Drivers of ecosystem services and sustainable development in a mountain environment at Mariepskop, South Africa

By

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Summary

Mariepskop Mountain is the highest peak on the northern Drakensberg escarpment at an elevation of 1945 m above sea level (asl). The Klaserie River emanates from the Mariepskop in a south-easterly direction whilst the Blyde River flows along the north-western parts of the mountain creating a canyon. The Mariepskop is made up of microclimates forming habitats for a wide range of flora and fauna. This study found that Mariepskop is an important source of useful ecosystem services and livelihoods for the three main local groups. These include, the residents of Acornhoek, Kampersrus and the commercial farmers living in the lowlands of the mountain. This study found that these three communities have major differences in their resource use patterns. In this study, the term Acornhoek was used in reference to the rural villages between the Mariepskop Mountain and the town of Acornhoek. Acornhoek is a high density residential area located on the eastern slopes of the Mariepskop and with a population actively dependent on the mountain for wild edible plants, firewood and water. Kampersrus is a small village on the Northern foothills of the mountain with a population that particularly enjoys the scenery and recreational facilities of the Mariepskop. The commercial farms are located on the Northern and North-Western sides of the mountain and the farmers rely on the water from the Blyde River for irrigation of largely citrus crops. Socio-economic characteristics of these communities were identified to be the primary drivers of resultant mountain natural resource use patterns. A set of international United Nations Millennium Development Goals (UN MDG) and Sustainable Development Goals (SDG) indicators, as well as localised sustainability indicators, were assessed for their applicability at the local level and their local and international values compared and ranked to determine the levels of sustainability. An assessment current and future sustainability of Acornhoek resource patterns for water, wild edible plants and firewood using population trajectories, yielded results that show current and medium-term sustainability and long-term unsustainability if resource use remains the same. The study found that though the international indicators had not been developed for application at the local level, they are quite useful when modified or localized to accommodate the local social, economic and environmental landscape. Also we found that, different local areas need to develop their own unique set of sustainability indicators that encompass and address issues specific to that local area in order to adequately monitor sustainability levels.

Declaration

I declare that the thesis I am submitting for an MSc (Geography) degree to the Centre For Environmental Studies (CFES) at the University of Pretoria, is my own work and has not been previously been submitted for a degree at this or any other tertiary institution.

Signature ______________________ Date ____________________

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List Abbreviations

M	metres
kl	Kilolitre
kg	Kilogram
km	Kilometres
mm	Millimetres
asl	Above sea level
^{o}C	Degrees celcius
ha	Hectares
y	Year
SJN	Sipiwe Janet Ngwenya
ZAR	South African Rand
$US	United States Dollar
ARD	Agricultural Research for Development
Glz	Generalized linear model
KNP	Kruger National Park
AWARD	Association for Water and Rural Devfelopment
NRF	National Research Fund
MDG	Millennium Development Goals
SDG	Sustainability Development Goals
UN	United Nations
RR	Resource Rent
TR	Total Revenue
FC	Fixed Costs
IC	Intermediate Costs

S	Standing biomass of forest
A	Total area of the forest
Y	Number of years
FRR	Forest regeneration rate
HIV	Human Immunodeficiency Virus
E. coli	Escherichia coli
GPS	Global Positioning System
NGO	Non-Governmental Organisation
SAPS	South African Police Services

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Introduction

1.1 Background

Mountains have been present since the beginning of time and have always played a major role in the lives of human beings as landmarks and sources of natural resources (Messerli *et al*. 1988; Byers *et al*. 2013). Their ecosystems support a range of livelihoods becoming habitats for unique flora and fauna, rich biological diversity hotspots, providing minerals and nutrient rich lands for agriculture (UN 2002; Viviroli and Weingartner 2004; Sharma *et al*. 2010; Khan *et al*. 2013). Mountains are fundamental for the creation of streams and rivers since they act as watersheds and also as habitats for the millions of humans living on the lowlands (Price 1998). About 20% of the world population lives on mountains or at their edges with half of humankind being dependent on mountain resources directly or indirectly, particularly in developing countries (MEA 2005). Threats against these natural formations are largely from anthropogenic interactions and activities through overharvesting of natural resources, pollution and global warming (Folke *et al.* 2010).

Though climate change is a global phenomenon, the extent of its effects are likely to vary from place to place due to geographical differences and any interventions in adaptation will have to be localized (IPCC 2013; 2014). With global temperatures projected to increase by between 1.4 and 5 ^{o}C by 2100 (IPCC 2001), this increase could affect vegetation biomes and species at different microclimates along varying longitude and elevation (Price 1998; Langdon and Lawler 2015). Mountain areas are especially sensitive to climate change, primarily temperature increases (Bates *et al.* 2008; Simane *et al*. 2012) and extreme weather events such as floods and landslides due to their steep slopes. Therefore, mountains are ideal in detecting and monitoring the onset or extent of climate change impacts (Shah *et al.* 2015).

Freshwater ecosystems emanating from mountains are particularly vulnerable because their hydrology and morphology may be directly affected by rainfall and temperature changes (Price 1998; Jacobsen *et al*. 2012; Immerzeel *et al*. 2013). This makes these freshwater systems particularly fragile and vulnerable to the adverse effects of climate change on plant and animal species (UN 2002). These multi-dimensional aspects of mountains therefore make it important to promote full participation and involvement of mountain communities in the decision-making process whilst integrating indigenous knowledge in their management (UN 2002, Sharma *et al*. 2010), as well as, using science-based information for decision making.

1.2 Mountain ecosystem services

Mountain ecosystems are complex systems which supply provisioning, regulating, cultural and supporting goods and services (MEA 2005). Human communities benefit from provisioning ecosystem services through the direct use of natural resources for food to supplement diets, water, raw materials and also as a source of livelihoods. Cultural mountain ecosystem services are also important to human communities, predominantly for aesthetic, recreation, spiritual gatherings and traditional ceremonies. Supporting ecosystem services include nutrient cycling and soil formation and regulating ecosystem services include disease, flood, climate regulation and water purification (MEA 2005). The various functions of mountains are vital for the well-being of healthy communities. Provision of permanent water flow is a basis for life support systems in the surrounding densely populated plains and lowlands (Messerli *et al*. 1988). Also, tropical African mountains support many more rural people than the surrounding lowland areas because they have wetter climates (Shackleton *et al*. 1998), permitting the establishment of permanent agricultural systems (Blyth *et al*. 2002). Tropical mountain ecosystems also have benefits like higher densities of vegetation and wild edible plants (Shackleton *et al.* 1998). This direct reliance on rainfall increases the vulnerability of communities to the negative impacts of climate change (Gentle and Maraseni 2012). Most of the negative impacts of climate changes are likely to be experienced by poor vulnerable communities due to a lack of capacity to adapt to strongly modified ecosystems (MEA 2005; Smit and Wandel 2006).

1.3 Characteristics and challenges of African mountains

Some of the resolutions from the 2002 World Summit on Sustainable development included developing and implementing policies and programmes that help eliminate inequities facing mountain communities and promoting the diversification of traditional mountain economies through promotion of small-scale production systems and training programmes in eco-tourism (UN 2002). Despite these resolutions, the state of mountains in most parts of the African continent and the world has remained under a series of threats (Felix and Gheewala 2011) and with forests in various states of deterioration largely due to deforestation (Geist and Lambin 2002; Dessie and Kleman 2007; Hall *et al*. 2009). This makes mountains less productive and this negative trend may be exacerbated by climate change.

Rising population levels weigh heavily upon resources available per capita, particularly in developing countries (Beniston 2003). Mountains in Africa are especially at risk of degradation (Messerli *et al*. 1988) due to the high populations and poverty levels in rural areas which lead to heavy reliance on natural resources as the sole livelihood opportunity (Twine 2011). High dependence on mountain resources by local rural communities results in the overharvesting of natural resources, and rampant land clearing for agriculture. Deforestation in mountain landscapes, leads to increased landscape degradation and siltation of water bodies from soil erosion through runoff (Hurni 1988). The process of erosion is accelerated by the mountain steep slopes and this eventually reduces the quality of nutrient rich topsoil. Most mountain communities experience high poverty rates and low levels of education (Huddleston *et al*. 2003). Poor communities also have limited energy alternatives and natural forests provide a direct source of affordable energy in Africa. Firewood is still the primary source of fuel for cooking and heating. This is the same in South Africa's rural areas and particularly in the Lowveld region where the average household uses between 3.5 - 4 tonnes of fuel wood per annum (Shackleton and Shackleton 2000). Despite increased electrification of rural households in South Africa the use of firewood for cooking and heating has not declined (Madubansi and Shackleton 2007).

1.4 Drivers of natural resource use in South African mountains

Poverty is one of the main drivers of rural mountain natural resource use in South Africa. The socio-economic status particularly household income or wealth levels of the populations living near and surrounding forests usually determine their resource use patterns (Twine 2011). Lack of employment opportunities in rural areas is compounded by low levels of education, and ultimately poor households rely more on local natural resources like firewood, wild edible plants and raw materials. Other, household characteristics such as age and gender of the household head also provide the important drivers of resource use (Twine 2011).

Commercialisation of natural resources for sale to households living far away from forests is another important driver of unsustainable firewood extraction (Shackleton 2001). Furthermore, household economic shocks, such as loss of employment or the sickness or death of a breadwinner, promote higher use of essential natural goods and services (Shackleton and Shackleton 2004; Twine and Hunter 2011). Forests then become safety nets that supplement livelihoods through the use and sale of harvestable natural resources (Shackleton 2001).

Communal land tenure systems, which are typical of South Africa's former 'homelands', require strong governance and regulation structures to monitor and guide community resource uses. Weak institutional regulation and enforcement often result in the forests being regarded as common pool resources and thus prone to unsustainable use (Twine 2011). Rural communities are often dependent upon natural resources within protected areas and where access to these resources is limited or illegal (Adams and Infield 2003).

1.5 Livelihoods and ecological changes on mountains

Environmental changes may occur naturally due to the effects of climate on mountains or as a result of anthropogenic factors, that is, the changes are the result of interactions between people and their environment (Beniston 2003). The complex human-environment interactions can shape the landscape and local ecosystems leading to a reduction or disruption in the supply of ecosystem goods and services (Vogel 1995; Twine 2011). Increased changes in climate and land use patterns have been projected to cause changes in vegetation communities, animal and plant species, as they find new favourable habitats (Langdon and Lawler 2015).

Ecological changes can also be buffered by the high resilience of ecosystems as particular landscapes remain stable maintaining their functions after disturbances (Folke *et al.* 2010). Ecosystems with low inherent resilience may be negatively affected, causing reduced resource availability. Extreme weather conditions brought on by climate changes may trigger natural disasters which damage ecosystems and human livelihoods, and the effects are worsened by people's vulnerability and lack of awareness (Webster *et al*. 2008). Therefore, changing ecosystems may increase the vulnerability of poor rural communities to the negative impacts of climate change, with reduced ecosystem productivity and loss of biodiversity eroding their natural buffer (Aryal *et al*. 2013).

Poor households have limited livelihood options and are already having to substitute purchased goods with those they can freely obtain from the environment. Due to the already vulnerable nature of poor households ecological changes threaten to remove or reduce the capacity of ecosystems to act as safety nets and increase loss of ecosystem goods and services value perpetuating the cycle of poverty.

The purchasing of firewood from vendors and increased walking distances to collect firewood indicate fuel wood shortages that some rural households are already experiencing in the lowveld of South Africa (Giannecchini, Twine, and Vogel 2007). Unsustainable ecosystem goods harvesting also leads to loss or extinction of key species, potential alteration of food chain processes and changes in water regimes of watersheds. Landscape changes ultimately lead to ecosystem functions being undermined and altered, eventually compromising ecosystem services and their delivery. This impacts the livelihoods of people living on mountains, at their foothills and in the lowlands. The changes in the ecological systems of Mariepskop will largely affect communities living near the mountain and those who derive the most ecosystem goods and services from it. Ecological changes may over time reduce the availability of firewood, water and wild edible plants to the households living near the Mariepskop Mountain.

