analysts often find that the response variables are correlated [67,73]. But it should be noted here that MANOVA gives same values as the GLM approach. In fact it is recommended to start with MANOVA first because it creates a liner equation upon which a variable which will maximally discriminate amongst the groups of independent variables is identified [67]. Without doing MANOVA some power of identifying influential factors is lost.

DFA is an extension of univariate regression analysis and ANOVA and it is similar to multiple regression analysis [74]. In the DFA, the canonical discriminant functions are defined as linear combinations that separate groups of observations, and the canonical variates are defined as linear combinations associated with canonical correlations between two sets of variables [75,76]. In standardized form, the coefficients in either type of canonical function provide information about the joint contribution of the variables to the canonical function. The standardized coefficients can be converted to correlations between the variables and the canonical function [ibid]. These correlations generally alter the interpretation of the canonical functions. For canonical discriminant functions, the standardized coefficients are compared with the correlations, with partial $t$ and $F$ tests, and with rotated coefficients [ibid]. The DFA output includes among others, the standardized discriminant function coefficients which show the relative contribution of each variable to the variates. The derived canonical variates summarize between-group variation and provide a simultaneous test describing which variables best account for group differences [ibid]. The canonical discriminant analysis (CDA) involves deriving the linear combinations (i.e., canonical functions) of the variables that will discriminate the best (i.e., maximize the variation) among the predefined groups [ibid].

## 4.5 Study Area and Methodology

### 4.5.1 Normality testing

The results of normality tests using visualization (boxplots) helped to identify the outliers and remove them. As illustrated in Figure 4.2 for selected independent variables (i.e. age of household head, household size, and size of farmland) and dependent variables (i.e. adoption of agroforestry and adoption of beekeeping), if the variances for adopters and non-adopters of NIGAs were equal, then the total length of the boxplots in this figure would be approximately similar for both groups. However, the boxplots show that, in many cases the observations for adopters of NIGAs were much greater than the spread of observations for non-adopters implying that the variances for these two groups were different. In Figure 4.2, examples of outliers are presented as numbers marked by asterisks (e.g. observation number 35 and number 69). These observations together with other outliers were removed from the original dataset making the sample size to decline from 201 to 154 in the MANOVA, ANOVA and DFA.

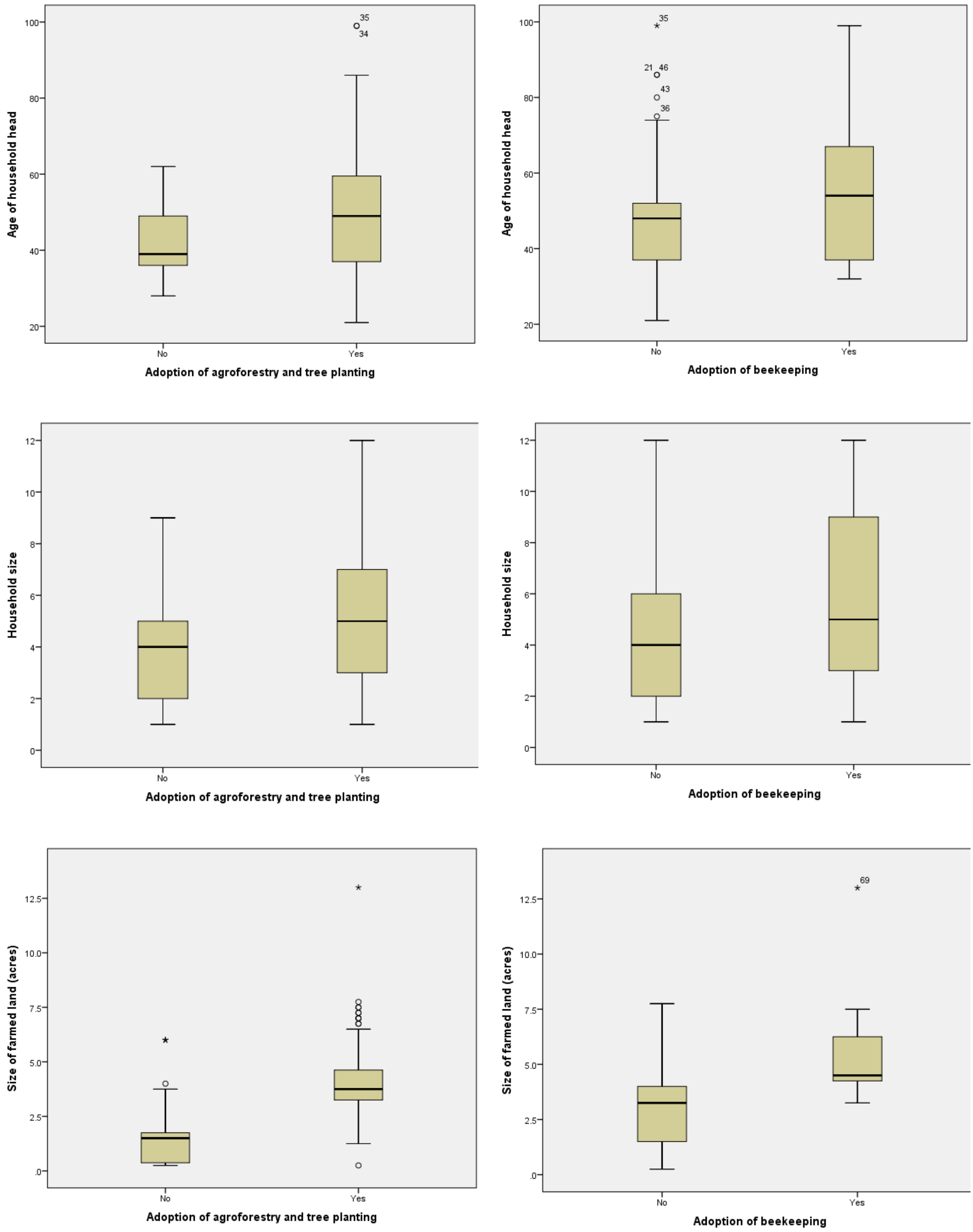


**Figure 4.2: Boxplots for selected predictor variables between adopters and non-adopters of agroforestry and beekeeping**

The P-P plots and histogram of the square of standardized residual against continuous predictors (Figure 4.3) also display some interesting visualizations. As expected, the results of an Independent *t* Test and Levene's Test yielded significant outputs for the predictors as shown in this figure. More discussion about the interpretation of the Levene's test statistics is presented in the next sub-section.

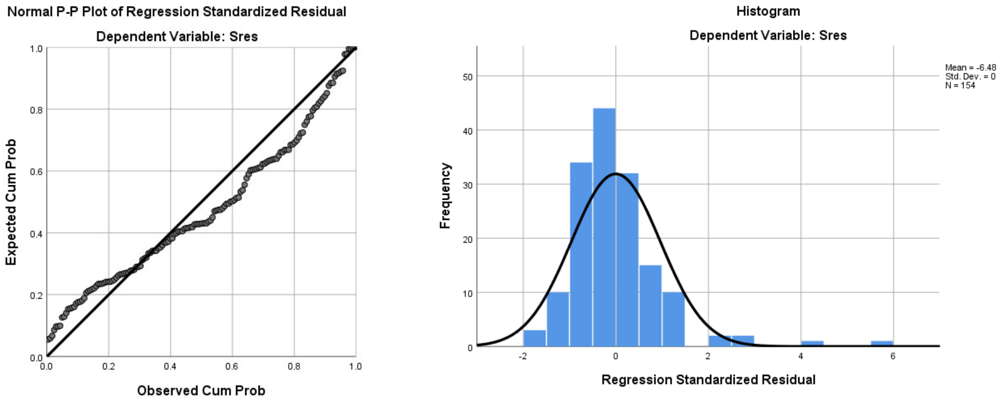


**Figure 4.3: P-P plot and histogram of the square of unstandardized residual against continuous predictor variables**

The results of test of goodness of fit for different NIGAs' models are presented in Table 4.3. The agroforestry model registered the best relationships (smallest values) for all model selection criteria (i.e., AIC, BIC, AICC, and CAIC). This is followed by beekeeping and soil and stone bunds models. The terraces and contour farming model yielded the largest AIC, BIC, AICC and CAIC values making it to rank the last amongst the four models tested for goodness of fit.

**Table 4.3: Results of test of goodness of fit for different NIGAs (n = 154)**

| Criteria | Agroforestry | Terraces/ Contours | Soil/stone bunds | Beekeeping |
|---|---|---|---|---|
| Deviance | 0.000 | 192.264 | 53.355 | 45.830 |
| Scaled Deviance | 0.000 | 192.264 | 53.355 | 45.830 |
| Pearson χ2 | 0.000 | 155.019 | 73.571 | 99.547 |
| Scaled Pearson χ2 | 0.000 | 155.019 | 73.571 | 99.547 |
| Log Likelihood[b] | 0.000 | -96.132 | -26.677 | -22.915 |
| AIC | 24.000 | 216.264 | 77.355 | 69.830 |
| AICC | 26.213 | 218.477 | 79.567 | 72.043 |
| BIC | 60.443 | 252.708 | 113.798 | 106.273 |
| CAIC | 72.443 | 264.708 | 125.798 | 118.273 |

### 4.5.2 Results of MANOVA, ANOVA and DFA

One of the components of ANOVA output constitutes the Box's test statistics which are used to test the null hypothesis that the observed covariance matrices of the dependent variables are equal across groups. The Box's test statistics showed significant values (i.e. *Box's M* = 57.235, *F* = 5.156, *p* = 0.000). The *p*-value in this case was less than 0.05), hence, the covariance matrices were not equal (i.e. they were significantly different) and the assumption of equal covariance matrices was therefore violated. It is important to note that, if the matrices were equal (and therefore the assumption of homogeneity being satisfied) this statistic should be non-significant. However, since the group sizes in our study were equal, we ignored this test and applied the Pillais Trace, Wilk's Lambda, Hotelling's Trace and Roy's largest root, which test the statistical significance of the different effects of independent variables. These are used because they are robust to the violation of homogeneous covariance matrices.

Accordingly, we tested the interaction effect of four groups (i.e. sex of household head, farmland location, major source of working capital, and membership to Savings and Credit Cooperatives (SACCOS) and or Village Community Banking (VICOBA) to determine whether this effect is consistent across the four NIGAs (i.e. agroforestry, terraces/contour farming, soil/stone bunds, and beekeeping). It should be noted that the "interaction effect" determines whether the effect of our predetermined NIGAs is similar for the four groups or independent variables. The interaction effect in this case would be considered as statistically significant if the *p*-value is less than 0.05 (i.e. $p < 0.05$), otherwise, if $p > 0.05$ the interaction effect is considered as not statistically significant. We present the summary of interaction effect in Table 4.4.