1.6 Research problem statement

Mountains hold critical importance to many populations in the world (Debarbieux and Price 2008) either directly or indirectly as a source of water for drinking, irrigation and industry, timber for fuelwood and construction, wild edible plants for food and medicine. Mountains have high biodiversity and they form different plant and animal communities and habitats at various elevations (Byers, Price, and Price 2013). Human activities such land use changes and unsustainable resource extraction, are key factors accelerating the rate of environmental change on mountains (Latocha 2009).In order to identify the drivers of mountain ecosystem services use and monitor the sustainability of mountain natural resource use, it is important to study mountains from various regions. This is because human-environment interactions and dependence tend to differ due to the household socio-economic status of communities. These socio-economic characteristics include household income, employment, size and age which act as drivers of natural resource use (Twine 2011). Any changes to the mountain ecosystems through natural or anthropogenic activities that alter water regimes and deteriorate the quality and flow of ecosystem services to the local communities dependent on the mountain ecosystems.

This study is concerned with the Mariepkop Mountain with an elevation of 1945m situated at the border of Limpopo and Mpumalanga Provinces of South Africa. Mariepskop plays a vital role in the livelihoods of the surrounding commercial farmers, in the basic survival of Acornhoek households and in the well-being of the Kampersrus community. The demand for mountain natural resources by communities increases the vulnerability of the mountain to environmental changes because of its steep slopes and high altitudes.

Research on the nature of complex interactions of human communities and the physical mountain environment is important if these relationships are to be understood. There are limited studies that have been carried out on the socio-economic characteristics of human communities and resource use drivers around the Mariepskop Mountain and none of them specifically focus on the mountain resources use patterns.

This study will contribute to the currently limited understanding of the different human communities and their interactions with the Mariepskop Mountain. Of particular interest are the poor households of Acornhoek who, by virtue of being poor, become more vulnerable to climatic and ecological changes, thus becoming even more susceptible to the negative changes.

1.7 Aims and objectives of the study

The aim of this study is to understand the relationships communities living around the Mariepskop Mountain have with the mountain and its resources. The objectives of the study are listed below:

Objective 1

To analyse the Mariepskop Mountain, resource use patterns of the surrounding communities of Kampersrus, Acornhoek and commercial farmers, and how these vary due to socio-economic status.

This was achieved by a survey of 200 Acornhoek households using questionnaires focusing mainly on socio-economic characteristics and mountain resource use of the households. This survey also included three focus group community meetings to gather information on the resource access and availability issues of the Acornhoek community. Another survey of 20 Kampersrus households was done to identify their natural resource use patterns using a specific questionnaire. A total of 30 citrus and game farmers in the area were also surveyed.

Objective 2

To identify the major drivers of natural resource use, their interactions and the value of Mariepskop Mountain ecosystem goods and services.

An analysis of the data collected from the surveys of the three different groups living around the Mariepskop Mountain was done for the Acornhoek quantitative and qualitative data in order to highlight the main drivers of Mariepskop natural resource use. The monetary value of the ecosystem services benefitting Acornhoek households and the commercial farmers was quantitatively calculated using the Replacement Cost and Resource Rent methods.

Objective 3

To assess the current and future sustainability of the Mariepskop Mountain and Acornhoek area and the value of using international and local sustainability indicators

This was achieved by an assessment of the applicability of a selection of relevant international and customised local sustainability indicators at the local Mariepskop and Acornhoek level and subsequent sustainability ranking using indicator data. Also, a household natural resource unit was then used to estimate current and future natural resource use patterns in Acornhoek taking into account the annual population growth rate.

1.8 Organization of report

1. Chapters 2 and 3 of this report have been edited and referenced for submission for publication to different accredited journals. The Mariepskop Mountain as a source of various goods and services for the three main community groups of Acornhoek, Kampersrus and the commercial farmers settled around it, is contained in Chapter 2. This chapter analyses differences and drivers of natural resource use patterns of the three communities. A comparison of access to mountain benefits to households near and further away from the Mariepskop is

done in this chapter. Ecosystem services monetary valuation is carried out for Acornhoek households and the commercial farmers.

2. Chapter 3 reflects the assessment of current and future sustainability levels of the Mariepskop Mountain through the use of relevant international and localised sustainability indicators. This Chapter also highlights the overall importance of the development and monitoring of local indicators for sustainable development, resource use patterns and actual trend analysis.

3. Chapter 4 includes concluding remarks and recommendations.

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2

Mountains as a critical source of ecosystem services: the case of the Mpumalanga Drakensberg, South Africa

Abstract

Mountain natural resource use and consequent ecosystem services for three diverse rural communities around the Mariepskop Mountains in the Mpumalanga Drakensberg, South Africa, were studied using interviews and focus group meetings.These mountains provide a diverse range of critical ecosystem services to surrounding rural communities up to distances further than 20km. Of the low income village-level households, 90% continuously depend on firewood and water. Commercial farmers value mountain water and indigenous insect pollinators. For more affluent village inhabitants the aesthetic and historic value of the mountain was paramount. The ecosystem services identified by these three communities differed strongly with different community-specific ecosystem services. Ecosystem services identified by these communities were primarily influenced by household distance from the mountain and socio-economic status. The replacement cost method was used to access the value of firewood, water, wild edible plants and other resources by Acornhoek households, while the resource rent method was used to assess the value of ecosystem services to commercial farmers in the area. The importance of these mountains to livelihoods whilst ensuring resilience, require governance that takes into account socio-economic based diversity in ecosystem services and spatial diversity of natural resources utilization.

Key words: ecosystem services; wild products; environmental change; rural livelihoods, Drakensberg

2.1 Introduction

Mountains are important for natural resource provision such as water, fuel wood and raw materials to densely populated lowlands (Price 1998). These provisioning ecosystem services are used by particulary rural communities to substitute food through the use of wild edible plants, fruits and bushmeat and as source of livelihood as natural resources are used or sold for income. Other important ecosystem services provided by mountains include supporting, cultural and regulating services. Subtropical mountain ecosystems are subject to environmental effects due to high rainfall, steep slopes, and sensitivity to disturbance, making them susceptible to lower critical thresholds (UN 2002; Folke *et al*. 2010). Global change (including climate change) is projected to undermine individual and household livelihoods, reduce food and water availability through droughts, floods and increases in disease causing vectors (Bates *et al*. 2008). These processes affect ecosystem resilience (Messerli and Winiger 1992), that is, the ability and capacity of the ecosystem to return to its original state after experiencing a disturbance whilst sustaining its principal functions and structure (Walker *et al.* 2004; Folke *et al*. 2010). Mountain areas in developing countries often experience excessive harvesting of resources (Bitariho and McNeilage 2008), through deforestation, overgrazing, and over-cultivation of shallow soils by heavily dependent communities (Beniston 2003; Ikkala 2011) especially in tropical and subtropical mountain regions (Armenteras, Gast, and Villareal 2003). This human pressure causes formally protected mountain areas to experience constant illegal extraction of resources (Sheil *et al*. 2011). The sustainable supply and management of natural resources, by local communities and the ability to devise resilient livelihoods and promote resilient ecosystems have become critical questions (Falkenmark and Rockström 2010). Ecosystem resource use is likely to show differences due to socio-economic variances of households (Twine 2011). Mountain communities are often impacted by the negative effects of ecological changes because of their high dependence on mountains for their livelihoods in developing countries.

Many studies on regional effects of particularly climate change on water resource availability, use and allocation, emphasize the likelihood of conflict over the resource

(McNally, Magee and Wolf 2008; De Stefano *et al*. 2012) arising from projected increases in rainfall intensity and variability, resulting in water stresses (Bates *et al*. 2008). Environmental variability and disturbances are expected to reduce the resilience of social–ecological systems because they augment the exposure of local communities to hazards and uncertainties (Falkenmark and Rockström 2006).

Africa has in the past experienced food insecurity from climatic impacts such as droughts and floods. The vulnerability, population growth, food shortage and need for aid are likely to increase in the face of climate change (Vogel and Smith 2002). Presently, most rural mountain communities have high population densities, low levels of education and high unemployment rates that weigh heavily on natural resources (Beniston 2003). Studies on the underlying drivers of resource use in the subtropical Africa have focused on resilience and vulnerability, transitions and transformations of socio-ecosystems with a focus on adaptability (Folke and Gunderson 2010). This is in reaction to the challenges of rural communities, which eventually lead to unsustainable livelihood practices (Twine 2011; Shackleton 2001; Pollard, Shackleton, and Curruthers 2003). There is a strong need to understand natural resource use in mountain areas and the dependence on the resulting ecosystem services to foster more resilient socio-ecological systems and more sustainable livelihoods. At the same time, the study of mountain communities provides a critical understanding of how complex social and ecological systems are interlinked and how they impact on the larger ecosystems in the world.

Determination of ecosystem value also plays a role in developing systems that protect and promote the sustainable use of ecosystems, as humans invariably pay attention and protect what they deem valuable (Komakech 2013) and this applies to mountainous landscapes too. The supply and flow of goods and services depends on ecosystem features (e.g. forests, wetlands) and ecosystem health (Laurila-Pant 2015). The flow and quality of goods and services can therefore be used to determine the health and value of ecosystems. The value of ecosystem services also varys with the needs and characteristics of the local user community (Schägner *et al.* 2013; Bartkowski, Lienhoop, and Hansjürgens 2015). Attaching a monetary value to ecosystem services has become an important tool in identifying and assessing the ecosystem services most valuable to people (Schägner *et al.* 2013).

Within the above context, we selected a mountain site with a number of socio-economically and culturally different communities. The objectives of our study were to define the ecosystems services of different communities around the mountain and assess their resource use patterns and the potential consequences of ecological changes. Such objectives require that ecosystem services should be defined. Ecosystem services are components of nature, directly enjoyed, consumed, or used to yield human well-being (Boyd and Banzhaf 2007). We therefore see ecosystem services as the direct or indirect benefits that humans obtain by using the natural resources provided by their natural environment. Without the corresponding natural resources it would not be possible for an ecosystem to yield ecosystem services. A particular natural resource can yield more than one ecosystem service (wood for burning or for construction) and a particular ecosystem service could be obtained from more than one resource (electricity from water or from coal).

We specifically addressed the following questions:

1) How important is the Mariepskop Mountain in providing natural resources to the surrounding communities?
2) What ecosystem services are provided to the local communities by using these natural resources and what are their values particularly for the Acornhoek households and the commercial farmers?
3) Which factors determine the dependency of communities on natural resources and the particular ecosystem services obtained from the mountains?

2.2 Study site

The Mariepskop Mountain (24°32'34"S, 30°52'07"E) straddles the border of the Mpumalanga and Limpopo provinces, South Africa (Figure 2-1). Reaching an altitude of

1945 metres, it forms part of the northern Drakensberg Escarpment known as the Mpumalanga Drakensberg. The physiognomy of natural vegetation at the bottom of the mountain is typical of a wooded savanna. Tree density increases with altitude and changes to mist belt indigenous forest from about 1000 to 1900m asl, above which it progressively becomes evergreen shrubland similar to the Cape Fynbos (Mucina and Rutherford 2006). The south-eastern part of the mountain includes the remnants of extensive forestry closed in 2004 when the South African government decided to make the mountain a protected area. The plantation formerly comprised *Eucalyptus* and *Pinus* species, on around 1681 ha (Schijff and Schoonraad 1971) making up 33.5% of the mountain total area. This plantation provided timber to the nearby sawmill that employed people from the nearby settlement, Acornhoek.

The Klaserie River emanates from the south eastern-slopes of the Mariepskop whilst the Blyde River cuts across the mountain on its north-western side and drains large parts of the plateau to the south west. Annual rainfall averages 1500 mm on the top of the mountain and 750 mm at the bottom. Mean summer mountain temperatures are around 24°C and mean winter temperatures 18°C. Temperatures decrease with altitude and different parts of the mountain experience different weather conditions at the same time. A study of the mountain's soils show rocky soils at the mountain top with red clays in the middle zone and sandy substrate at the bottom.

Our study included three different human communities. Firstly, the Acornhoek settlement (with villages of Boelang, Green valley, Brooklyn, Moloro and Arthurseat) lies to the east of Mariepskop within the Bushbuckridge Municipality in Mpumalanga Province with a population of about 150,000 people including the outlying areas (Sugrue 2005). It is a former homeland and has a high population density of 150-300 people km^{-2} (Shackleton *et al.* 1998; Pollard, Shackleton, and Curruthers 2003), with high levels of chronic poverty and pressure on local natural resources (Twine 2011). Household plots average 0.2 ha and most households perform subsistence farming, typically vegetables, fruit and maize (*Zea mays*). With high regional levels of unemployment, young people seek work in nearby commercial farms, predominantly as seasonal workers. Acornhoek represents an important aspect of this study because of the natural resources required by the large, low-income population on relatively small plots of land, differing from those of the surrounding commercial farms.

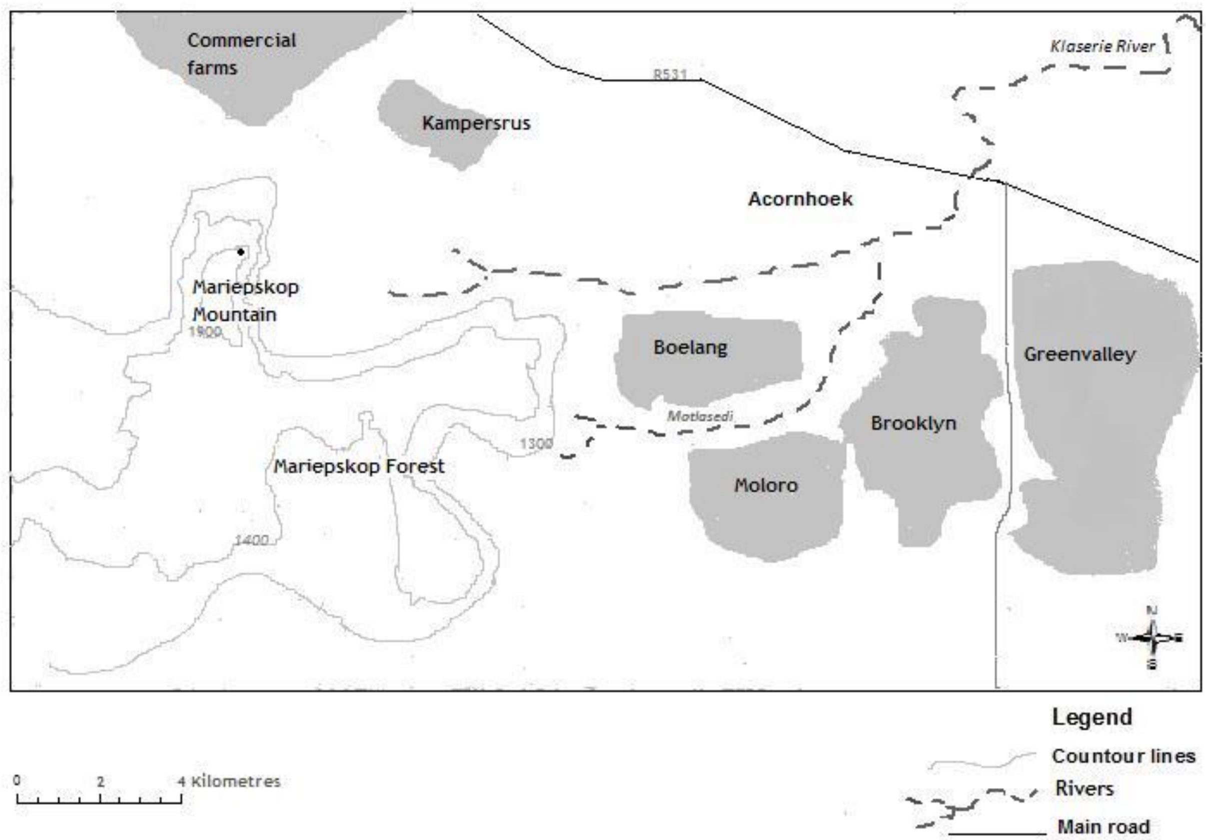

Figure 2-1: Map showing the location of Mariepskop,the commercial farms, Kampersrus,and the main villages forming Acornhoek

Irrigation and game farmers represent a second group, scattered on the north and north-western side of the mountain. The commercial farmers, with properties ranging from ten to 2300 ha mainly grow citrus trees and horticultural crops with some also including game farming.

Lastly, the area also includes a village at the northern foothills of the mountain (Kampersrus), mostly comprising retired commercial farmers or government employees.

Kampersrus has been included in the study to represent a group likely to differ from the farming community in the area regarding their relationship to the mountain and its natural resources.

We performed a comparison of ecosystem services of households living close to the mountain (our primary data set) and those living away from the Mariepskop approximately 40-60 km linear distance adjacent to the Kruger National Park (KNP).
Comparative household data for communities near the KNP used were obtained from the literature from two groups who have done extensive studies in areas adjacent to the KNP: the University of the Witwatersrand Rural Project (Twine 2011; Twine *et al*. 2003; Shackleton *et al.* 1998; Banks *et al*. 1996) and from the Association for Water and Rural Development in Bushbuckridge municipality (Pollard, Shackleton, and Curruthers 2003; Pollard and du Toit 2011). This comparison highlighted the most important differences in ecosystem services obtained by the different communities, their availability and ease of access.

2.3 Methods

An important aspect of the study was to compare the ecosystem services for communities close to and further away from the mountain. This was achieved in two ways: 1) data were collected along a distance gradient up to 21 km from Mariepskop; 2) data were compared to those from communities close to the KNP (around 50 km from Mariepskop), obtained by the two external projects discussed above.

2.3.1 Acornhoek household surveys

Firstly, questionnaire-based surveys of 200 households were performed focusing on socio-economic characteristics (age, gender, income, distance from mountain and household size) and trends in their resource use patterns. Interviews were performed in five villages at Acornhoek: Boelang, Brooklyn, Green Valley, Moloro and Arthurseat. Interviews were conducted in the local languages, either partly or totally mastered by

SJN with either the head of the household or their spouse depending on availability at the time of the interview. The University of Pretoria ethical procedures were followed and ethical clearance was obtained before the survey was commenced. Informed consent was also obtained from each interviewee before the interview process began. Systematic sampling was used to choose the particular households and every tenth house (Shively 2011) from an updated house list from the local municipality was selected for the interview. Questionnaires were structured such that the most pertinent issues were addressed more than once in different ways to test for consistent responses. To capture the natural resources obtained by the households a mixture of open-ended and closed-ended questions were used in the questionnaire. For analysis, data were grouped into socio-economic categories, age of household head (20-39, 40-59 and 60-99 years) and distance from the mountain (0-5, 5.1-10, 10.1-15, and 15.1-21 km). This distance clustering represents progressively increasing difficulty in travelling to collect any particular natural resource from the mountain. With income, the grouping was done to represent the poorest households earning less than ZAR 1000 per month during 2012, followed by ZAR 1001-2000, ZAR 2001-3000 and lastly those above ZAR 3000.

Secondly, following the initial household interviews, three focus group meetings were held at the community halls in Greenvalley, Boelang (including Moloro) and Brooklyn villages in Acornhoek. The groups included 25 to 35 voluntary participants of different ages and gender clustered into homogenous sub-groups to encourage free discussion and participation. This was done to get a holistic picture and understanding of the people's perceptions of their local environment, how this impacts the community, major issues in the community and how these affect the mountain environment. The information acquired was largely qualitative and each sub-group had to share its dialogue with the rest of the meeting which corroborated or contradicted the findings. The individual groups also drew maps and diagrams of their villages showing the location of their most valued natural resources relative to their homesteads (ARD 2009) and for what purposes each of these resources were used. These qualitative results form an essential part of this study and were analysed concurrently with the quantitative data.

2.3.2 Farm and residential area surveys

Thirty commercial farms and conservation areas were selected from an updated farm list from the local district municipality. Every third farm was chosen and interviews performed using questionnaires to establish which natural resources farmers derive from the mountain, how these resources are used and how they are dependent on these. Both qualitative and quantitative data were collected.

Finally, 20 interviews (every second household chosen from an updated house list) were performed at Kampersrus using questionnaires to get an understanding of the benefits that the community derived from natural resources and of their interaction with the Mariepskop Mountain. The information obtained from these interviews was mostly qualitative and open-ended questions were used.

2.3.3 Data analysis for close ended questionnaires

The data obtained were both qualitative and quantitative: binomial, ordinal and continuous values. The five major independent variables were age, sex, income, distance from the mountain and household size. A generalized linear model (glz) was used to analyse the full data set for resource use data against the independent variables. Statistical analyses were performed with R version 2.13.0 (The R Core Team 2011) on the dependent and independent variables, using a logit transfer function. The significance of statistical tests were assessed using the Wald test.

2.3.4 Ecosystem services

The ecosystem services identified as important by the households at Acornhoek, Kampersrus and commercial farmers were listed including those they were generally unaware of, and compared to the ecosystem services available to the households close to the KNP. Identification of ecosystem services and their categorisation used was similar to that used in the Millennium Ecosystem Assessment Synthesis (2005).

2.3.5 The cash value of natural resources

The cash value of natural resources for two study groups, commercial farmers and Acornhoek households, was calculated using two different approaches. The resource rent method as used by Remme *et al.* (2015) was used to calculate the value of ecosystem services for the commercial farmers who farm around Mariepskop Mountain. This method was chosen to calculate the monetary value of natural resources because it measures the profit from the use of ecosystem services (UN *et al.* 2009) in citrus crop production, including those that are difficult to measure, such as pollination and soil nutrients. Resource rent was calculated as follows:

$$RR = TR - (IC + LC + FC)$$

Where: RR= Resource Rent, TR= Total Revenue, LC= Labour Costs, FC= Fixed Costs, IC = Intermediate costs (operating current expenses). Resource rent refers to the income remaining after all the costs of capital, labour and operating costs have been deducted in a farming enterprise. The calculations used were derived from studies of commercial citrus agriculture of Oosthuizen (2014) and Southern African Business (1999).

Calculating the cash value of firewood, water, wild edible plants and raw materials for the Acornhoek households was done using the replacement rent method (UN *et al.* 2014). This method estimates the value of ecosystem services from the cost and availability of its substitute or alternative if it were to be lost (Remme, Schröter, and Hein 2015; UN *et al.* 2014). The replacement cost method was used because the substitute for the Acornhoek households was the least costly option, it could be eventually used to replace the natural resource and the substitute could fulfil the functions of the natural resource (UN *et al.* 2014). The replacement cost cash value for one household provisional good harvested from Mariepskop (eg firewood), was calculated initially using current market prices. The replacement cost for the astimated resource use of one household/ annum was then multiplied by the total estimated number of households in Acornhoek, that is 10 000, to obtain the total replacement cost of the households.

2.4 Results

2.4.1 Acornhoek socio-economic characteristics and resource use

The results here are discussed from two perspectives: socio-economic categories and the individual natural resources and their ecosystem services. The natural resources that the Acornhoek community directly derives from the Mariepskop Mountain include water (90% of households), firewood (75%), poles (25%), wild edible plants and herbs (50%), reeds (2%), sand (11%) and scenic beauty (10%) (Figure 2-2a). A total of 93.5% of households in Acornhoek use electricity and the above figure only includes households who collect or use firewood from the mountain.