**Table 4.4: Results of multivariate tests (n = 154)**

| Effect (a.) | | Value | F | Hypothesis df | Error df | Sig. |
|---|---|---|---|---|---|---|
| Intercept | Pillai's Trace | 0.612 | 54.365[b] | 4.000 | 138.000 | 0.000 |
| | Wilks' Lambda | 0.388 | 54.365[b] | 4.000 | 138.000 | 0.000 |
| | Hotelling's Trace | 1.576 | 54.365[b] | 4.000 | 138.000 | 0.000 |
| | Roy's Largest Root | 1.576 | 54.365[b] | 4.000 | 138.000 | 0.000 |
| Sex | Pillai's Trace | 0.034 | 1.199[b] | 4.000 | 138.000 | 0.314 |
| | Wilks' Lambda | 0.966 | 1.199[b] | 4.000 | 138.000 | 0.314 |
| | Hotelling's Trace | 0.035 | 1.199[b] | 4.000 | 138.000 | 0.314 |
| | Roy's Largest Root | 0.035 | 1.199[b] | 4.000 | 138.000 | 0.314 |
| Land location | Pillai's Trace | 0.104 | 4.016[b] | 4.000 | 138.000 | 0.004 |
| | Wilks' Lambda | 0.896 | 4.016[b] | 4.000 | 138.000 | 0.004 |
| | Hotelling's Trace | 0.116 | 4.016[b] | 4.000 | 138.000 | 0.004 |
| | Roy's Largest Root | 0.116 | 4.016[b] | 4.000 | 138.000 | 0.004 |
| Major source of capital | Pillai's Trace | 0.163 | 6.728[b] | 4.000 | 138.000 | 0.000 |
| | Wilks' Lambda | 0.837 | 6.728[b] | 4.000 | 138.000 | 0.000 |
| | Hotelling's Trace | 0.195 | 6.728[b] | 4.000 | 138.000 | 0.000 |
| | Roy's Largest Root | 0.195 | 6.728[b] | 4.000 | 138.000 | 0.000 |
| Membership to SACCOS/VICOBA | Pillai's Trace | 0.010 | .339[b] | 4.000 | 138.000 | 0.851 |
| | Wilks' Lambda | 0.990 | .339[b] | 4.000 | 138.000 | 0.851 |
| | Hotelling's Trace | 0.010 | .339[b] | 4.000 | 138.000 | 0.851 |
| | Roy's Largest Root | 0.010 | .339[b] | 4.000 | 138.000 | 0.851 |
| Sex * Land location | Pillai's Trace | 0.026 | .928[b] | 4.000 | 138.000 | 0.450 |
| | Wilks' Lambda | 0.974 | .928[b] | 4.000 | 138.000 | 0.450 |
| | Hotelling's Trace | 0.027 | .928[b] | 4.000 | 138.000 | 0.450 |
| | Roy's Largest Root | 0.027 | .928[b] | 4.000 | 138.000 | 0.450 |
| Sex * Major source of capital | Pillai's Trace | 0.059 | 2.165[b] | 4.000 | 138.000 | 0.076 |
| | Wilks' Lambda | 0.941 | 2.165[b] | 4.000 | 138.000 | 0.076 |
| | Hotelling's Trace | 0.063 | 2.165[b] | 4.000 | 138.000 | 0.076 |
| | Roy's Largest Root | 0.063 | 2.165[b] | 4.000 | 138.000 | 0.076 |
| Sex * Membership to SACCOS/VICOBA | Pillai's Trace | 0.010 | .366[b] | 4.000 | 138.000 | 0.833 |
| | Wilks' Lambda | 0.990 | .366[b] | 4.000 | 138.000 | 0.833 |
| | Hotelling's Trace | 0.011 | .366[b] | 4.000 | 138.000 | 0.833 |
| | Roy's Largest Root | 0.011 | .366[b] | 4.000 | 138.000 | 0.833 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Land location * Capital | Pillai's Trace | 0.046 | 1.649[b] | 4.000 | 138.000 | 0.166 |
| | Wilks' Lambda | 0.954 | 1.649[b] | 4.000 | 138.000 | 0.166 |
| | Hotelling's Trace | 0.048 | 1.649[b] | 4.000 | 138.000 | 0.166 |
| | Roy's Largest Root | 0.048 | 1.649[b] | 4.000 | 138.000 | 0.166 |
| Land location * Membership to SACCOS/VICOBA | Pillai's Trace | 0.006 | .192[b] | 4.000 | 138.000 | 0.942 |
| | Wilks' Lambda | 0.994 | .192[b] | 4.000 | 138.000 | 0.942 |
| | Hotelling's Trace | 0.006 | .192[b] | 4.000 | 138.000 | 0.942 |
| | Roy's Largest Root | 0.006 | .192[b] | 4.000 | 138.000 | 0.942 |
| Capital * Membership to SACCOS/VICOBA | Pillai's Trace | 0.029 | 1.026[b] | 4.000 | 138.000 | 0.396 |
| | Wilks' Lambda | 0.971 | 1.026[b] | 4.000 | 138.000 | 0.396 |
| | Hotelling's Trace | 0.030 | 1.026[b] | 4.000 | 138.000 | 0.396 |
| | Roy's Largest Root | 0.030 | 1.026[b] | 4.000 | 138.000 | 0.396 |
| Sex * Capital * Membership to SACCOS/VICOBA | Pillai's Trace | 0.013 | .444[b] | 4.000 | 138.000 | 0.777 |
| | Wilks' Lambda | 0.987 | .444[b] | 4.000 | 138.000 | 0.777 |
| | Hotelling's Trace | 0.013 | .444[b] | 4.000 | 138.000 | 0.777 |
| | Roy's Largest Root | 0.013 | .444[b] | 4.000 | 138.000 | 0.777 |
| Land location * Major source of capital * Membership to SACCOS/VICOBA | Pillai's Trace | 0.040 | 1.419[b] | 4.000 | 138.000 | 0.231 |
| | Wilks' Lambda | 0.960 | 1.419[b] | 4.000 | 138.000 | 0.231 |
| | Hotelling's Trace | 0.041 | 1.419[b] | 4.000 | 138.000 | 0.231 |
| | Roy's Largest Root | 0.041 | 1.419[b] | 4.000 | 138.000 | 0.231 |

a. Design: Intercept + Sex + Land_Locat + Capital + Membership + Sex * Land_Locat + Sex * Capital + Sex * Membership + Land_Locat * Capital + Land_Locat * Membership + Capital * Membership + Sex * Land_Locat * Capital + Sex * Land_Locat * Membership + Sex * Capital * Membership + Land_Locat * Capital * Membership + Sex * Land_Locat * Capital * Membership
b. Exact statistic

The results in Table 4.4 indicate that the significant values of *F*-ratios which reach the criterion for significance at 0.05 level are the farmland location ($p$ = 0.004) and major source of operating capital ($p$ = 0.000). These two covariates show similar *p*-values for Pillai trace, Wilks' lambda, Hotelling's trace and Roy's largest root. Thus, we can conclude that there is a statistically significant interaction effect for these two groups. Stated differently, the effect of adopting NIGAs was not the same for farmland location and major sources of capital. These two independent variables do indeed differ in terms of effect on adoption of NIGAs. However, the nature of effect is still not clear from our multivariate test statistics for these independent variables as it does not clearly indicate the nature of effect (i.e. which groups differed from which). To determine the nature of the effect, reverting to our results of Levene's test of equality of error variance and DFA would be helpful. The results of Levene's test are presented in Table 4.5. It is important to note that, the Levene's test examines the null hypothesis that the error variance of the dependent variable is equal across groups (i.e. the assumption of homogeneity of variance) and the test should be non-significant for all dependent variables if this assumption has been met [77].

**Table 4.5: Results of Levene's test of equality of error variances (n = 4)**

| | | Levene Statistic | df1 | df2 | Sig. |
|---|---|---|---|---|---|
| Adoption of agroforestry | Based on Mean | 52.912 | 11 | 141 | 0.000 |
| | Based on Median | 2.941 | 11 | 141 | 0.002 |
| | Based on Median and with adjusted df | 2.941 | 11 | 94.415 | 0.002 |
| | Based on trimmed mean | 44.102 | 11 | 141 | 0.000 |
| Adoption of terraces/contour farming | Based on Mean | 3.993 | 11 | 141 | 0.000 |
| | Based on Median | 0.574 | 11 | 141 | 0.848 |
| | Based on Median and with adjusted df | 0.574 | 11 | 135.856 | 0.848 |
| | Based on trimmed mean | 3.993 | 11 | 141 | 0.000 |
| Adoption of soil and stone bunds | Based on Mean | 11.763 | 11 | 141 | 0.000 |
| | Based on Median | 2.370 | 11 | 141 | 0.010 |
| | Based on Median and with adjusted df | 2.370 | 11 | 63.277 | 0.016 |
| | Based on trimmed mean | 9.710 | 11 | 141 | 0.000 |
| Adoption of beekeeping | Based on Mean | 8.698 | 11 | 141 | 0.000 |
| | Based on Median | 2.340 | 11 | 141 | 0.011 |
| | Based on Median and with adjusted df | 2.340 | 11 | 64.345 | 0.017 |
| | Based on trimmed mean | 7.517 | 11 | 141 | 0.000 |

Our results of Levene's test show that, the assumption ($p > 0.05$) is met for only one dependent variable (adoption of terraces/contour farming), based on median as well as on median and with adjusted df ($p = 0.84$). Since the other three dependent variables do not meet the assumption of $p > 0.05$, the case for assuming that the multivariate test statistics are robust is then faded. As such, it becomes useful to carry out a univariate ANOVA to test for the between-subjects effects [77]. The statistics of univariate ANOVA for testing between-subjects effects are presented in Table 4.6.

**Table 4.6: Results of univariate ANOVA for tests of between-subjects effects (n = 154)**

| Source | | Type III SSs | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|
| Corrected Model | Adoption of agroforestry and tree planting | 8.177[a] | 12 | 0.681 | 4.211 | 0.000 |
| | Adoption of terraces and contour farming | 2.170[b] | 12 | 0.181 | 0.762 | 0.688 |
| | Adoption of soil and stone bunds | 2.842[c] | 12 | 0.237 | 2.904 | 0.001 |
| | Adoption of beekeeping | 1.844[d] | 12 | 0.154 | 2.154 | 0.017 |
| Intercept | Adoption of agroforestry and tree planting | 29.269 | 1 | 29.269 | 180.872 | 0.000 |
| | Adoption of terraces and contour farming | 6.968 | 1 | 6.968 | 29.359 | 0.000 |
| | Adoption of soil and stone bunds | 2.256 | 1 | 2.256 | 27.669 | 0.000 |
| | Adoption of beekeeping | 0.364 | 1 | 0.364 | 5.099 | 0.025 |
| | Adoption of beekeeping | 0.011 | 1 | 0.011 | 0.151 | 0.698 |
| Farmland location | Adoption of agroforestry and tree planting | 1.460 | 1 | 1.460 | 9.025 | 0.003 |
| | Adoption of beekeeping | 0.580 | 1 | 0.580 | 8.132 | 0.005 |
| Source of capital | Adoption of agroforestry and tree planting | 1.248 | 1 | 1.248 | 7.711 | 0.006 |
| | Adoption of soil and stone bunds | 1.513 | 1 | 1.513 | 18.557 | 0.000 |
| Sex*Capital | Adoption of soil and stone bunds | 0.600 | 1 | 0.600 | 7.362 | 0.007 |
| Farmland location*Capital | Adoption of agroforestry and tree planting | 0.629 | 1 | 0.629 | 3.890 | 0.051 |

a. R Squared =0 .264 (Adjusted R Squared = 0.201)

b. R Squared = 0.061 (Adjusted R Squared = 0.019)

c. R Squared = 0.198 (Adjusted R Squared = 0.130)

d. R Squared = 0.155 (Adjusted R Squared = 0.083)

The *F*-ratios for each univariate ANOVA and their significance values are listed in the columns labelled *F* and *Sig.*, respectively. It is important to note that these values are identical to those obtained in one-way ANOVA we conducted for each dependent variable independently. The values of *p* in test output indicate that there were significant differences between groups in terms of adoption of agroforestry for farmland location ($p = 0.003$), major source of capital ($p = 0.006$) and slightly for the conjoined effect of farmland and major source of capital ($p = 0.051$). The output also shows significant differences between groups in the adoption of beekeeping for farmland location ($p$ = 0.005). In addition, there were also significant differences between groups in the adoption of soil and stone bunds for major source of capital ($p$ = 0.000) and for the conjoined interaction between sex of household head and major source of capital ($p$ = 0.007). We can therefore argue that, respectively, these independent variables (groups) had a significant effect on the adoption of agroforestry, beekeeping as well as soil and stone bunds. However, we have to qualify this assertion further by using the results of DFA (Table 4.7) which show the initial statistics from the discriminant analysis (the Eigenvalues).

**Table 4.7: Eigenvalues and canonical correlations**

| Covariate | Eigenvalue | Canonical correlation | Canonical $R^2$ |
|---|---|---|---|
| Sex of household head | 0.09318 | 0.29196 | 0.085 |
| Farmland location | 0.29384 | 0.47656 | 0.227 |
| Major source of capital | 0.21032 | 0.41686 | 0.174 |
| Membership to SACCOS/VICOBA | 0.03176 | 0.17546 | 0.031 |

Procedurally, we tested the model as a whole and then removed variates one at a time to see whether what's left is significant. It should be restated here that the results of standardized canonical discriminant function coefficients tell us about the relative contribution of each variable to the variates. In DFA, the eigenvalues constitute an interesting part of the output. They are statistics of the matrix product of the inverse of the within-group sums-of-squares and cross-product matrix and the between-groups sums-of-squares and cross-product matrix [77]. The eigenvalues represent a linear combination of dependent variables that the analyst creates to establish the canonical variable, eigenvalues and the canonical correlation associated with it [ibid]. They are related to the canonical correlations and they describe how much discriminating ability a function possesses. The magnitudes of the eigenvalues are indicative of the functions' discriminating abilities [ibid]. Our results in Table 4.7 indicate different eigenvalues for the four independent variables we used in our analysis with farmland location having the largest eigenvalue (0.29384) and a squared partial canonical correlation of 22.7%. The major source of operating capital yielded an eigenvalue of 0.21032 and canonical $R^2$ of 17.4%. This implies that about 22.7% of the variability in canonical variables (the "super" dependent variables) was accounted for by farmland location and 14.4% by major source of working capital.

Another useful component of the DFA output is the multivariate *F*-test, the statistics of which are presented in Table 4.8. The results show that, with exception of membership to SACCOS and or VICOBA, there are some significant *F*-values for the other three functions (i.e. the sex of household head, farmland location and major source of capital). Note that, due to the absence of functions significant at level alpha ($p$ = 0.05), the MANOVA did not report any canonical discriminant or correlation analysis for effect of membership to SACCOS and or VICOBA.

**Table 4.8: Results of multivariate *F*-Tests with (1, 152) DF (n = 154)**

| Variable | Hypothesis SS | Error SS | Hypothesis MS | Error MS | F | Sig of F |
|---|---|---|---|---|---|---|
| Sex of household head | | | | | | |
| Adoption of agroforestry | 1.75010 | 29.24341 | 1.75010 | 0.19239 | 9.09658 | 0.003 |
| Adoption of terraces/contour farming | 0.87365 | 34.76271 | 0.87365 | 0.22870 | 3.82004 | 0.052 |
| Adoption of soil/stone bunds | 0.10979 | 14.22787 | 0.10979 | 0.09360 | 1.17292 | 0.281 |
| Adoption of beekeeping | 0.15071 | 11.75188 | 0.15071 | 0.07732 | 1.94935 | 0.165 |
| Farmland location | | | | | | |
| Adoption of agroforestry | 4.81391 | 26.179590 | 4.81391 | 0.17223 | 27.94983 | 0.000 |
| Adoption of terraces/contour farming | 0.43636 | 35.200000 | 0.43636 | 0.23158 | 1.88430 | 0.172 |
| Adoption of soil/stone bunds | 0.72134 | 13.616330 | 0.72134 | 0.08958 | 8.05232 | 0.005 |
| Adoption of beekeeping | 1.02913 | 10.873470 | 1.02913 | 0.07154 | 14.38616 | 0.000 |
| Major source of capital | | | | | | |
| Adoption of agroforestry | 2.90480 | 28.08871 | 2.90480 | 0.18479 | 15.71910 | 0.000 |
| Adoption of terraces/contour farming | 0.15088 | 35.48548 | 0.15088 | 0.23346 | 0.64628 | 0.423 |
| Adoption of soil/stone bunds | 1.43282 | 12.90484 | 1.43282 | 0.08490 | 16.87655 | 0.000 |
| Adoption of beekeeping | 0.25206 | 11.65054 | 0.25206 | 0.07665 | 3.28853 | 0.072 |
| Membership to SACCOS/VICOBA | | | | | | |
| Adoption of agroforestry | 0.51791 | 0.51791 | 0.51791 | 0.20050 | 2.58315 | 0.110 |
| Adoption of terraces/contour farming | 0.08640 | 0.0864 | 0.08640 | 0.23388 | 0.3694 | 0.544 |
| Adoption of soil/stone bunds | 0.20693 | 0.20693 | 0.20693 | 0.09297 | 2.22585 | 0.138 |
| Adoption of beekeeping | 0.06057 | 0.06057 | 0.06057 | 0.07791 | 0.77745 | 0.379 |

The results of discriminant function coefficients (Table 4.9) show further that the adoption of NIGAs in the study area differed amongst the four dependent variables on the three independent variables with the adoption of agroforestry carrying the highest weights based on sex of household head (0.67448) and farmland location (0.69308). Based on the major source of capital, the adoption of soil and stone bunds carries the highest score (0.74674). In absolute terms, the lowest standardized discriminant function coefficients are registered for sex of household head (0.23497) and farmland location (0.28080) in the case of the adoption of soil and stone bunds. For beekeeping the lowest discriminant function coefficients are observed for the major source of capital (0.02599).

**Table 4.9: Discriminant function coefficients (n = 154)**

| Variable | Raw | Standardized |
|---|---|---|
| Sex of household head | | |
| Adoption of agroforestry | 1.53771 | 0.67448 |
| Adoption of terraces/contour farming | -1.20358 | -0.57559 |
| Adoption of soil/stone bunds | 0.76799 | 0.23497 |
| Adoption of beekeeping | 0.90094 | 0.25051 |
| Farmland location | | |
| Adoption of agroforestry | 1.67002 | 0.69308 |
| Adoption of terraces/contour farming | -0.66277 | -0.31894 |
| Adoption of soil/stone bunds | 0.93820 | 0.28080 |
| Adoption of beekeeping | 1.75885 | 0.47043 |
| Major source of capital | | |
| Adoption of agroforestry | 1.33511 | 0.57393 |
| Adoption of terraces/contour farming | -0.67919 | -0.32817 |
| Adoption of soil/stone bunds | 2.5628 | 0.74674 |
| Adoption of beekeeping | 0.09388 | 0.02599 |

Another way of interpreting this is to look at the correlation between the dependent and canonical variables or “super” variables created based on unstandardized coefficients (see Table 4.10). In fact, all our four dependent variables for adoption of NIGAs correlate with the canonical variables or super variables. The standardized canonical discriminant function coefficients were used to calculate the discriminant score for each case. The scores were calculated as products of standardized coefficients and the standardized variables. The magnitudes of the coefficients in Table 4.10 indicate how strongly the discriminating variables affected the score. The results indicate that the sex of household head registered the highest score in the adoption of agroforestry($r$ = 0.80140) whilst, farmland location scored the highest in adoption of agroforestry ($r$ = 0.79107) and beekeeping ($r$ = 0.56754). The major source of capital yielded the largest scores in the adoption of soil and stone bunds ($r$ = 0.72657) and agroforestry ($r$ = 0.770121).

**Table 4.10: Standardized discriminant coefficients and correlations between dependent and canonical variable (n = 154)**

| **Variable** | **Coefficients** | **Correlations** |
|---|---|---|
| Sex of household head | | |
| Adoption of agroforestry | 0.67448 | 0.80140 |
| Adoption of terraces/contour farming | -0.57559 | -0.51933 |
| Adoption of soil/stone bunds | 0.23497 | 0.28777 |
| Adoption of beekeeping | 0.25051 | 0.37098 |
| Farmland location | | |
| Adoption of agroforestry | 0.69308 | 0.79107 |
| Adoption of terraces/contour farming | -0.31894 | -0.20540 |
| Adoption of soil/stone bunds | 0.2808 | 0.42461 |
| Adoption of beekeeping | 0.47043 | 0.56754 |
| Major source of capital | | |
| Adoption of agroforestry | 0.57393 | 0.70121 |
| Adoption of terraces/contour farming | -0.32817 | -0.14218 |
| Adoption of soil/stone bunds | 0.74674 | 0.72657 |
| Adoption of beekeeping | 0.02599 | 0.32074 |

We finally conducted a one-way ANOVA using the canonical or “super” variable to maximize discrimination between independent variables. In particular, we created a new variable namely “revised canonical variable” by flipping or switching the individual negative values into positive ones and vice versa, before running our model and the output is provided in Table 4.11. The mean squares were significantly largest for farmland location (8.965) and major source of working capital (6.367) accounting for the 7.4% and 5.3% of the variability in canonical or “super” variables respectively.

**Table 4.11: Tests of between-subjects effects for revised canonical variable as a dependent variable using univariate ANOVA (n = 154)**

| Source | Type III Sum of Squares | df | Mean Square | F | Sig. | Partial Eta Squared |
|---|---|---|---|---|---|---|
| Corrected Model | 53.400[a] | 12 | 4.450 | 5.564 | 0.000 | 0.321 |
| Intercept | 46.769 | 1 | 46.769 | 58.480 | 0.000 | 0.293 |
| Sex | 0.989 | 1 | 0.989 | 1.236 | 0.268 | 0.009 |
| Farmland location | 8.965 | 1 | 8.965 | 11.210 | 0.001 | 0.074 |
| Major source of capital | 6.367 | 1 | 6.367 | 7.962 | 0.005 | 0.053 |
| Membership to SACCOS/VICOBA | 0.072 | 1 | 0.072 | 0.090 | 0.765 | 0.001 |
| Sex * Farmland location | 0.189 | 1 | 0.189 | 0.236 | 0.628 | 0.002 |
| Sex * Major source of capital | 0.223 | 1 | 0.223 | 0.279 | 0.598 | 0.002 |
| Sex * Membership to SACCOS/VICOBA | 0.077 | 1 | 0.077 | 0.097 | 0.757 | 0.001 |
| Farmland location * Major source of capital | 2.863 | 1 | 2.863 | 3.580 | 0.061 | 0.025 |
| Farmland location * Membership to SACCOS/VICOBA | 0.176 | 1 | 0.176 | 0.221 | 0.639 | 0.002 |
| Capital * Membership to SACCOS/VICOBA | 0.083 | 1 | 0.083 | 0.103 | 0.748 | 0.001 |
| Sex * Capital * Membership to SACCOS/VICOBA | 2.939E-05 | 1 | 2.939E-05 | 0.000 | 0.995 | 0.000 |
| Farmland location * Major source of capital * Membership to SACCOS/VICOBA | 0.755 | 1 | 0.755 | 0.944 | 0.333 | 0.007 |
| Error | 112.763 | 141 | 0.800 | | | |
| Total | 271.368 | 154 | | | | |
| Corrected Total | 166.163 | 153 | | | | |

a. R Squared = .321 (Adjusted R Squared = .264)

### 4.5.3 Summary and discussion of key findings

We summarize the key findings from our different analyses in the following three ways. Firstly, our study indicates significant effects on the adoption of NIGAs based on farmland location and major source of capital. The test statistics generated from the Pillai's trace, for example, show significant statistics for farmland location, $V = 0.104$, $F(4, 138) = 4.016$, $p = 0.004$, and major source of capital, $V = 0.163$, $F(4, 138) = 6.728$, $p = 0.000$. As for Pillai's trace, the Wilks' lambda test statistics also indicate statistically significant interaction effect on adoption of NIGAs for farmland location, $F(4, 138) = 4.016$, $p = 0.004$; Wilks' $\lambda = 0.896$, and for major source of working capital, $F(4, 138) = 6.728$, $p = 0.000$; Wilks' $\lambda = 0.837$. Our separate univariate ANOVAs on the outcome variables also revealed significant effects of farmland location, $F(1, 8.965) = 11.210$, $p = 0.001$, and major source of capital, $F(1, 6.367) = 7.962$, $p = 0.005$. Secondly, our results of MANOVA, which was followed up with discriminant analysis revealed canonical $R^2$ of 22.7%, 17.4%, 8.5%, and 3.1% for farmland location, major source of capital, sex of household head, and membership to SACCOS or VICOBA respectively. State differently, these results imply that 22.7% of the variability in canonical variables we generated from our four dependent variables (adoption of agroforestry, terraces/contour farming, soil/stone bunds, and beekeeping) was accounted for by farmland location. About 14.4% of the variability was accounted for by the major source of working capital. The remaining two independent variables, sex of household head and membership to SACCOS and or VICOBA, conjointly accounted for only 11.6% of the variance in canonical dependent variables. However, the results of our ANOVA for revised variables show that farmland location and major source of working capital accounted for relatively larger proportions of variability in the canonical or "super" variables, that is, 7.4% and 5.3% respectively.