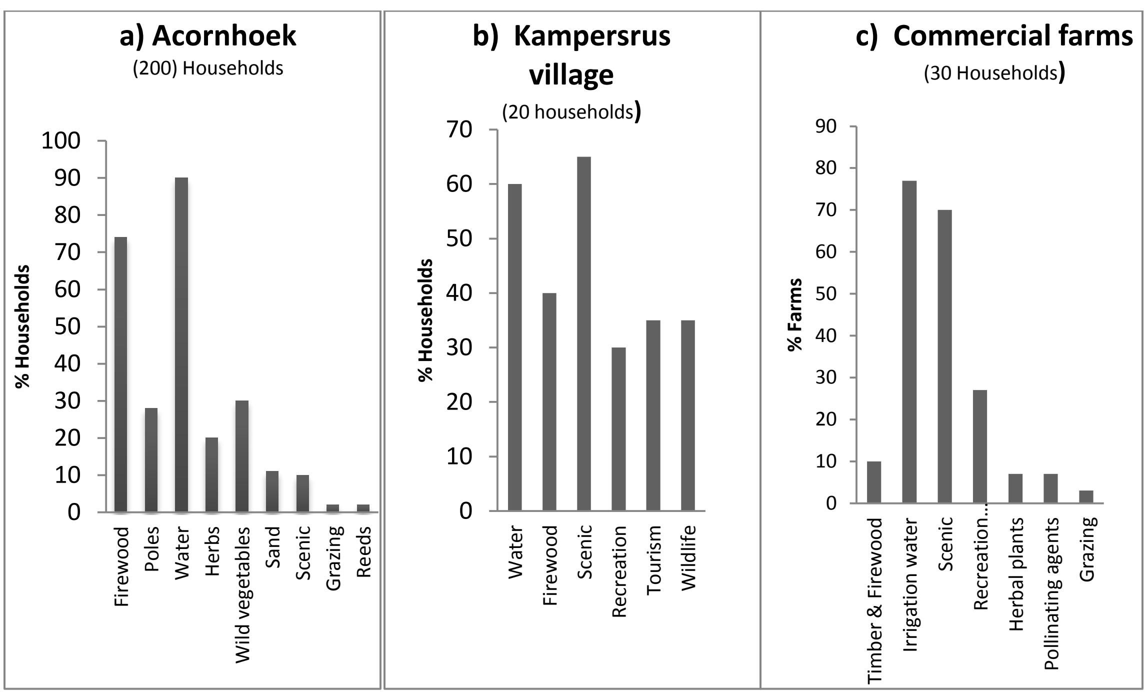

Figure 2-2: Acornhoek, Farm and Kampersrus mountain resource use patterns, reflecting the resources that were mentioned as being very important.

2.4.2 Natural resource use on local farms

Two farms grow maize (sweet and baby corn) and livestock with one farm growing herbs and another specializing in guavas. Commercial farmers use irrigation systems such as micro, drip and pivot irrigation, mostly for citrus trees. Farmers (80% of interviewees) were highly depend on the water from the Blyde River for the adequate growth of their crop and therefore water quantity and quality is of principal concern.

Water was cited by 85% of the commercial farmers as the most important resource because of irrigation needs (Figure 2-3a). The Mariepskop Mountain's scenic beauty was mentioned by 80% of the farmers, which suggests it is valued as an essential aesthetic resource. The mountain is also an important source of recreation and tourism (30%) and, although less importantly, timber (10%). The mountain's function in the regulation of climate and providing pollinating agents was mentioned by 10% of the farmers.

2.4.3 Natural resource use by Kampersrus residents

Kampersrus residents rely on the mountain for water and scenic beauty (Figure 2-3b), with most residents citing the mountain as the reason for settling there. The aesthetic beauty (65%) of the mountain was cited the most, followed by water (60%) then firewood (40%). The mountain also acts as an important source of recreation for the residents by providing picnic spots, hiking and birding activities which attract tourists and boosts businesses in the village's restaurants and lodges. Furthermore, the mountain has historical importance to the people of Kampersrus who settled decades ago.

2.4.4 The effects of socio-economic categories in Acornhoek

The socio-economic characteristics that had a significant effect on resource use patterns in Acornhoek were age, household size, distance and income.

Effect of age: The highest number of household heads was between 40 to 49 years. Older people (60-99) are more dependent on natural resources from the mountain

(Figure 2-3a), particularly herbs and wild edible plants in comparison to the other two groups. Age had a significant negative effect on the use of tank water and a significant positive effect on grazing on the Mariepskop Mountain (Table 2-1) because the older people are the ones that own the most livestock. Households with younger household heads (20-39) use wild herbs and grazing the least in comparison to the older groups (Figure 2-3a).

Effect of household size: Household size had a mode of 5-7 people when using categories of 1 - 4, 5 - 7 and 8 - 17 (Figure 2-3b). There is a significant positive relationship between the size of the household and the use of herbs and firewood (Table 2-1).

Table 2-1: Results from generalised linear models and coefficients indicating the socio-economic and geographic factors that affect use of water and other natural resources by Acornhoek community. Significant values marked with an asterisk.

Resource	**Age**	**Household size**	**Gender**	**Income**	**Income per capita**	**Distance from mountain**
Water	0.643	0.385	0.275	- 0.0056**	0.62	0.909
River	0.337	0.963	0.706	0.879	0.838	- 0.0025**
Tank	- 0.024*	0.071	0.576	0.788	0.318	- 0.028*
Piped	0.501	0.587	0.697	0.589	0.589	0.062
Borehole	0.719	0.939	0.829	0.036*	0.842	0.743
Spring	0.068	0.954	0.136	0.191	0.563	0.40
Firewood	0.582	0.843	0.245	0.818	0.085	- 0.0001***
With vehicle	0.807	0.0076**	0.207	0.677	0.801	- 0.013*
Without vehicle	0.703	0.652	0.838	- 0.024*	0.777	0.882
Poles	0.628	0.150	0.464	0.524	0.72	- 0.0038**
Herbs	0.412	0.041*	0.726	0.076	0.201	0.610
Wild vegetables	0.632	0.807	0.493	0.461	0.083	- 0.0021**
Sand	0.719	0.948	0.551	0.189	0.972	0.408
Scenic beauty	0.503	0.754	0.229	0.084	0.26	0.135
Grazing	0.0198*	0.736	0.999	0.691	0.645	- 0.0061**
Reeds	0.098	0.593	0.236	0.013*	0.069	0.065

Effect of distance from the mountain: Distance had a highly significant negative effect on the use of firewood, poles, wild vegetables and grazing (Table 2-1, Figure 2-3c). In addition, there was a highly significant negative relationship between distance and the use of the river as a water source (Table 2-1). Distance has a more pervasive effect on the use of more of the natural resources than any of the other independent variables (Table 2-1).

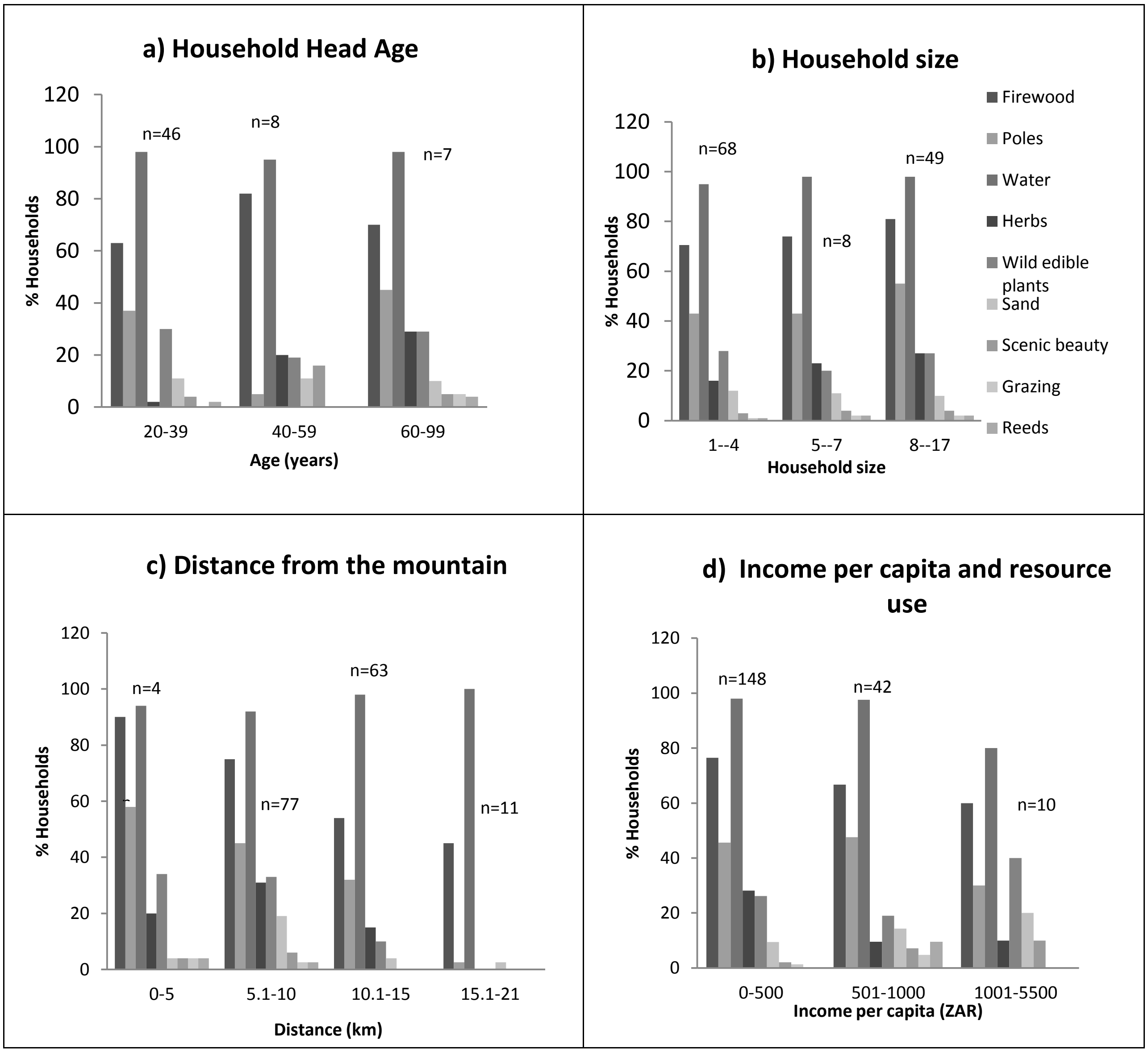

Figure 2-3: Factors affecting resource use by the Acornhoek community: a) Age of household head, b) Household size, c) Distance from mountain (km), d) Monthly income per capita (ZAR)

Effect of income and income per capita: The distribution of income reflects that 64% of households in Acornhoek earned ZAR 2 000 or less per month. This total income includes grants, pensions, remittances and earnings from wages and self employment. Households earning less than ZAR 1 000 were the most dependent on natural resources from the mountain. There was a significant positive relationship between total income and the use of reeds from the mountain, borehole water, grazing and the appreciation of scenic beauty (Table 2-1).

Higher income households use reeds more than the other lower income groups, products from reeds could be the source of income and the preferred resource for ornament making. Households with the least income per capita of less than ZAR 500 use the most herbs and households with the highest income per capita ZAR 1 001-ZAR 5 500 use wild vegetables the most (40%) (Figure 2-3d).

2.4.5 The natural resources used in Acornhoek:

Water. The Acornhoek community uses five sources of water which include river (18% of households), tank (8%), borehole (20%), piped (31%) and spring (23%). Households made use of more than one water source, depending on water availability. They use untreated water from tanks filled from community reservoirs such as the Acornhoek Dam. Size of the household and gender of the household head had no significant effect on the water source used (Wald z<0.9). Distance from the mountain had a significant negative effect on the direct use of rivers or springs as a water source by households in Acornhoek (Table 2-1) and on the use of tanks as a water source (Table 2-1). Also, there is a significant positive relationship between the total income of a household and the use of boreholes as a water source, with more affluent households at Acornhoek being able to afford this (Table 2-1).

Firewood. The Acornhoek community uses firewood as a primary energy source especially for cooking and heating while electricity is used largely for lighting and electrical appliances such as radio or television. Collection of firewood from the mountain is done mainly using a vehicle (70% of households) and by head-load or wheelbarrow (20%). The remaining 10% of the households use mainly electricity and paraffin to meet their energy requirements. The number of times firewood is collected by household per month using head-load or wheelbarrow declines at a distance further than 15 km from the mountain (Figure 2-3c). There is significant inverse relationship between the number of times firewood is collected by head-load or wheelbarrow, that is, without a vehicle, and the total income earned by a household (Table 2-1). Age, size of household and gender had no significant effect on the collection of firewood without a vehicle from the mountain (Wald $z<0.45$).

However, there is a 3 way statistical interaction between age, distance, and total income on the number of times firewood is collected without using a vehicle (Wald $z=2.32$, $p=0.022$). Age, distance and total income do not act independently with prior emphasis on a two-way interaction between distance and income. Age and distance correlate inversely with total income. As distance, age and total income increase they interact to reduce the number of times firewood is collected by head-load or wheelbarrow.

Firewood collection by use of a vehicle is done at least once a month by 31% households in Acornhoek. There is a significant negative relationship between distance from the mountain and number of firewood collection using a vehicle (Table 2-1). In addition, there is a significant positive relationship between the size of a household and the number of firewood collections using a vehicle (Table 2-1). Total income, age and gender had no significant effect on the number of times firewood is collected using vehicle by households, from the mountain (Wald $z<1.3$).

Grazing. Cattle, owned by 10% of households in Acornhoek, graze on the mountain and are a reflection of wealth. There is a significant negative relationship between the use of grazing as a natural resource and distance from the mountain (Wald $z=-2.770$, $p=0.0061$). There is also a positive significant relationship between grazing and age of household (Wald $z=2.348$, $p=0.0198$) since older people own most of the cattle.

Herbs. Herbs are widely used by rural households in traditional ceremonies and for medicinal purposes. There is a significant positive relationship between size of the household and the use of herbs (Wald z=2.058, p=0.041).

Wild vegetables. Wild vegetables are collected to supplement food and for traditional purposes. Households close to the mountain make more use of wild vegetables (Wald z=-3.118, p=0.002).

Reeds. Reeds are collected from river banks for making mats, brooms and traditional ornaments. Wealthier families tend to use more reeds from the mountain than the poorer families (Wald z=2.462, p=0.013).

Sand and Scenic beauty. Sand from the mountain is mostly used for making bricks and building houses and the scenic beauty is the appreciation of the beauty of Mariepskop Mountain. Age, household size, gender, income and distance all had no effect on sand collection and use, and on scenic beauty. Cultural practices such as initiation schools for boys as they get into adulthood are held on the mountain by the Acornhoek community whilst other people go to the mountain for spiritual worship and upliftment.

2.4.6 Comparison of Acornhoek community with rural areas close to the KNP

Water: The people of Acornhoek have a distinct advantage in terms of the ecosystems services available in comparison to the communities living closer to the KNP. Rainfall is roughly halved from the western edge of Acornhoek at the foot of Mariepskop (around 800 mm/y) eastwards towards the KNP (around 400 mm/y; Shackleton *et al*. 1998). As rainfall decreases, the amount of surface water, fuel wood and supplementary wild foods available to households decrease (Banks *et al*. 1996, Shackleton *et al*. 1998). Pollard and du Toit (2011) found that catchments to the western boundary of the KNP experience high water stresses with annual rainfall of less than 450 mm. Acornhoek residents have a wider selection of water sources that include rivers, springs, boreholes and piped water from dams and tanks (Table 2-1). In contrast, the main water sources at Welverdiend near the KNP boundary, suffering from acute water shortages, are boreholes, communal standpipes and seasonal rivers. During droughts boreholes sustain the community as underground water is pumped to a reservoir and is marred by decreased water quality (Water dialogues 2009). This village is characterized by long queues at communal taps, people walking long distances to standpipes and sometimes residents having to hire cars to collect water from other villages.

Firewood: Households at Welverdiend have also been experiencing fuel wood scarcity for the past two decades, forcing them to invest more resources (time and cost) in securing fuel wood or seek alternative sources of energy (Banks *et al.* 1996; Matsika, Erasmus, and Twine 2012). On the other hand, fuel wood is readily and directly obtained by the vast majority of Acornhoek households (Figure 2-2a). The prevalence in the use of firewood in Acornhoek villages close to the mountain is 75% and the households in the villages close to the KNP were all using firewood from the 1970s to the 1990s largely due to limited access to electricity (Giannecchini, Twine, and Vogel. 2007). The villages close to the KNP show high firewood use with 60 to 75% of households of Athol and Welverdiend using a mix of electricity and firewood (Matsika, Erasmus, and Twine 2012) and 90% of the villages using firewood in the study by Dovie, Shackleton and Witwoski (2002).

Primary productivity: The western boundary of the KNP has a geology characterized by granite and gneiss with local gabbro intrusions (Venter, Scholes, and Eckhardt 2003). The biomass woody cover of rangelands and fields over granite substrates is less than 10% because granitic landscapes have nutrient-poor soils comprising moderate to shallow sands (Wessels *et al*. 2010). In contrast, the bottom lands of the Mariepskop have deeper duplex fertile and apedal soils (Twine *et al*. 2003; Shackleton *et al*. 1998). The Western boundary of the Kruger National Park (KNP) is characterized by high livestock numbers, overgrazing, soil erosion, excessive wood harvesting and low productivity (Twine *et al*. 2003).

Wild herbs and food: Shackleton *et al.* (1998) found that, the numbers of wild herbs used by villages in Bushbuckridge in the higher precipitation areas (next to the mountains) were 38 to 44 species which decreased to 25 to 35 species in the two drier villages proximate to the KNP. They also found that 83% of the households in the driest villages dried and stored these wild herbs for use in the drier months compared to the 57% in the villages with more rain (Shackleton *et al*. 1998). Villages in higher rainfall areas have more choices in deciding which of the wild herbs to harvest to supplement diets than villages in lower rainfall areas. Communities in areas of lower rainfall felt they could collect the most common edible plants near their homes and that commercialization of these edible plants was done to supplement household incomes (Shackleton *et al*. 1998). In contrast, the households in Acornhoek use edible plants mainly to supplement diet for better nutrition (Table 2-2 and 2-3).

Table 2-2: Ecosystem services across communities surrounding the Mariepskop Mountain and communities further away, near the KNP, according to the present study and previous studies in Bushbuckridge. Ecosystem services marked with asterisks (*) are considered important by the different communities

Acornhoek		Commercial farmers		Kampersrus		Proximate to the KNP	
***Water**– Potable water directly from rivers and springs	90 % of households use water from the mountain for domestic purposes.	***Water** Irrigation water	80% of the farmers use water from the Blyde and Klaserie Rivers for irrigation. Farm households use borehole for domestic use.	***Water** – Potable water from Mariepskop for domestic use	60% of the residents at Kampesrus identified the mountain as important for providing water	**Energy** – Firewood for cooking and heating obtained from mountain	Poor households sometimes collect firewood and water in the forest next to the mountain, a long distance away, instead of purchasing the resources (Hunter, Twine, and Johnson 2011). Wood supply increases as distance from the villages increases (Banks *et al*. 1996) Areas more than 1200 m from settlements had double the biomass of the conservation areas (Wessels *et al*. 2013)
***Energy** - Firewood for cooking and heating purposes	75% of the households in Acornhoek use firewood collected from Mariepskop for cooking and heating, Households use 3-4 tonnes of fuelwood per annum (Madubansi and Shackleton, 2007)	***Pollination** – pollination of citrus fruit trees by pollinators such as bees and flies	10% of the farmers stressed the importance of pollinating agents	***Energy** – Used for recreation	Firewood for recreational barbeques	**Water** – Potable water for the poor households.	Villages experience less rainfall, which may lead to increased crop failure (Shackleton *et al*. 1998)
***Shelter** – Building materials: sand and poles	28% of households collecting poles and 11% of households collecting sand for construction from the mountain.	***Aesthetic** – Visual beauty of the mountain	70% of the farmers regarded the aesthetic beauty of the mountain as important	***Aesthetic** – The beauty of the mountain	65% of residents thought the beauty of Mariepskop was very important	**Nutrition** – Wild edible plants (fruit, vegetables & herbs) to supplement income	A wider variety of wild edible plants is collected in villages with higher Mean Annual Rainfall (MAR) than in villages with lower MAR (Shackleton *et al*. 1998)
***Nutrition** – Wild edible fruits and	25% of households collects wild edible plants from the	***Recreational and tourism** – A place where	27% of the farmers identified the	***Recreational** Recreation, hikes,	35% of residents believe the mountain is		

herbs	mountain	people go for picnic, bird watching and other recreational activities	mountain for their recreational needs and for tourism.	swimming	important for recreation, tourism and wildlife conservation		
***Traditional/ Heritage** – Important cultural customs that all youths have to attend e.g. initiation schools and rituals on the mountain	Residents of Acornhoek feel attached to the mountain because the presence of ancestral graves on it and the history of the area			**Heritage** – Historical importance	Ancestors graves on the mountain		

Table 2-3: Ecosystem services (ESs) derived from the mountain and utilized by different communities around Mariepskop. ESs marked with an asterisk are considered important by the communities themselves. Additional ESs are also used by the communities as observed during this study.

	Acornhoek	Commercial farmers	Kampersrus	Areas in proximity to KNP
Provisioning	*Energy-Firewood *Nutrition-Water, wild edible plants & fruits *Shelter-poles, sand, thatch grass	*Energy –firewood for barbeques *Water-irrigation of citrus trees	*Energy- firewood for recreation *Water-for domestic consumption	Energy Nutrition
Regulating	*Clean water & air & higher rainfall Disease regulation Seed dispersal	*Pest control	Climate-higher rainfall	
Supporting	*Production- Soil formation subsistence farming Nutrient cycling	*Pollination-pollinating birds & insects Soil formation-deeper, fertile soils *Production Nutrient cycling		
Cultural	*Heritage-historical site, ancestors graves landmark Traditional-ceremonies *Spiritual	*Aesthetic *Heritage-historical site Recreational-hiking, swimming Spiritual	*Aesthetic *Heritage-historical site, ancestors graves *Recreational-hiking, birding, swimming *Tourism Educational Spiritual	Heritage-historical site

2.4.7 Acornhoek community perceptions on sustainable mountain ecosystem services

In the Acornhoek community, there was a clear understanding of the importance of the mountain as a source of firewood, poles and as a historical landmark especially with the older generation, evident from the diagrams drawn by the different groups in the focus group meetings. All of the diagrams depict the forest being an important source of natural resources particularly firewood. In all three meetings, water sources appear on diagrams drawn by the community in the form of rivers, tanks, taps and boreholes reflecting the importance of water.

Weakness in governance. The Acornhoek community strongly felt that the derelict pine and eucalyptus plantations should be re-opened to provide much needed employment and that such a step would decrease the dependence of households on the natural resources and the corresponding ecosystem services. This feeling is accompanied by some resentment that they have not been consulted about the land use change on the mountain and that the natural resources governance needs improvement.