Thirdly, our analysis show that the adoption of NIGAs in the study area were significantly differentiated by farmland location, $\lambda = 0.773$, $\chi^2(4) = 38.642$, $p = 0.000$, major source of capital, $\lambda = 0.826$, $\chi^2(4) = 28.633$, $p = 0.000$], and sex of household head, $\lambda = 0.915$, $\chi^2(4) = 13.364$, $p = 0.01$. However, the statistics of correlations between outcomes and the discriminant functions (the standardized canonical discriminant function coefficients), revealed that the adoption of agroforestry loaded more highly onto farmland location ($r = 0.69308$) and sex of household head (0.67448) than the other functions. The adoption of terraces and contour farming loaded more on the major source of capital ($r$ = 0.69308) than the other functions. Therefore, we can argue that, the adoptive decision-making amongst smallholder farmers with regard to NIGAs in the study area was significantly tied to farmland location, major source of capital, and the sex of household head. Innately, it is also reasonable to affirm that these three factors were inter-related and conjointly affecting the capacity of individual farmers to adopt NIGAs.

The reasons for the relationships explained by our model coefficients can be several but one would intuitively expect the adoption of NIGAs to decrease with the distance from homestead to farmland because it becomes more demanding for smallholder farmers to mobilize resources, such as labour and time when the farmland is located far from homestead than when it is close to homestead. Similarly, the type of major source of capital for smallholder farming households determines the level of NIGA adoption. Farmers who rely solely on sale of own farm products and assets are less likely to adopt expensive NIGAs than their counterpart farmers who also access financial resources from other sources, such as, borrowing from SACCOS, VICOBA and other formal and informal financial institutions. In fact, most NIGAs are capital and labour-intensive making them too demanding for smallholder farmers to afford, especially in agro-ecologies of mountain areas where topographic limitations are rampant. Converging on these limitations, one would also argue that, the smallholder female-famers are less likely to adopt expensive NIGAs compared to their counterpart smallholder male-farmers. Thus, the disparities in sex/gender, farmland location, and type of major source of capital conjointly determine the level of NIGA adoption and hedging against risks and losses amongst smallholder farmers in the study area. As such, it is also important to note that any investment decision depends on how profitable it is perceived to be by the investor. The allocation of the available resources to invest in NIGAs is therefore rationally driven by the perception of smallholder farmers in study area as rational investors.

The role of these factors in influencing adoption of GAPs, NIGAs and Climate-Smart Agricultural (CSA) practices is generally widely acknowledged in the literature. In the King Cetshwayo District Municipality of South Africa, for example, the study by Abegunde et al. [78] revealed that the distance of farm to homestead was statistically significant but negatively correlated with the level of adopting Climate-Smart Agricultural (CSA) practices. They also found membership of an agricultural association or group (synonymous to membership to SACCOs and or VICOBA in our study), to be statistically significant and positively correlated with the level of adoption of these practices. Accordingly, they recommend that farmer associations or groups should be given adequate attention to facilitate CSA adoption as a means to mitigate climate change and enhance resilience. The research by Laosutsan *et al*. [79], who evaluated factors influencing the adoption of GAPs and export decision amongst Thailand's vegetable farmers also, showed that location was the most influential factor in the adoption of GAPs by participating vegetable farmers. In line with the arguments of agricultural location theory, Lucas & Chhajed [80,81] and Laosutsan *et al*. [79] recommend exporters and relevant government agencies to make GAP certification compulsory to effectively increase the GAP adoption rate among the Thai vegetable growers. In Sokoto State of Nigeria, the study by Ojoko *et al*. [81] revealed that membership of a social group and access to credit were significant determinants of CSA adoption. In Ghana, the study by Akrofi-Atitianti *et al.* [82] who also investigated CSA adoption among cocoa farmers, found location of farms to be one of the most influential factors. In the Indo-Gangetic plains of India, Aryal *et al.* [83] who evaluated the factors influencing the adoption of CSA practices by farmers found that farmers' characteristics such as gender, as well as social and economic capital, were some of the key determinants of CSA adoption amongst the farmers. The literature underscores the need for addressing gender related disparity in the development and adoption of GAPs [see 84]. In this regard, Murray et al. [84] argue that the labour of many women smallholder farmers is constrained by the lack of access to labour–saving technologies and the rudimentary form of farm tools they use. They furthermore argues that for female smallholder farmers to become more climate change resilient, more serious attention should be directed to gender analysis to address the constraints facing these farmers in accessing basic agricultural technologies.

In a nutshell, our study contributes to enriching the adoption literature in three major ways. Firstly, our focus on ecologically fragile mountain areas to investigate the factors which determine adoption of NIGAs is not only timely but also urgent. As already mentioned, mountain areas are home to most endemic and endangered species, but are increasingly threatened by loss of biodiversity due to increasing human population and unsustainable anthropogenic activities. By focusing on these valuable agro-ecologies, we provide some important lessons to inform policies and strategies to achieve the mutual goals of sustainable livelihoods and nature conservation in these areas. Secondly, as also already mentioned earlier, the rate of NIGA adoption in mountain areas is seemingly lower than expected by the promoters of NIGAs in these areas. As such, understanding the real causes of low adoption is even more important now than ever as human population densities and unsustainable anthropogenic activities are increasing at higher rates. Thirdly, our study uses different approaches, such as MANOVA, ANOVA, and DFA in an attempt to capture interconnected and complex relationship between dependent variables and independent variables and uncover a more meaningful underlying of relationships between the outcomes and causal factors. This is critical to get an understanding of how the different NIGAs complement or substitute each other. We attempt to achieve this by identifying the factor which maximally discriminated amongst the preselected determinants.

### 4.5.4 Limitations of the study

There are at least two important limitations of our study. Firstly, due to the diverse but interconnected and complex nature of mountain agro-ecologies, modelling of the factors which influence adoption of NIGAs in these areas can be cumbersome. For example, the statistics in our final stage of analysis (Table 4.11) show that our model was able to describe only 26.4% of all the causal-effect relationships, that is, the test statistics of between-subjects effects for our revised canonical variable show a multiple determination ($R^2$) of 26.4%. Actually, one may rate this value as still a weak goodness of fit for our model, understanding that $R^2$ measures the proportion of variation in the dependent variables that can be predicted from the preselected set of independent variables. When the regression equation fits the data well, $R^2$ will be large and vice versa.

Secondly, our model is based on cross-sectional instead of time series data. This can also be misleading unless the year under study precisely represents the long-term scenario of the phenomena under study. The use of time series data is preferred because it has the advantage of enabling natural ordering which makes it distinct from cross-sectional studies, in which there is no natural ordering of observations [85,86]. Most standard data analysis methods used in adoption studies, such as, ANOVA and OLS regression assume linear association between variables of interest. Time series analysis has an additional advantage of modelling both linear and nonlinear relationships between variables over time. In fact, nonlinear functions are reported to provide better approximation of the true relationship between adoption-related variables [84].

Despite these limitations our study still offers some very useful insights to inform agricultural policy reforms for balancing the existing trade-offs between economic gains and sustainable nature conservation in fragile agro-ecologies of mountain areas. The study identifies some of the key determinants of NIGA adoption upon which the policy reforms should focus on, notably, the issues related to access to land and financial resources. Equally important is the whole issue of combating inequality in access to land and financial resources between female and male farmers. We provide some key recommendation to address these issues in the next section.

### 4.6 Conclusion and Policy Recommendations

This study investigated the factors which influenced the adoption of introduced NIGAs in Uluguru Mountains, Tanzania using the Generalized Linear Binary Probit model/Multivariate Analysis of Variance (MANOVA), complemented by Discriminant Function Analysis (DFA). Different from most of the previous adoption research, our study considered and incorporated the fact that NIGAs are not necessarily mutually exclusive and that farmers may implement more than one NIGA simultaneously on a single plot.

The key findings in this study reveal that the variables of farmland location (whether close or far from homestead), major source of capital (whether sale of farm products and assets or other sources), and type of household based on the sex of household head (whether female or male –headed household) exert the most influence over smallholder farmers' decision to adopt NIGAs. Based on these findings, we recommend the government and non-state agencies promoting NIGA adoption in mountain areas to address the issue of gender inequality in access to land and financial resources. This should be supported by effective implementation of land laws and regulations that address gender inequality, and more generally the empowerment of female farmers. The latter (empowerment of female farmers) can be done in different ways, one of which being the establishment of tailor-made financing schemes, particularly targeted to address gender inequality and enhance livelihoods of smallholder farmers while at the same time conserving nature in mountains areas. In addition, public policies should recognize that gender gaps in separate dimensions complement and reinforce one another and therefore, have to be dealt with simultaneously. A naïve policy targeting a single gap in isolation is unlikely to have substantial achievement in the short run. Typically, inequalities in access to land and financial resources are not independent from each other. For example, if credit –constrained female-headed household face weak property rights, the household may also be unable to access certain markets, and may have mobility and time constraints, then the marginal return to capital may nevertheless be less for this household. We conclude that promising NIGA policy directions that would benefit smallholder farmers in mountain areas should establish a strong linkage between gender equality and pro-nature agendas.

Based on the limitations of our study as mentioned in the previous section, we also recommend further research to investigate the factors influencing NIGA adoption using time series data that facilitate the capacity to model and predict related processes. Time series analysis also has the capacity to enhance causal inference about the relationships between phenomena of interest. The ability to establish the temporal ordering of variables is desirable because it can greatly enhance researchers' ability to draw causal inference from their data.

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# CHAPTER FIVE

## 5.0 KEY CONTRIBUTIONS, CONCLUSIONS AND RECOMMENDATIONS

### 5.1 Introduction

This chapter highlights the key contributions the present study has made to the body of existing knowledge. It also presents some concluding remarks, policy recommendations, and outlines the areas that need further studies.