Pollution and social responsibility is seen as someone else's problem. Two focus groups had concerns about refuse collection and access to potable water sources. In addition, these cited that lack of tertiary education and employment opportunities force the youth to seek livelihoods which may be unsustainable to the environment such as poaching, selling firewood and sand. Households were reluctant to use the untreated river water for domestic purposes due to high levels of pollution which was blamed on women directly disposing used diapers in the water system. Importantly, there is little sense of ownership towards the environment and its general health, for example, household response to the question of who should take responsibility for the well-being of the mountain was the government and local leadership (80%). When asked what improvements they would like to see on the mountain 56% replied that they wanted better access to the mountain and its resources while 24% said they had no knowledge of what was happening there and 20% answered that since the mountain still provided firewood there was no need for any management or improvements.

One of the three meetings noted a decrease in the availability of natural resources such as firewood, wild edible plants from the mountain over the last decade in comparison to 30 years ago. In one meeting some of the older participants expressed the hope of returning to live on the mountain, the reason for relocating being to be close to the ancestors buried there and having better access to natural resources.

2.4.8 Perceptions of commercial farmers and Kampersrus communities

Commercial farmers had strong concerns on environmental changes which could alter the mountain ecosystems and impact negatively on ecosystem services including birds and insects which play a vital role in pollination of their fruit trees.
Upstream illegal settlements and their associated activities were feared to potentially compromise water quality of the water downstream of the Blyde River. The farmers advocated that the mountain becomes a conservation area to protect wildlife from extinction and maintain its aesthetic beauty and that forestry activities be resumed in order to provide much need employment.

The creation of employment for local communities in tree plantations was identified in order to reduce the dependence of poor communities on mountain resources. The current harvesting and use of the mountain natural resources was identified as unsustainable due to the rampant cutting down of trees for fuel wood. Also, if the unsustainable use of the natural resources continues, this may eventually lead to resource shortages not only for the Acornhoek community but for the commercial farmers as well. The Kampersrus community views the mountain in a conservationist manner preferring that it should be turned into a protected area where resource harvesting is strictly monitored to promote sustainable use.

2.4.9 Mariepskop ecosystem goods and services monetary evaluation

The total annual estimated use of wild edible plants of 68.9 kg/household was derived from a study by Twine *et al.* (2003) and the replacement cost calculated by using household monthly vegetable cost estimates of ZAR 197.72 from the National Agricultural Marketing Council (NAMC 2015) of South Africa. The annual estimated quantity of wild bushmeat used per household is 2.9 kg (Twine *et al.* 2003) and the replacement cost was calculated at a mean retail cost estimate of ZAR 50/kg for Acornhoek households. Mean water use for Acornhoek households was estimated at 70 litres per day from the household survey and this figure was then multiplied by 365 days to get 25 550 litres (25.5 kl) per annum for each household. The cost of municipal water per kilolitre (ZAR 12.52/kl) was subsequently used to estimate the replacement cost of water. The mean estimated number of wooden poles used by a household per year was 8.5 for fencing poles and 0.4 for housing poles both calculated at 5% replacement rate (Twine *et al.* 2003) and the replacement cost calculated by the retail cost of 3m building poles at ZAR 220 each.

The practice of replacing natural goods with purchased items is significant for Acornhoek households and this reflects the substantial value of the natural goods sourced from the mountain economy (Table 2-4). The replacement cost for 10 000 Acornhoek households was ZAR 99 million for firewood, ZAR 23.7 million for wild edible plants and ZAR 3.2 million for water (Table 2-4).

Table 2-4: Results of the estimated replacement value of selected Mariepskop ecosystem essential and optional goods and services by Acornhoek households

Ecosystem good or service	Mean household resource use annually	Replacement value per household/ annum (ZAR)	Replacement rent/ value for 10 000 households annually (ZAR millions)	Sustainability of natural ecosystems
Essential goods				
Firewood	4 tonnes Estimation from household sample survey assuming 1 truck load carries 1 tonne at a mean of 4 times per year	9 900 (Equivalent to the cost of purchasing electricity or using a mean of 550 kwh monthly household consumption at R1.50/kwh)	99	An ecosystem can be considered sustainable if demand for a good is less than supply. The replacement cost is very high per household for Acornhoek due to the high demand for energy. Mariepskop is currently able to supply household firewood. Commercialisation of firewood (supply to a greater number of households) could lead to unsustainable extraction.
Wild edible plants	68.9 kg* Estimated by Twine *et al* 2003	2372 (Equivalent to the retail cost of vegetables at R197.72/ month estimated from data from Stats SA)	23.7	The annual estimated demand for wild edible plants and their value is less than that of firewood. This situation appears sustainable given the faster rejuvenation rates of wild edible plants
Bush meat	2.9 kg** (Estimated by Twine *et al* 2003)	145 Retail cost of R50 kg of meat	1.5	Bush meat refers to various sources of protein obtained from the mountain. The annual estimated quantity of bush meat use is low and not every household goes hunting making its use sustainable.
Water	25 550l*** (25.5 kl) (Estimated from Acornhoek household survey of mean 70l per household per day multiplied by the 365 days in a year)	319.26 Cost of municipal water at R12.52/ kl	3.2	Water is a valuable household resource and in drought free years use of springs, rivers and pipes is sustainable. Less water is available during droughts which may lead to higher replacement costs for households as they have to buy water. Adequate potable water provision is one of the priority issues of Bushbuckridge municipality.
Non-essential goods				
Poles	8.9	1958	19.6	Use of poles per household appears sustainable. The commercialisation of the

	(Mean estimated number of poles used by a household per year (Twine *et al*, 2003)	(Retail cost of R220 for 3m lenth building poles		poles harvesting could become unsustainable with a potential shortage of supply exposing households to a very high replacement cost. The Bushbuckridge municipality has goals to provide housing for its residents which will reduce the demand of poles for housing.
Total			175.8	The total monetary valuation of Mariepskop goods is substantial to the local community. Use of goods from the mountain area appears sustainable at this point, but increased pressure as Mariepskop expands could put increased pressure on natural resources

*68.9 kg per year from household estimates by Twine *et al* 2003
**2.9 kg per year from household estimates by Twine *et al* 2003
*** 25 550 l derived from 70l water per household/day x 365 days

The total annual resource rent for the farming lands and perennial crops fed by the Blyde River was around ZAR 278.5 million (Table 2-5). The calculations for the resource rent for commercial citrus and mango crops (Table 2-5) include the local production costs (labour and other inputs) and exclude the export and marketing costs**.**

Table 2-5: Resource rent values of the Blyde River ecosystem services for the commercial farmers near the Mariepskop.

Commercial cash crop	***Intermediate Costs (ZAR millions)**	**Labour Costs (ZAR millions)**	**Fixed costs (ZAR millions)**	**Total Farm Expenditure ZAR (All farms) (millions)**	**Hectares (ha) under crop**	**Gross income (ZAR millions)**	**Total Resource rent (ZAR millions)**
Citrus	97.9	22.1	6.5	126.5	3700	283.7	157.2
Mangoes	75.6	17.1	5	97.7	3500	219	121. 3
Total	173.4	39.2	11.6	224.2	8200	502.7	278.5

Methodology: Oosthuizen 2014. Modelling the financial vulnerability of farming systems to climate in selected case study areas in South Africa and own calculations. *Intermediate costs are operating expenses.

The Blyde River irrigation scheme is located in the Lower Olifants water management area, which has a total estimated economic value of ZAR 411.2 (DWA 2011). Therefore, the scheme makes up 45.2 % of the sub-catchment's total economy.

2.5 Discussion

2.5.1 Households closer to Mariepskop have better access to mountain ecosystem services

Water: Water from the mountain is a natural resource that is very important up to at least 20 km from the mountain. Household uses of water comprise food, sanitation and watering small gardens. The household dependence on water from the mountain remains high at between 90-98% over these distances (Figure 2-3c).

There is a decreasing rainfall gradient from approximately 1200 mm from the Drankensberg Mountains in the west decreasing in the eastern direction to 450 mm towards the KNP boundary (Wessels *et al*. 2013; Banks *et al*. 1996). This moisture gradient strongly affects the methods of obtaining water. Close to the mountain, river, spring and untreated tanked water is available (Table 2-1). Further from the mountain many Acornhoek villagers use piped water, provided by the local municipality and obtained from the Acornhoek Dam. Due to increasing distances from the mountain some wealthier households in Acornhoek have sunk boreholes to have improved access to water (Table 2-1). Villages adjacent to the KNP experience less rainfall and therefore reduced access to water (Wessels *et al*. 2013) households there mostly depend on underground water sources such as community boreholes (Water dialogues 2009).

Firewood: The use of firewood from the mountain decreased from about 90% of households to around 50% at 20 km from the mountain. Firewood is used mainly for cooking and heating in Acornhoek (Table 2-2). The 20% of households that collect firewood using head-load or wheelbarrow either live within 5 km from the mountain or earn a low total household income. Giannecchini, Twine, and Vogel (2007) and Twine (2005) found that households were not prepared to walk much further than 1 km to collect firewood, which has led to the use of vehicles for wood collection or purchasing wood from commercial vendors. Other Acornhoek households (70%) use vehicles to collect wood because of the distance and the convenience of using a vehicle. Therefore, distance to the woody resource is an important determinant of its utilisation. However, Wessels *et al.* (2013) found that, in Bushbuckridge, woody biomass was low close to settlements and distances for collecting wood increased from 100 m in the 1980s to 1000 m in the 1990s due to consumption of all the nearby wood supplies. Non-sustainable harvesting may therefore change the spatial patterns of wood collection at Mariepskop. Villages next to the KNP boundary collecting wood on foot have to walk very long distances because of the increasing biomass gradient as distance increases from settlements (Wessels *et al*. 2013). This led to many households relying on purchasing fuel wood from vendors in the area. Although the importance of wood declined further from Mariepskop (Figure 2-3c) and as households found other sources of wood or energy, it remains a vital resource.

Other resources: A marked distance-to-resource trend existed with respect to the use of wood for construction (Figure 2-3c). The use of poles by Acornhoek households is at 58% of households within the first five km and this percentage decreases to 32 % between 10-15 km and further to less than 5% after 15 km (Figure 2-3c). Poles are used by the community for building houses, fencing homes and kraals. The use of herbs from the mountain is highest within the first 10 km (30% of households), decreasing to 15% between 10-15 km after which no collection of herbs from the mountain was recorded. Wild vegetables collected by households remain between 30 and 35 % within 10 km from the mountain and then drops to 10% and less as distance increases (Figure 2-3c). The collection and use of wild edible plants (30%) and herbs (20%) of the households was found to be markedly less than the figures from the study by Twine (2003). The study found high values of wild herbs (97%), fruits (95%) and medicinal plants (52%) used by rural Limpopo villages (Twine 2003). The lower values from this study could be a result of respondents only mentioning wild edible plants as a natural resource they obtain specifically from the mountain and not necessarily at the bottom lands.Higher rainfall areas have a higher density and variety of indigenous wild edible plants and herbs that supplement household diets than lower rainfall areas (Shackleton *et al.* 1998). Acornhoek households nearest to the mountain allow their cattle to graze on the mountain. The use of sand is mainly for building houses and making bricks and less than 20% of households use sand regardless of the distance from the mountain.

Scenic beauty and reed use was relatively low at 5% or less in Acornhoek regardless of household distance from the mountain. Overall, this indicates that households close to the mountain had much better access to natural resources than those far away.