### 5.2 Key Contributions of the Study

The study has confirmed the earlier findings that many development partners and researchers have designed and launched programmes and initiatives to balance conservation goals and livelihood needs but the outcomes have been disappointing (Bhatia and Buckley, 1998; Sunderlin and Huynh, 2005; Ruheza *et al.,* 2012; Ayubu, 2017), for reasons which were not very well known by the proponents. Motivated by this understanding, the current study was therefore deemed necessary to inform policies and strategies to ensure sustainable utilization of ecosystems and improved livelihoods in mountain areas. The novelty of the current study derives from many aspects. Firstly, by focusing on mountain agro-ecologies, it provides some important lessons to inform policies and strategies to achieve the mutual goals of sustainable livelihoods and biodiversity conservation in mountain agro-ecologies. The study findings are relevant and provide important implications for various change agents, including policymakers, governmental bodies, sponsorship or funding agencies, extension agents and non-governmental agencies. Secondly, through the identification of interlinked factors that consistently determine adoption of NIGAs, it is hoped that the current study will serve as a significant knowledge base by providing information which can be used in either envisaging the reactions of potential adopters to NIGAs or to modify either the NIGAs themselves or the way in which they are introduced so as to be more harmonious with the motivational drivers of potential adaptors. Thirdly, our study recognises the reciprocal nature of the mutual objectives of ensuring sustainable livelihood and biodiversity conservation. Regarding this, the study conducted a participatory ranking of all the NIGAs introduced in the study using the yardstick of their potential effects on both livelihoods and biodiversity conservation prior to the selection of NIGAs for further analysis. Fourthly, our study treated NIGAs as not necessarily mutually exclusive as farmers may implement more than one Nature-based Income Generating Activity (NIGA) simultaneously on a single plot, which is a common practice, at least in mountain areas where land resource is major limiting factor. The study, therefore, adds substantially to the knowledge base in these particular aspects.

## 5.3 Areas for Further Studies

The study has identified the following two additional areas for further studies so as to provide more insights into the potential of NIGAs as livelihood coping and biodiversity conservation strategies in Uluguru and similar mountain areas:

**a)** Future viability studies of NIGAs using a combination of empirical models and judgment to predict future discount rates and evaluate correlation of results. This is important because future discount rates are inherently uncertain due to uncertainty in the rates of growth in consumption and returns to investment.

**b)** Since the present study has used cross-sectional data to investigate the determinants of NIGA adoption, further research is needed that will use time series data to facilitate the capacity to model and predict related processes. Time series analysis also has the capacity to enhance causal inference about the relationships between phenomena of interest. The ability to establish the temporal ordering of variables is desirable because it can greatly enhance researchers' ability to draw causal inference from the data.

## 5.4 Conclusions

This dissertation is based on a study which was conducted in Uluguru Mountains, Tanzania. The general objective of the study was to investigate the extent to which Nature-based Income Generating Activities (NIGAs) introduced in the Uluguru Mountains have served as effective livelihood and biodiversity conservation strategies. The specific objectives were to: a) assess the perceptions of local communities in the study area regarding the role of different NIGAs as livelihood coping and biodiversity conservation strategies, b) evaluate the economic viability of two highly ranked NIGAs, and c) evaluate factors influencing the adoption of NIGAs in the study area. The following conclusions have been drawn for each specific objective.

### 5.4.1 Perceptions of local communities

This objective is addressed in detail in CHAPTER TWO: "perceptions of smallholder farmers on nature-based income generating activities as potential livelihood and biodiversity conservation strategies in Uluguru Mountains, Tanzania." The results of perception assessment yielded point estimate of the coefficient of concordance of 0.40 which was about the same value as the average over all possible Spearman correlation. This suggests that the farmers agreed with each others to a reasonable though not super high extent ( $\chi^2$ (4) = 241.527, $p$ = 0.000). The asymptotic $p$–value of 0.000 strongly suggests that the coefficient of concordance was not zero, meaning that there was some agreement among judges in terms of how they ranked the NIGAs. Accordingly, the null hypothesis that the Kendall's *W* was zero (i.e. there was perfect disagreement among the judges or respondents) was rejected.

The results of statistical tests using the Kendall's tau and Spearman's rho indicate that the *p*-values of correlations between the adoption of agroforestry/tree planting and soil/stone bunds were statistically significant ( $r_s$ = 0.212, $p$ = 0.009). The adoption of agroforestry was also positively associated with adoption of beekeeping ( $r_s$ = 0.189, $p$ = 0.019). The adoption of terraces and contour farming was positively interrelated with soil/stone bunds ( $r_s$ = 0.273, $p$ = 0.001). The *p*-value of correlation between the adoption of soil/stone bunds and beekeeping were statistically significant ( $r_s$ = 0.356, $p$ = 0.000). It was also statistically significant between the adoption of soil/stone bunds and other NIGAs ( $r_s$ = 0.512, $p$ = 0.000). Consequently, we failed to reject the null hypothesis that the NIGAs adopted by smallholder farmers in the study area are interrelated.

The results of perceptions analysis using Likert-type and Likert scale data showed cumulative scores 76% and 61% for reduced reliance on firewood and building poles respectively. The mean (average) scores were 3.1 and 2.6 for reduced reliance on firewood and building poles. These results suggest that communities in the study area have moderately reduced reliance on firewood and building poles from the Uluguru Forest Reserve (UFR). However, there was no evidence to statistically conclude that the communities have reduced reliance on wood products because the cumulative score and mean score for wood products were 44.2% and 2.2% respectively, which fall under the "low" or "poor" category of grading criteria. The mean Likert scale score was 2.6 and the cumulative mean score was about 7.9 both supporting the assertion that communities in the study area moderately reduced their reliance on timber products from the reserve (firewood, building poles and wood considered together). Hence, it is concluded that biodiversity conservation in Uluguru Mountains has reasonably improved with agroforestry performing relatively better than the other NIGAs.

Though beekeeping was ranked as the second important NIGA that has the potential to enhance livelihoods, it was practiced by very few farmers, only 8.4% of all farmers. The low adoption of beekeeping was attributed to many factors, including the lack of suitable land at the proximity of farmer's homestead, inadequate access to extension services and lack of capital.

### 5.4.2 Economic viability of NIGAs

This objective is discussed in CHAPTER 3: "economic viability of smallholder agroforestry and beekeeping projects in Uluguru Mountains, Tanzania: a cost benefit analysis." The results of CBA yielded positive NPVs for both agroforestry and beekeeping projects at discount rates not higher that 8.2% and 8.5% respectively. Using the discount rate equal to the inflation rate (i.e., $r$ = 3.2%) the NPVs of the two projects were TZS 700 459.40 and TZS 188 092.63 per acre respectively. The two projects were viable even at a higher discount rate of 8% yielding NPVs of TZS 84 610.21 and TZS 82 479.98 per acre respectively. For agroforestry, the BCRs at discount rates of 3.2% and 8% were 1.22 and 1.14 respectively, and BCRs for beekeeping were 1.05 and 1.03 for beekeeping, respectively. Based on these findings it is concluded that agroforestry was relatively more profitable, in terms of both NPVs and BCRs, than beekeeping at discount rates equal or less than 8.2% and 8.5% respectively. However, these two projects can jointly be implemented to enhance farmers' livelihoods and support biodiversity in the study area.

### 5.4.3 Determinants for adoption of NIGAs

This objective is dealt with in CHAPTER FOUR: "Determinants for adoption of nature-based income generating activities in Uluguru Mountains, Tanzania. Three key findings emerge from this section. Firstly, the test statistics generated from the Pillai's trace show significant statistics for farmland location, $V = 0.104$, $F(4, 138) = 4.016$, $p = 0.004$, and major source of capital, $V = 0.163$, $F(4, 138) = 6.728$, $p = 0.000$. As for Pillai's trace, the Wilks' lambda test statistics also indicate statistically significant interaction effect on adoption of NIGAs for farmland location, $F(4, 138) = 4.016$, $p = 0.004$; Wilks' $\lambda$ = 0.896, and for major source of working capital, $F(4, 138) = 6.728$, $p = 0.000$; Wilks' $\lambda$ = 0.837. The separate univariate ANOVAs on the outcome variables also revealed significant effects of farmland location, $F(1, 8.965) = 11.210$, $p = 0.001$, and major source of capital, $F(1, 6.367) = 7.962$, $p = 0.005$.

Secondly, the results of MANOVA, which was followed up with discriminant analysis revealed canonical $R^2$ of 22.7%, 17.4%, 8.5%, and 3.1% for farmland location, major source of capital, sex of household head, and membership to SACCOS or VICOBA respectively. These results imply that 22.7% of the variability in canonical variables generated from the specified four dependent variables (adoption of agroforestry, terraces/contour farming, soil/stone bunds, and beekeeping) was accounted for by farmland location. It is therefore concluded that about 14.4% of the variability was accounted for by the major source of working capital. The remaining two independent variables, sex of household head and membership to SACCOS and or VICOBA, conjointly accounted for only 11.6% of the variance in canonical dependent variables. However, the results of ANOVA for revised variables showed that farmland location and major source of working capital accounted for relatively larger proportions of variability in the canonical or “super” variables, that is, 7.4% and 5.3% respectively.

Thirdly, the study findings show that the adoption of NIGAs were significantly differentiated by farmland location, $\lambda = 0.773$, $\chi^2(4) = 38.642$, $p = 0.000$, major source of capital, $\lambda = 0.826$, $\chi^2(4) = 28.633$, $p = 0.000$], and sex of household head, $\lambda = 0.915$, $\chi^2(4) = 13.364$, $p = 0.01$. However, the statistics of correlations between outcomes and the discriminant functions (the standardized canonical discriminant function coefficients), revealed that the adoption of agroforestry loaded more highly onto farmland location ($r = 0.69308$) and sex of household head (0.67448) than the other functions. The adoption of terraces and contour farming loaded more on the major source of capital ($r = 0.69308$) than the other functions. Therefore, it is concluded that, the adoptive decision-making amongst smallholder farmers with regard to NIGAs was significantly tied to farmland location, major source of capital, and the sex of household head. Inherently, it is also reasonable to conclude that these three factors were inter-related and conjointly affecting the capacity of individual farmers to adopt NIGAs.

## 5.5 Recommendations

Overall, the study findings suggest an important policy implication regarding the necessity for policy makers and development partners to understand the real needs and priorities of target communities prior to the implementation of projects and initiatives that aim at enhancing the livelihood and biodiversity conservation. Accordingly, the following key recommendations are drawn:

**a)** Understanding the specific attitudes and perceptions of target farmers should be considered as a prerequisite for developing the relevant transforming structures and processes of promoting adoption of NIGAs;

**b)** The government and other development partners should support smallholder farmers through training and inspire them to shift from orthodox farming to sustainable NIGAs, such as, agroforestry and beekeeping;

**c)** NIGA policy directions that would benefit smallholder farmers in mountain areas should establish a strong linkage between gender equality and pro-nature agendas. Addressing the issue of gender inequality in access to land and financial resources is particularly critical. This should be supported by effective implementation of land laws and regulations that address gender inequality, and more generally the empowerment of female farmers. The latter (empowerment of female farmers) can be done in different ways, one of which being the establishment of tailor-made financing schemes, particularly targeted to address gender inequality and enhance livelihoods of smallholder farmers while at the same time conserving nature in mountains areas. In addition, public policies should recognize that gender gaps in separate dimensions complement and reinforce one another and therefore, have to be dealt with simultaneously. A naïve policy targeting a single gap in isolation is unlikely to have substantial achievement in the short run.

# APPENDICES

## Appendix 1: Research tools for household survey, FGDs and KII interviews

### HOUSEHOLD QUESTIONNAIRE

**SECTION A: IDENTIFICATION PARTICULARS, STAFF & SURVEY TIME DETAILS**

| |
|---|
| 1. NAME OF THE INTERVIEWER: |
| 2. DATE OF INTERVIEW: |
| 3. DISTANCE TO UNFR: |
| 4. QUESTIONNAIRE NUMBER: |
| 5. REGION: |
| 6. DISTRICT: |
| 7. DIVISION: |
| 8. WARD: |
| 9. VILLAGE/HAMLET: |

**SECTION B: HOUSEHOLD DEMOGRAPHICS**

10. Total size of the household……………….. Number of children.......................... Number of Adults……………..

11. Provide the following information for the respondent

| Gender 1=F 2=M | Age | Marital status | Education level | Main occupation |
|---|---|---|---|---|
| | | | | |
| | | | | |

Code: Marital status 1= Married, 2 = Single, 3 = Widowed , 4= Divorced
Main occupation 1 = Farmer, 2 =others (specify)
Education level Number of years in school

**SECTION C: HOUSEHOLD PRODUCTION AND INCOME**

1. Please provide information on land tenure

| **Land tenure structure** | **Size (Acres)** |
|---|---|
| Private (titled) land | |
| Rented land | |
| Borrowed land | |
| Village government | |
| Total | |

2. Total agricultural production (husband and wives and children) **LAST YEAR**.

| Type of crop | Total production (in bags, tin) | Unit Price (Tsh.) MIN | MAX |
|---|---|---|---|
| | | | |
| | | | |
| | | | |
| | | | |

3. Indicate the types and number of livestock kept

| Type of livestock product | Number of livestock owned |
|---|---|
| Cattle | |
| Goat | |
| Sheep | |
| Chicken | |
| Duck | |
| Others | |

4. What are other sources of your income?

| Item | Total income (Tsh.) |
|---|---|
| Timber products (TPs) | |
| Local brew | |
| Casual labour | |
| Formal employment | |
| Business | |
| Remittances | |
| Pension or life insurance annuity benefits | |
| Dividends (from company shares or banks) | |
| Others | |

**SECTION D: NATURE-BASED INCOME GENERATING ACTIVITIES (NIGAs)**

1: Types of NIGAs introduced and practiced by farmers

| What are the types of NIGA practiced by **your household**? | Rank the NIGAs practiced by **your household** starting with the 1st (most important) to the last (least important). | What are the name of institutions, programmes or initiatives which introduced these NIGAs in your village | Year introduced | Reason for introduction | Rank according to its role in enhancing livelihood and biodiversity |
|---|---|---|---|---|---|
| | | | | | |

2. How much does it cost for each NIGAs mentioned above?

| | NIGA 1 | | NIGA 2 | | NIGA 3 | | NIGA 4 | |
|---|---|---|---|---|---|---|---|---|
| Item | Unit Cost | Total cost | Unit Cost | Total cost | Unit Cost | Total cost | Unit Cost | Total cost |
| Capital cost | | | | | | | | |
| Raw material cost | | | | | | | | |
| Labour cost | | | | | | | | |
| Power cost | | | | | | | | |
| Other variable cost | | | | | | | | |

3. What are the types of NIGAs practiced in your plots? How much do you earn from each farm plot?

| Plot | Type of NIGA and products | If daily (Tshs) | If weekly (Tshs) | If monthly (Tshs) | If yearly (Tshs) | Total cash (Tshs) |
|---|---|---|---|---|---|---|
| 1 | | | | | | |
| 2 | | | | | | |
| 3 | | | | | | |
| 4 | | | | | | |
| 5 | | | | | | |
| 6 | | | | | | |
| 7 | | | | | | |

3. What influenced you to adopt these NIGAs?
4. Under what type of ownership for each plot is? (e.g. inherited, purchased, borrowed, etc.)
5. What was the initial capital (Tshs) of your farm enterprise?
6. If you are to sell or accept compensation for each plot how much would you be willing to accept as a minimum amount of compensation?
7. Perceptions of farmers about the role of introduced NIGAs

| Has this NIGA enhanced **livelihoods** of households who practice it in the village?<br><br>*1 = Strongly agree; 2 = Agree; 3 = Neutral;4 = Disagree; 5 = Strongly Disagree* | Please, give reasons for your answer. | Has this NIGA resulted in improved **biodiversity conservation** in the area?<br><br>*1 = Strongly agree; 2 = Agree; 3 = Neutral;4 = Disagree; 5 = Strongly Disagree* | Pleas, give reasons for your answer. | Have these NIGAs reduced the reliance on and frequency of using forest products from the Uluguru Forest Reserve?<br><br>*1 = Strongly agree; 2 = Agree; 3 = Neutral;4 = Disagree; 5 = Strongly Disagree* | Please, give reasons for your answer. |
|---|---|---|---|---|---|

8. How do you find the condition of the village forest reserve?
9. Would your household be willing to pay something to maintain the Uluguru Nature Forest Reserve (UNFR) in good condition? 1= Yes, 2= No
10. If YES: How much would your household be willing to pay per year in order to maintain the Uluguru Nature Forest Reserve in good condition?

11. IF NO: Why is your household not willing to pay anything in order to maintain the Uluguru Nature Forest Reserve in good condition?

**SECTION E: EXTENSION SERVICES AND MARKET INFORMATION**

1. Area (size) of the farm…………………………..…………….
2. Have you been visited by an extension agent over the past 2 years?
3. What are the input requirements per acre or unit NIGA (e.g. 5 or 10 beehives etc.)

| Input | Amount required | Unit price |
|---|---|---|
| | | |
| | | |
| | | |

4. Products and prices

| Input | Unit price | Transport cost/volume | Quantity produced |
|---|---|---|---|
| | | | |
| | | | |
| | | | |

5. Where do you sell the products?
6. Who are your customers and how do you reach them?
7. What mechanisms are used in setting your products prices?
8. What are the challenges of accessing the market?
   a) There is no market place
   b) Long distance
   c) No potential customers
   d) Others?

9. If no, what actions to you take to solve the market challenges
10. What technology do you use to process your farm products?
11. How do you transport products from the harvesting sites to the market place?
12. Is there any association among collectors, transporters and end users of raw materials?
13. Do you store or have storage facilities for your products?
14. How do you sell/market your products? (spot purchases, contracts?)
15. Is the demand of products rising? Constant? or declining?
16. Is marketing of these products difficult? Why?
17. Are there any trade restrictions? Taxes paid? Royalties?
18. What are the main problems affecting consumption/utilization of the products and marketing of the products?
19. What do you think should be bone to improve consumption and marketing of farm products?

**SECTION F: FOREST USE INFORMATION**

1. Which of the following services does your village get from the Uluguru Nature Forest Reserve (UNFR)

| Service | Quantity per day (Indicate units) | Price per unit (Tshs/unit) | If you cannot give the price what is WTP for the service? |
|---|---|---|---|
| Source of water | | | |
| Climate amelioration | | | |
| Soil erosion prevention | | | |
| Biodiversity | | | |
| Scenic view | | | |
| Others | | | |

2. How much revenue was collected last year in the village from the Uluguru Nature Forest Reserve (UNFR)

| Item | Revenue collected (Tsh.) |
|---|---|
| Ecotourism | |
| Confiscated products | |
| User fees (including research fees) | |
| Sale of forest products (if any) | |
| Others | |

3. How much does the Uluguru Nature Forest Reserve (UNFR) contribute to the economy of the household (cash and own consumption at home), and the village?

4. Is there any farm area in the village or produce destroyed by the Uluguru Nature Forest Reserve (UNFR) due to encroachment?

| Crops destroyed | Area destroyed (Acre) | Yield per acre ( bags) | Price (Tsh. per bag) | Estimated cost of damage (Tsh.) |
|---|---|---|---|---|
| | | | | |
| | | | | |
| | | | | |

**SECTION G: MEMBERSHIP TO COMMUNITY GROUPS & ORGANIZATIONS AND ACCESS TO EXTENSION SERVICES**

1. Have you or any other members of your household joined a community group or organization1= Yes, 2= No
2. Why did neither you nor any other member of your household join community groups or organizations?
   a) No need
   b) Do not know how to join
   c) No group/organization available locally
   d) Too expensive to join them
   e) Lack of sensitization
   f) Other (specify

3. The groups established or promoted/funded by
   a) Government
   b) Private individual
   c) Non-governmental Organization (specify)
   d) Other (specify)

4. Name the group/ organizations the household is a member
5. Conditions and benefits obtained from the group
6. Do you have access to extension services? 1= Yes, 2= No
7. Do you have any other comments or questions?

THANK YOU VERY MUCH FOR YOUR TIME

## CHECKLIST FOR FOCUS GROUP DISCUSSION

A: IDENTIFICATION VARIABLES

| ITEM | NAME/NUMBER |
|---|---|
| 1. Date of Interview | |
| 2. Name of respondent | |
| 3. Village name | |
| 4. Ward | |
| 5. Division | |
| 6. District | |
| 7. Region | |

B: OTHER ISSUES
1. How did the Nature Based Income Generating Activities start in your village?
2. Which Nature Based Income Generating Activities is mostly practiced in your village?
3. Why other Nature Based Income Generating Activities are not practiced by many in your village?
4. Can you provide all the cost and benefits of the Nature Based Income Generating Activities practiced by the communities?
5. How the Nature Based Income Generating Activities practiced in your area contribute to the conservation of forest resources and improve local communities' livelihoods:

| Activity | How NIGA contributed to conservation of forest resources | How NIGA contributed to improve community livelihood |
|---|---|---|
| | | |
| | | |
| | | |
| | | |

6. Benefits of the Uluguru Nature Forest Reserve at local, national and global level

| Benefit | Local | National | Global |
|---|---|---|---|
| | | | |
| | | | |
| | | | |
| | | | |

7. List of goods and services you get from the UNFRs before and after becoming a reserve.

| S/N | Goods/services | Before becoming a UNFR | Before becoming a UNFR |
|---|---|---|---|
| | | | |
| | | | |
| | | | |
| | | | |

8. What economic activities communities have heard that they are done in other places and they think could also be done in their village, **how** and **why**?

| S/N | NIGA | How is done | Why can be done in the village |
|---|---|---|---|
| | | | |
| | | | |
| | | | |

9. How did the practiced Nature Based Income Generating Activities reduce communities' dependency from forest resources?
10. What factors affect the performance of the NIGAs practiced in your area?
11. What is your advice on how to improve performance of the NIGAs?
12. Do you have marketing challenges? 1=YES[ ], 2=NO[ ]
a) If YES, what are the challenges?
b) Suggest the solutions to be used in solving marketing challenges.
13. Do adjacent communities plant trees? 1=YES[ ], 2=NO[ ] If YES, What type of tree species planted by villagers
14. How are local communities involved in conserving the Uluguru Nature Forest Reserve?
15. Since local communities have being engaged in Nature Based Income Generating Activities (NIGAs), have the illegal activities inside theUluguru Nature reserve reduced?
16. What should be done to improve the conservation initiative of Uluguru Nature Forest Reserve?
17. Rank the existing and potential NIGAs based on:

    a) Perceived cost and benefits
    b) Market performance
    c) Capacity building (training by government experts, NGOs, CSO, etc.)
    d) Environmental impact
    e) Potential livelihood impact
    f) Gender
    g) Youths

| S/N | NIGA | CBA | Market | Capacity (training, NGO, CSO, etc.) | Environmental Impact | Potential livelihood impact | Gender, Youths |
|---|---|---|---|---|---|---|---|
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |

18. Do you have any other remarks or comments

.........................................................................................