Ecosystem services: The ecosystem services available to households closer to the mountain is higher and more diverse than those that live further away from it, that is, ecosystem services decrease with increasing distance from the mountain (Table 2-2, Figure

2-3c). This is evident in several ways. a) In terms of food provision, households close to the mountain have better access to water, edible plants, and grazing for cattle. Wild edible plants are especially important to the poor (Table 2-1) who use it as a safety net (Twine and Hunter 2011). b) For energy and heating, households close to the mountain can easily obtain wood which is readily available and affordable. In most households electricity is used for lighting. c) In terms of products for medicinal use and sanitation, households close to the mountain have higher access to surface water and herbs used for medicinal and healing purposes as they do not have to walk long distance to collect these. d) In terms of cultural services households close to the mountain are proximate to their ancestors' graves, can hold traditional ceremonies and be close to their grazing cattle which are a sign of wealth and security.

The three communities we studied at Mariepskop have the higher access to the mountain's provisioning, regulating, supporting and cultural ecosystem services, compared to communities 50 km away adjacent to the KNP. Under provisioning services the common ecosystem services for Acornhoek, Kampersrus and the commercial farmers are energy and water, though for different purposes (Table 2-3). Firewood provides energy used for cooking and heating in Acornhoek, whilst it is used for recreational barbeques by the Kampersrus residents and farmers.

Acornhoek residents obtain basic livelihood ecosystem services from Mariepskop such as wild edible plants for nutrition, poles and sand for the provision of shelter. On the other hand, it is difficult for the communities near KNP to access the ecosystem services close to the mountain largely because of the distance from the mountain.

2.5.2 Ecosystem services differ widely among the cultural groups at Mariepskop

Residents of Acornhoek and Kampersrus, as well as commercial and game farmers obtain widely different benefits from the Mariepskop Mountain due to differences in socio-economic circumstances and sources of livelihood. Acornhoek households use surface water from the mountain (rivers and springs) for basic domestic uses (food and sanitation). The Kampersrus residents also use the water from the mountain also for household purposes but largely make use of boreholes. Commercial farmers use the surface water primarily for crop irrigation whilst the game farmers use water mainly for watering their game animals and surface water is not used for household purposes. Water is of great importance to all groups, although for different purposes (Table 2-2).

Acornhoek households use firewood from the mountain to obtain energy for cooking and heating because of a lack of easily-obtainable and affordable energy alternatives. The commercial and game farmers together with Kampersrus residents on the other hand, use firewood for recreational barbeques as they use electricity for their basic energy requirements. Poles and sand are used by the people in Acornhoek in the construction and fencing of homesteads while these ecosystem services are not important for the other two communities.

Wild edible and medicinal plants from the mountain provide a source of medicine for different ailments in Acornhoek. These wild edible plants supplement diets especially for the Acornhoek households so that the available income can then be used for other household essentials. The Kampersrus residents and farmers may use herbs for adding flavours to food and ornamental purposes (Table 2-2).

Scenic or aesthetic beauty of the mountain is very important to the residents of Kampersrus, the commercial and game farmers for their well-being. The mountain also acts as a tourist attraction resulting in income to game farmers. Being able to visualize the landmark with all its biodiversity was appreciated by these groups (Tables 2-2 and 2-3). The Acornhoek households did not mention aesthetic beauty as an important aspect of their daily living but emphasised the cultural value of the mountain. The cultural significance of the mountain to the people of Acornhoek is particularly imbedded in the preservation of traditional practices such as initiation schools for the youth on the Mariepskop. Cultural ecosystem services provided by the mountain such as aesthetic beauty, historical and traditional significance and also as a source of recreation are essential services binding communities together and increasing well-being.

2.5.3 The mountain is important to the poor

Poorer households in Acornhoek are more dependent on the natural resources and their accompanying ecosystem services. Twine and Hunter (2011) found that natural resources serve as a safety net to rural households during times of disturbances or shocks such as droughts, floods and illness or death of a wage earner. Shackleton *et al.* (1998) found that in uncertain environments households adopt coping strategies to stretch available natural resources to supplement diet and income.

Natural resources from the mountain provide an affordable source of energy (firewood), shelter (poles) and water. These three resources are essential to most of the Acornhoek households regardless of how much their monthly income is (Figure 2-3d).

Herbs and wild edible plants supplement diets and provide sources of livelihood for the Acornhoek community. Some 35 – 40% of those households earning below ZAR 1000 a month make use of wild herbs and foods, compared to 20 – 25% in the higher income earners (ZAR 1000 – 11 000).

Age affects the use of natural resources, that is, 60-99 age group show higher use of resources such as herbs and wild edible plants (Figure 2-3a). The older people are no longer economically active and are in most instances dependent on government grants and therefore rely on wild edible plants to supplement their diets. However, the older generation also have much more knowledge on the benefits of using herbs and eating wild edible plants.

The largest households (8-17) in Acornhoek show a trend of higher usage of herbs and wild edible plants and this correlates with low income groups (ZAR 0-1000) who also use more of these resources. This however is not necessarily an indication that bigger families earned less monthly income but rather that they require more food as there are more people in the household to feed. This may be a result of households caring for extended family who cannot contribute to monthly income and thus have to increase reliance on herbs for treating ailments and wild edible plants for supplementing diet. The strongest effect of the mountain for poor households therefore relates to the food and medicinal use that they obtain from mountain resources.

2.5.4 The use of mountain ecosystem goods and services as replacements

Some Acornhoek household expenses can be reduced by use of replacement goods collected from the mountain (firewood, wild edible plants, bushmeat), while other important household requirements (school fees, transport, funeral costs) must be paid for in cash. Poor households often substitute cash items with 'free' natural resources to liberate some funds and pay for non-substitutable items. The results of replacement cost (Table 2-4) show that the Acornhoek community, given their socio-economic status, would not be able to survive if they were to purchase all the benefits they obtain from the Mariepskop Mountain as their household incomes are inadequate. These coping strategies may be short or long-term depending on the household financial situation (Twine and Hunter 2011).

2.5.5 Monetary valuation of ecosystem services

Ecosystem valuation is important since it is fundamentally concerned with the supply and demand of mountain goods and services which supply and satisfy physical and non-physical needs of people in this case, the various Mariepskop Mountain communities. The measurement of worth of an ecosystem is relative to the people who have access and make use of its resources (Komakech 2013; Mugombeyi *et al* 2015) and also the ability of the mountain ecosystem to maintain this flow.

In general, the ecosystem goods and services valuation process is rather complex due to the nature of ecosystem services and may not be very precise or accurate (Schägner *et al.* 2013; Sumarga *et al.* 2015) since it is based on approximations and user opinions. However, even a basic monetary valuation should capture the attention of decision makers, who may originally have seen areas as unimportant, yet also, highlights vulnerability in the over exploitation of a "mountain economy" and resource use. The value of Mariepskop's goods and services was found to be worth hundreds of millions ZAR (Table 2-4 and 2-5). This corresponds with the study by Remme *et al* (2015) where valuation of cropland was found to be the highest in worth in comparison to other ecosystem services. This large cash value simultaneously indicates good ecosystem health in that the mountain is currently able to supply these benefits.

2.6 Conclusion

We explored basic interactions of the different communities with the mountain resource base and the corresponding ecosystem services. The Mariepskop comprises a critical source of wide ranging natural resources and associated ecosystem services for communities as far as 20 km away. The household and farm surveys illustrated a strong relationship linking the poorer households, commercial farmers and Kampersrus community with the Mariepskop Mountain, albeit for different reasons. These groups collect significant amounts of provisioning ecosystem services from the mountain. Cultural ecosystem services such as aesthetic quality and tourism are valued by stakeholders and this also differed among communities. The Mariepskop Mountain is critical for ecosystem services to all the communities around it. These communities depend on it for the continued flow of ecosystem services in the future. This has a greater chance of happening if the mountain's ecosystem is managed for sustainable utilisation of natural resources.

Unsustainable harvesting of resources particularly deforestation from the mountain will lead to the deterioration of the mountain ecosystems hence compromising the quality and flow of ecosystem services. Deforestation coupled with the mountain steep slopes can markedly increase the rate of soil erosion down the mountain washing away the nutrient rich topsoil, hence reducing the quality of soil. The likelihood that natural resources harvesting from the mountain will increase in the future is high considering the growing population in Acornhoek. Therefore, decision-makers from the local municipality, traditional leaders with the participation of the ordinary community need to regulate the exploitation of natural resources, making it more sustainable.

Given the above importance of the ecosystem services derived from these mountains, the management and governance of these mountains and their resources are critical. However, governance, management and planning to encourage sustainable ecosystem services are not well developed. The conversion of the mountain into a protected area can generate some employment, but experience in the closely-situated Kruger National Park showed that the conservation areas do not provide large scale employment for local communities (Sungrue 2005). The closure of the forestry activities caused many people to lose employment and, consequently, their livelihood. The consequent reduction in income increased the dependency of the Acornhoek community on the mountain resources. The reopening of the plantations and the saw mill will provide employment among the large proportion of unemployed, a sentiment echoed by both the Acornhoek community and the commercial farmers, the motivation being that more economically empowered people are more resilient and less directly dependent on the ecosystem services from the mountain. Governance mechanisms that encourage socio-economic improvement and which promote water quality and sustainable fuel wood harvesting appear to be critical for sustainable ecosystem services at Mariepskop.

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3

The utility of international sustainability indicators in assessing local-scale sustainable development in a mountain rural community in Mpumalanga, South Africa.

Abstract

The applicability of international United Nations (UN) MDG indicators (2000 - 2015) and UN SDG sustainability goals and targets (2016 – 2030) was tested for relevance at a local village level at Acornhoek settlement and its nearby mountain, Mariepskop, in Mpumalanga province, South Africa. A set of 20 UN sustainability indicators were selected and assessed for their ease of application in the Mariepskop-Acornhoek local area. Access to and availability of data were the determining criteria for applicability. Of the selected set of 20 sustainability indicators, eight were found to be easily applicable at the village level, five were moderately applicable and seven were difficult to apply. A ranking system created to assess Mariepskop-Acornhoek using those international and local sustainability indicators with sufficient data revealed different sustainability rankings ranging from highly sustainable, sustainable, unsustainable to highly unsustainable, with some showing contradictory rankings. To verify sustainability, data from a survey of 200 households carried out in Acornhoek were used to obtain socio-economic characteristics and resource use patterns for the settlement. Census data were used to examine local demographic trends. The sustainability of resource use linkages between Mariepskop Mountain and Acornhoek was assessed for current and future sustainability in relation to population trajectories. Firewood, water and wild edible plants collection by the Acornhoek households was found to be currently sustainable, however, projections based on demographic trends showed that this situation is likely to become unsustainable if the population continues to increase and the rate of resource extraction is scaled up to match the population increases.

Key words: ecosystem goods and services, mountains, sustainability indicators, rural development

3.1 Introduction

Sustainable development has become part of a major international effort to achieve a balanced relationship between social, economic and environmental facets of society. A major challenge in attaining 'sustainable development' is setting goals and then measuring progress at different administrative levels (Rothwell *et al* 2015; Dahl 2012; Lyytimäki *et al* 2011). Sustainability indices for mountain areas are standards for establishing sustainability of natural resource use from mountain systems. Indicators are useful for this purpose as they can simplify complex situations and enhance decision making and planning processes by providing reliable summary information (Mascarenhas *et al* 2013). Indicator science and data analysis to inform development planning has become a very large field of endeavour, but international indicators are not always appropriate at a local level. This is because of spatial differences and different ways of measuring key metrics, for example, the international per capita poverty line of $1.90/day (equivalent to ZAR 855/ month) versus South Africa's poverty line of ZAR 501 per month.

The new international United Nations Sustainable Development Goals (UNSDGs) (UN 2015a) and Targets are expected to be important in stimulating and measuring development through the gathering and use of a wide range of social, economic and environmental data. These data can then be processed to rank the various aspects of development into different levels of sustainability (Munda 2005; Munda and Nardo 2009). The use of ranking to reveal levels of sustainability can be an effective method of comparing different indicator data seeking to achieve the same goal (assess sustainability) through assigning weights and priorities (Mendoza and Prabhu 2000).