## CHECKLIST FOR KEY INFORMANT INTERVIEWS

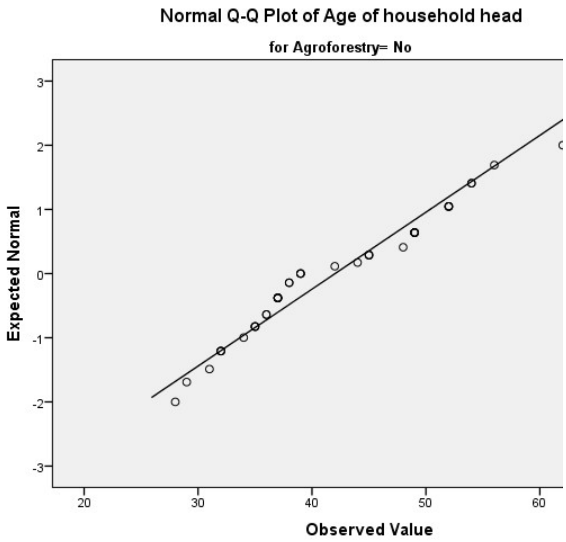
A: IDENTIFICATION VARIABLES

| ITEM | NAME/NUMBER |
|---|---|
| 1. Date of Interview | |
| 2. Name of respondent | |
| 3. Village name | |
| 4. Ward | |
| 5. Division | |
| 6. District | |
| 7. Region | |

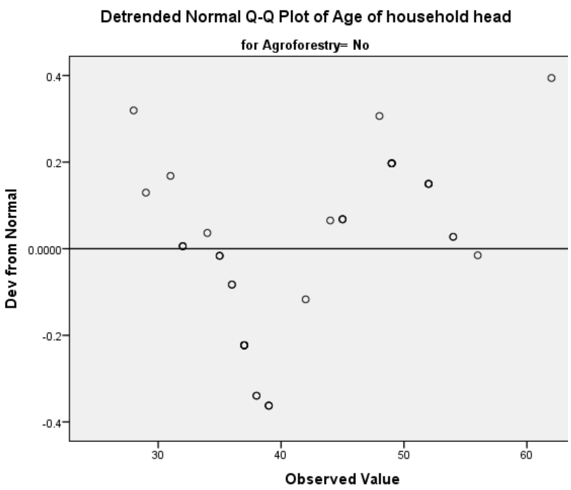
B: OTHER ISSUES

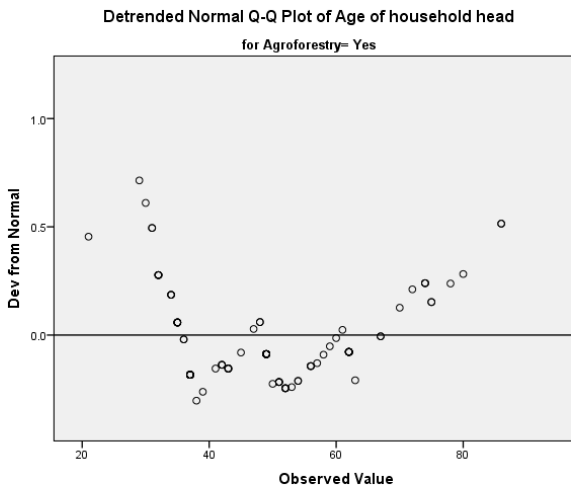
1. Are there any activities conducted at the Uluguru Nature Forest Reserve? 1=YES[ ], 2=NO [ ]
2. If YES, which activities are conducted at the UNFR?
3. List the Nature Based Income Generating activities being supported by your office to the local communities?
4. How did the Nature Based Income Generating Activities start in communities adjacent to Uluguru Nature Forest Reserve?
5. Which Nature Based Income Generating Activities is mostly practiced in these villages?
6. Why other Nature Based Income Generating Activities are not practiced by many adjacent villages?
7. Can you provide all the cost and benefits of the named Nature Based Income Generating Activities to the communities? (listed in question 2)
8. Does the practiced Nature Based Income Generating Activities increases income to the local communities?
9. What is the role of income generating activities in conservation of forest resources?
10. Have the local communities reduced their frequencies in depending on the resources from the Nature reserve after the introduction of NIGAs?
11. What is the performance of the supported NIGAs?
12. What are the factors affecting the economic performance of the supported income generating activities?
13. Do you involve the local community in conserving the Uluguru Nature Forest Reserve? 1= Yes, 2=No[ ]
    a) If Yes, how?
    b) If No, Why?
14. What challenges do you face in conserving the Uluguru Nature Forest Reserve?
15. What should be done to implement and improve the conservation initiative of Uluguru Nature Forest Reserve?

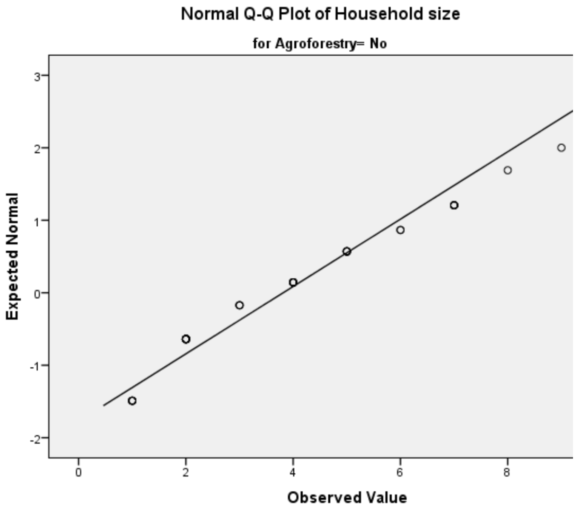
## Appendix 2: Selected Q-Q plots for agroforestry and beekeeping adoption





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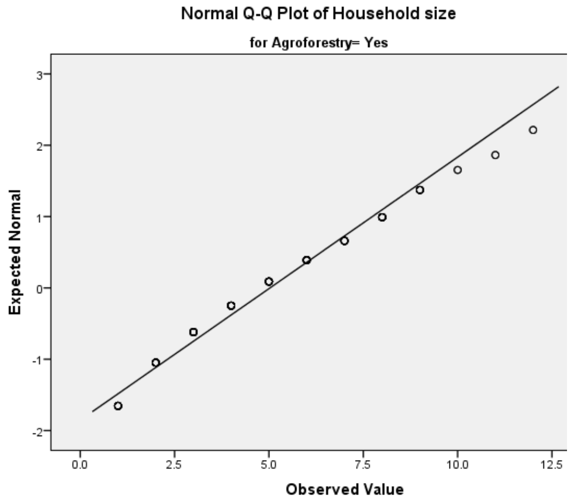
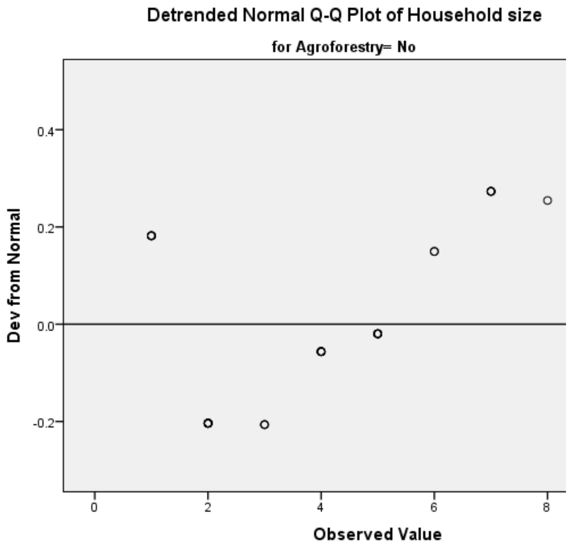
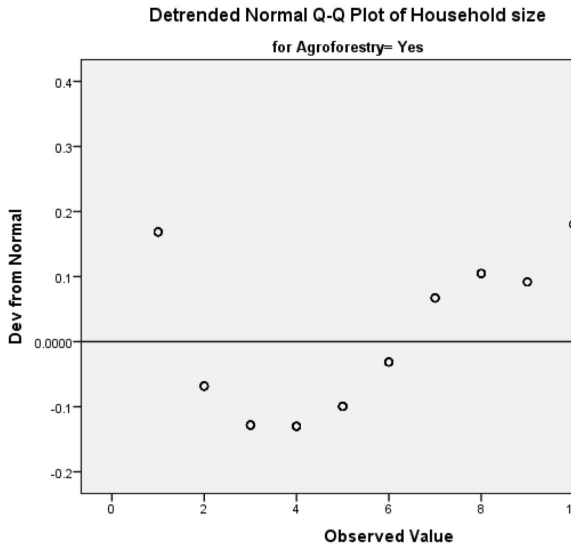
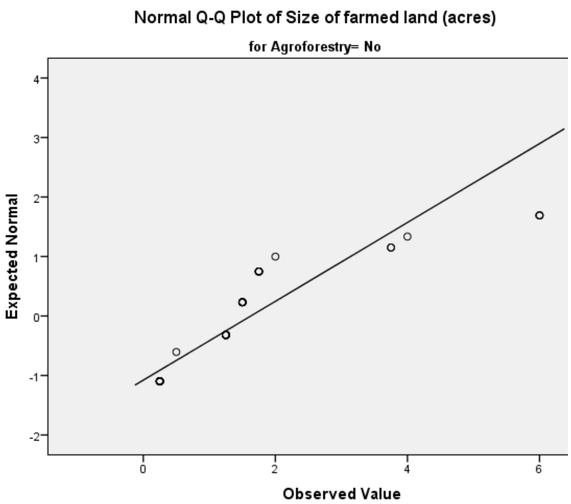
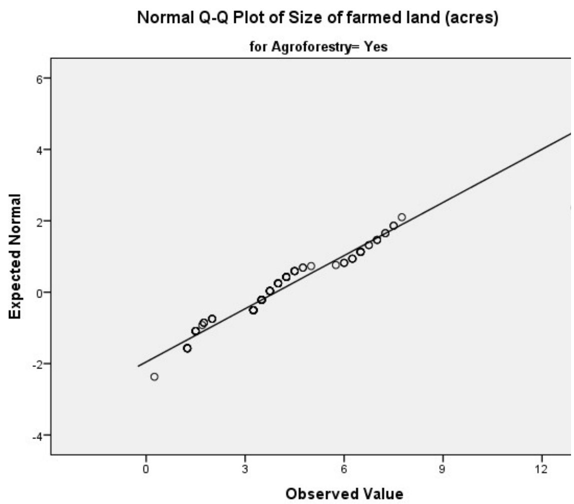
for Agroforestry= No
Expected Normal
Observed Value

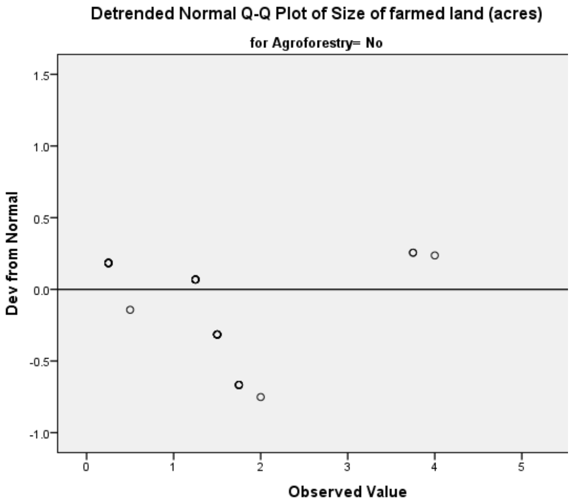

Normal Q-Q Plot of Household size
for Agroforestry= Yes
Expected Normal
Observed Value

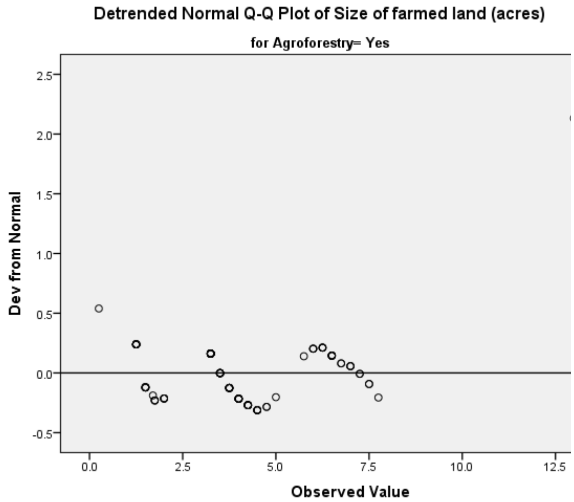

Detrended Normal Q-Q Plot of Household size
for Agroforestry= No
Dev from Normal
Observed Value

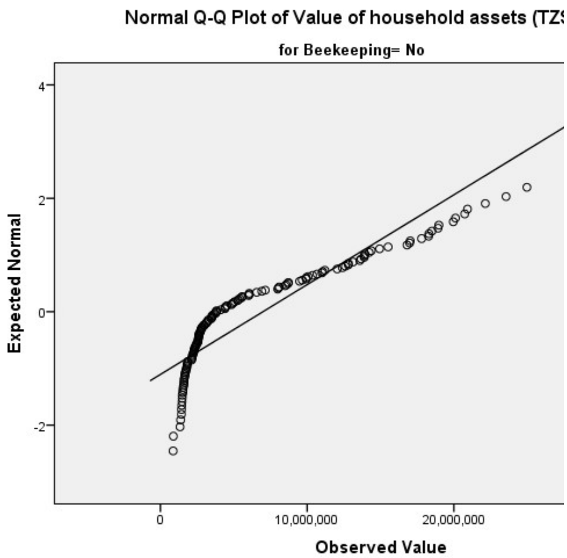

Detrended Normal Q-Q Plot of Household size
for Agroforestry= Yes
Dev from Normal
Observed Value

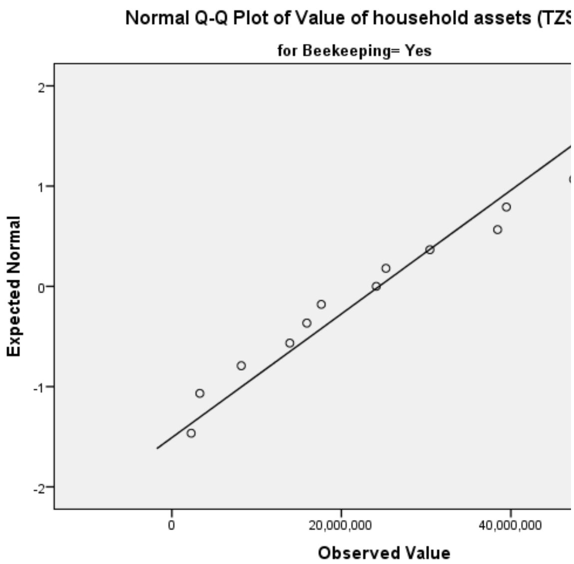

Normal Q-Q Plot of Size of farmed land (acres)
for Agroforestry= No
Expected Normal
Observed Value

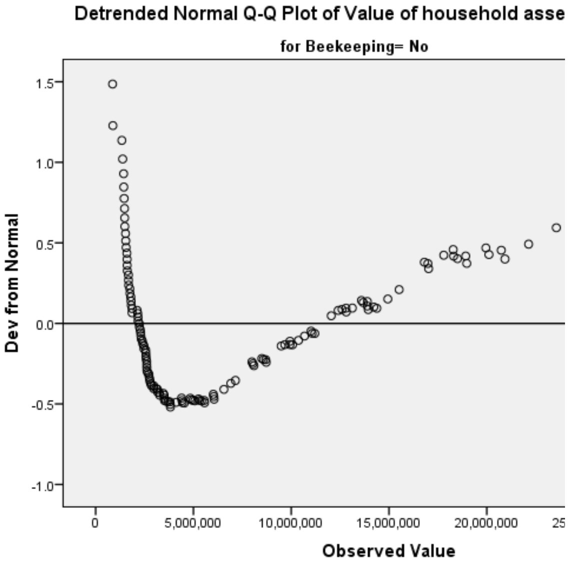

Normal Q-Q Plot of Size of farmed land (acres)
for Agroforestry= Yes
Expected Normal
Observed Value

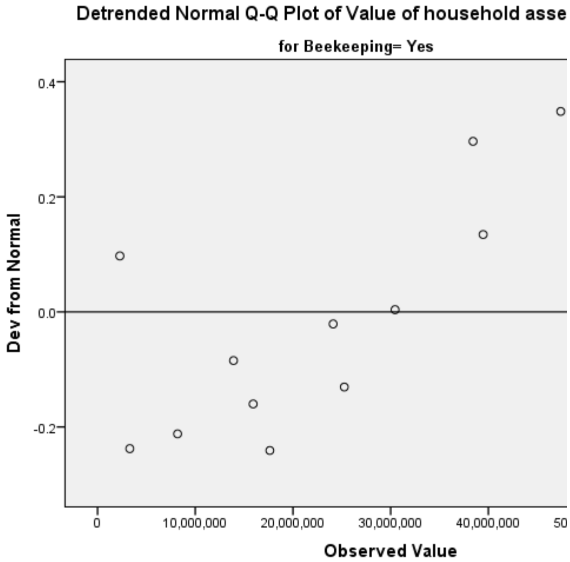

Detrended Normal Q-Q Plot of Size of farmed land (acres)
for Agroforestry= No
Dev from Normal
Observed Value


Detrended Normal Q-Q Plot of Size of farmed land (acres)
for Agroforestry= Yes
Dev from Normal
Observed Value


Normal Q-Q Plot of Value of household assets (TZS
for Beekeeping= No
Expected Normal
Observed Value


Normal Q-Q Plot of Value of household assets (TZS
for Beekeeping= Yes
Expected Normal
Observed Value


Detrended Normal Q-Q Plot of Value of household asse
for Beekeeping= No
Dev from Normal
1.5
1.0
0.5
0.0
-0.5
-1.0
0
5,000,000
10,000,000
15,000,000
20,000,000
25
Observed Value


Detrended Normal Q-Q Plot of Value of household asse
for Beekeeping= Yes
Dev from Normal
0.4
0.2
0.0
-0.2
0
10,000,000
20,000,000
30,000,000
40,000,000
50
Observed Value

**Appendix 3: Tree species commonly used by communities in Uluguru Mountains**

| Species* | Family | Main tree uses* |
|---|---|---|
| *Milicia excelsa* (Welw.) C.C. Berg. | Moraceae | Ti,Co,Fa,Do,Fi,Ca,Fo,Fe,Ch |
| *Albizia gummifera* (J.F. Gmel.) C. A. Sm. | Fabaceae | Co,Fo,Ch,Fa,Fe,Ca,Do,Me,Ti, Fi |
| *Annona senegalensis* Pers. | Annonaceae | Ca,Fa,CoFa,Fe,Fi,Ch,Me,Fo |
| *Dalbergia melanoxylon* Guill. & Perr. | Fabaceae | Ca,Ti,Me,Ch,Do,Ca,Fa,Fe,Co |
| *Erythrophleum suaveolens* (Guill. & Perr.) Brenan. | Fabaceae | Me,Do,Fi,Ca,Fo,Fa,Ca,Ch,Fe |
| *Mangifera indica* L. | Anacrdiaceae | Fe,Fa,Fi,Me,Ch,Ti,Do |
| *Cedrela odorata* L. | Meliaceae | Co,Ti,Fi,Ch,Ca,Fo,Fe,Fa |
| *Combretum spp*. | Combretaceae | Fi,Ch,Fa,Co,Me,Do,Ca,Fa |
| *Albizia versicolor* Welw. ex. Oliv. | Fabaceae | Fe,Do,Ch,Co,Ca,Ti,Me,Fi |
| *Vitex doniana* Sweet | Verbenaceae | Fo,Do,Me,Fa, Ch,Fi, Fe |
| *Scorodophleous fischeri* (Taub.) J. Leon | Fabaceae | Do,Fi,Ch,Ti,Co,Fa |
| *Khaya anthotheca* (Welw.) C. DC. | Meliaceae | Ti,Fi,Ch,Do,Ca,Fa |
| *Acacia albida* Delile | Fabaceae | Ch,Fi,Fo,Do,Ca |
| *Pterocarpus angolensis* DC. | Fabaceae | Ti,Co,Do,Ca,Fi,Ch |
| *Bombax rhodognaphalon* K. Schum. | Bombaceae | Ti,Me,Do,Ca |
| *Grewia similis* K. Schum. | Tiliaceae | Fe,Fa,Fi,Fo,Me |
| *Dombeya natalensis* Sond. | Sterculiaceae | Ch,Fa,Do,Ca,Fe |
| *Azadirachta indica* A. Juss. | Meliaceae | Me,Fe,Fo,Ch |
| *Millettia usamarensis* Taub. | Fabaceae | Co,Fe,Fo,Fi |
| *Terminalia sericea* Burch. ex DC. | Combretaceae | Me,Do,Fi.Ch |
| *Burkea africana* Hook. | Fabaceae | Co,Fi,Ch,Fa |
| *Ehretia amoena* Klotzsch. | Boragnaceae | Fo,Co,Ti,Do |
| *Afzelia quanzensis* Welw. | Fabaceae | Ti,Do,Fi,Co,Ca |
| *Oxyanthus goetzei* K. Schum | Rubiaceae | Do,Fi,Fe,Fa |
| *Terminalia sambesiaca* Engl. & Diels. | Combretaceae | Fi,Fa,Co,Ch |
| *Antiaris toxicaria* (Pers.) Lesch. | Moraceae | Ti,Co,Do |
| *Allanblackia ulugurensis* Engl. | Clusiaceae | Ti,Ca,Do |
| *Bridelia micrantha* (Hochst.) Baill. | Euphorbiaceae | Fa,Me |
| *Markhamia obtusifolia* Sprague | Bignoniaceae | Co,Ca,Do |
| *Ficus spp*. | Moraceae | Me,Fi |
| *Parinari excelsa* Sabine | Chrysobalanaceae | Ti,Fi,Co |
| *Ocotea usambarensis* Engl. | Lauraceae | Me,Ti,Co |
| *Vangueria infausta* Burch. | Rubiaceae | Do,Fi,Ch |
| *Harungana madagascariensis* Lam. ex. Poir. | Hypericaceae | Do,Co |
| *Lonchocarpus bussei* Harms. | Fabaceae | Ch,Fi |
| *Tectona grandis* L. f. | Lamiaceae | Ti,Fa,Fe |
| *Brachystegia bussei* Harms. | Fabaceae | Do,Co |
| *Diplorhynchus condylocarpon* (Müll.Arg.)Pichon. | Apocynaceae | Me |
| *Xylopia aethiopica* (Dunal) A. Rich. | Anacardiaceae | Me |
| *Xylopia longipetala* De Wild & T. Durand | Anacardiaceae | Me |
| *Voacanga africana* Stapf. | Apocynaceae | Co |
| *Sterculia quinqueloba* (Garcke) K. Schum | Sterculiaceae | Ti |

*Arranged in order of preferences

Fi = Firewood, Ch = Charcoal, Ti = Timber, Me = Medicinal, Co = Construction, Do = Domestic utensils, Ca = Carving, Fo = Fodder, Fe = Fencing, Fa = Farm implements
Source: Kacholi (2014)