The benefits of international programmes like the UN SDG include the capacity building of National Statistical Offices in developing countries, the standardized collection of internationally agreed upon indicator data and the accessibility of this data to researchers to improve planning and development strategies (BOS 2010; OECD 2015). As well as the UN international indicators which track a set of agreed international goals and targets, it is important to use local sustainability indicators to add fine scale texture to development information. This means that, for studying local sustainable development, researchers need to either develop their own indicators or customize international indicators for their own use.

While social and economic data are collected routinely by governments, environmental data collection, including data on the level of degradation, impacts of development and the human causal links have been neglected in the past, with environmental costs generally downplayed (Huxham *et al* 2015). This is because of the complex nature of environmental issues, lack of expertise and the pursuit of increased economic margins. This has changed with the inclusion of selected environmental indicators being included in the UN SDGs.

Lengthy consultation between member states, National Statistical offices and non-governmental role players has led to an integrated set of global priorities for the UN SDG, comprising 17 goals and 164 targets and a set of indicators still to be decided upon. Analysis and understanding of indicator data is done through probing the relationships between different indicators to determine trends in local sustainable development. Importantly, while the MDGs have been criticised for promoting silo thinking, the post-2015 SDG process acknowledges that so many elements of development are interlinked and complex, that ambitious data transdisciplinary data analysis that reveals unexpected trends and understand previously hidden development complexities and relationships are now required (OECD 2015).

The aim of this study is to test whether some of the international indicators could be applied at a local situation, namely to monitor the sustainability of Mariepskop Mountain ecosystems and the way in which the mountain landscape is used by local people in Acornhoek. The key mountain-linked ecosystems in the area are natural and planted woodlands (plantations), natural grasslands and the water catchment function. This study investigates the sustainability of Mariepskop Mountain local resource use through, (i) an assessment of 20 selected international sustainable development indicators (UN MDG and UN SDG) for their ability to capture sustainable development at the local Mariepskop-Acornhoek level, (ii) the consideration of other suitable local sustainability indicators, (iii) comparing and ranking of selected international and local indicatorsusing data from the Mariepskop-Acornheok area and (iv) an assessment of the long-term sustainability of natural resource use at Mariepskop, by analysing current household information on natural resource use.

3.2 Methodology

3.2.1 Study area

Acornhoek is a rural settlement comprised of a number of villages, located on the eastern slopes of the Mariepskop Mountain in the Bushbuckridge municipality of Mpumalanga province, South Africa. With an area of 2500 km^2, Bushbuckridge is a former homeland, with little economic infrastructure and that experienced an influx of Mozambican refugees in the 1980s which increased the human density to the current 104-350 people/km^2 (Madubansi and Shackleton 2007; Ngwato 2011). Bushbuckridge municipality has an unemployment rate of 52.1% and a high dependency ratio of 73.4% (StatsSA 2011). The community of Acornhoek use the Mariepskop Mountain as a source of food, water, energy and raw materials.

The Mariepskop Mountain (24°32'34"S, 30°52'07"E) 1945 metres above sea level (m a.s.l.) is one of the highest peaks on the northern Drakensberg escarpment. The mountain lower slopes at around 760 m a.s.l. are comprised of Western Maputaland Sandy Bushveld and Barberton Serpentine Sourveld vegetation types (Mucina *et al* 2007), changing to mist belt Afromontane forest at an altitude of 1000–1900 m, after which the vegetation becomes fynbos, a shrubland similar to the Cape Floral Kingdom (Capensis) (Mucina and Rutherford 2006; Schijff and Schoonraad 1971).

The Mariepskop commercial plantation was established in the 1960s and *Pinus* and *Eucalyptus* tree species were grown for timber until 2004. The Blyde River flows along the western side of the mountain and is a tertiary catchment of the Lower Olifants catchment supplying irrigation water to surrounding commercial farmers. The Klaserie River also forms part of the Olifants River catchment and originates on the southern side of the mountain and flows through Acornhoek providing households with water. Both the Blyde and the Klaserie Rivers are in very good ecological condition (water quality and aquatic health) (DWA 2009). The Acornhoek dam water is purified to potable levels at a local purification plant for domestic supply to the community. The water provided by the municipal plant is however insufficient to meet the water demands of all Acornhoek residents due to infrastructural limitations, leading to many local households using local unimproved water sources (rivers, springs).

3.2.2 Evaluation of international sustainable development indicators

Twenty international sustainability indicators and/or goals were chosen from the UN MDG indicators and UN SDGs goals and targets. The selected international indicators were reviewed in terms of their relevancy for monitoring sustainable development at Acornhoek. The applicability was assessed in terms of availability and accessibility of locally reliable data and indicators were classified as easy, moderate or difficult to apply. An indicator is considered 'easy' if there is readily available local data that is accessible; a moderately applicable indicator may be relevant but data is not readily available or accessible, possibly resulting from gaps or missing data. Indicators that were difficult to apply were considered as those that did not have readily available local data or access to the data was seriously restricted or the data unreliable.

Of the selected sustainability indicators used in this study, three were economic indicators, ten were social indicators and six were environmental indicators whilst one was a governance indicator.

3.2.3 Local data sources, indicators and information gaps

The indicators to compare with local Mariepskop/Acornhoek indicators were gleaned from UN MDG indicators and UN SDG goals and targets, but based on the social, economic and environmental facets of the area. This study of local indicators makes use of data from Statistics South Africa (StatsSA) census data for the years 2001 and 2011 and data sets from other government departments such as Department of Agriculture, Forestry and Fisheries (DAFF) and the Department of Water and Sanitation (DWS) (Appendix 1). These government departments are responsible for collecting information and monitoring changes in social, economic and environmental features specific to the geographic area.

Also, the study makes use of data from a set of household research surveys. A total of 200 households were sampled in six Acornhoek villages nearest Mariepskop Mountain and interviewed using household questionnaires. Households were selected through a systematic sampling of every tenth house (Shively 2011) from an updated municipality house list. Where the inhabitants of the selected household were absent the next house would be sampled. The socio-economic data from this Acornhoek sample survey were used to assess the impact of income, age, distance from the mountain, gender and household size on Mariepskop Mountain resource use patterns. The mean household size calculated from the sample survey was six persons and this figure was used to estimate the future number of households of Acornhoek from population projections and the future firewood, water and wild edible plants consumption rates.

The Acornhoek census information (StatsSA 2001; 2011) was the major source of demographic data for this study. Due to inconsistencies in local demographic data from the census results, the number of households was assumed to increase at a rate of 1% per year, using this growth rate from an Eskom dwelling count study (Blewett 2016). The 2016 Eskom study used aerial photographic interpretation and manual digitization of high resolution satellite imagery taken annually from 2006 to 2011 to map and classify building structures such as dwellings, hotels, schools and hospitals identified as points. From these images, the points categorised as dwellings were selected for Acornhoek and Mariepskop and a GIS map was developed reflecting the dwelling structures. The increase in number of dwellings per annum is assumed to correlate to the population growth rate of Acornhoek. Acornhoek census data from the 2001 and 2011 was used to compare education levels, access to water and sanitation facilities, key local social indicators used in this study.

For the purpose of this study and using the 2016 Eskom dwelling count survey (Blewett 2016) the projected future number of Acornhoek households was 15 000 for the year 2050 and 20 000 households for the year 2100. The future sustainability projections of Acornhoek were calculated under the assumption that the rate of resource use remained the same and the population continued to increase at a 1% annual growth rate.

3.2.4 Demographic data and natural resource use patterns

Household demographic data from the South African Census of 2001 and 2011 was used to assess the current state of development of Acornhoek. The socio-economic data from the census used in this study was analysed using a generalised linear model (glz) on independent and dependent variables using R version 2.13.0 (R Core Team 2011). The result of the analysis was used to derive resource use patterns for the different Acornhoek households.

3.2.5 Social cohesion and well-being in Acornhoek

The level of social cohesion was assessed by determining the number and types of social clubs, groups, associations and committees with information from the Sethlare Tribal Authority. Social cohesion can be an indicator of how well communities could respond to natural resource shortages. An important indicator of social well-being is the level of crime and SAPS (South African Police Services) statistics were obtained for 2004 to 2014 for the area (Acornhoek SAPS 2014).

3.2.6 Development of a method to rank sustainability

An approach was devised to rank indicators used in this study on the basis of sustainability or non-sustainability using guidelines from Poveda and Young (2015). To rank certain indicators, a system of quartiles, for example 0-25%, 26-50%, 51-75% and 76-100% was considered equivalent to a rank 1, 2, 3, and 4 respectively (Evaluation Rule 1). For other indicators, a system of quartiles 0-25%, 26-50%, 51-75% and 76-100% was considered equivalent to a rank of 4, 3, 2 and 1 (Evaluation Rule 2) respectively. The reason for this difference was that in some cases a 0-25% quartile indicated sustainability, while with other indicators a 0-25% quartile would indicate a situation of unsustainability. As not all indicators fit into Evaluation Rule Systems 1 or 2, customised ranking systems were devised for firewood consumption rate, crime rate, population growth rate, population density and water consumption according to international and local standards.

The selected economic indicators (poverty, unemployment) used income and employment as the main criteria to determine levels of poverty. Poverty was then used to probe households' mountain dependence and subsequent sustainability rank. In this case, increasing income and employment reflected increasing sustainability ranging from 1 to 4 (Table 3-1d). The income group with the largest percentage of households determined the level of sustainability ranking in Acornhoek with the South African monthly income per capita poverty line of ZAR 501 (StatsSA 2015) and the international daily poverty line of $US 1.90 (Jolliffe and Prydz 2016) as poverty standards. The higher the unemployment resulted in a more unsustainable ranking.

The level of social infrastructure, that is, the type of sanitation and water access infrastructure at household level was used as criteria for sustainability ranking. Social indicators such as access to improved water and sanitation at Acornhoek were ranked and the highest percentage of households using a particular water source or sanitation facility determined the rank. The percentages of people having enrolled and completed primary and those having gone through tertiary education levels were ranked (Table 3-1d) with the larger the percentage of people having completed an education level, the more sustainable the ranking. The population growth rate was used as criteria for ranking for the international indicator and population density for the local indicator. The higher the growth rate and density resulted in a lower sustainability ranking using international and national South African current norms.

Environmental indicators of water and firewood use and consumption rates were also used as criteria for local sustainability ranking. The mean water and firewood use rates per annum were ranked from 1-4 with 1 representing high consumption rates and low sustainability and 4 representing low consumption rates and high sustainability (Table 3-1d). For water consumption the standard used was the mean 70 litres/household/day of water in Acornhoek for the local indicator and 50-100 litres/person/day for the international indicator standard (WHO 2003). Percentage area under sustainable management on the Mariepskop was placed in equal quartiles between 0-100% and ranked increasing from 1-4, where 1 reflects that only 25% or less of the area is under sustainable management and 4 reflects 75-100% sustainably managed area and hence high sustainability.

Of the initial 20 international and local indicators assessed for applicability to Mariepskop/Acornhoek, only 14 were considered and ranked for sustainability with ranks from 1 to 4 according to their reflection of the level of social, economic and environmental sustainability with 1 being highly unsustainable, 2 being unsustainable, 3 being sustainable and 4 being highly sustainable when ranked using available sourced data. The criteria used for ranking the sustainability of Mariepskop Mountain and Acornhoek varied with the differences in social, economic, environmental indicators and also with the local and international indicators.

3.2.7 Future sustainability of Mariepskop and Acornhoek

The household unit is important in this study because it is the unit of estimation of current and future Mariepskop resource use patterns. For future natural resource use estimations, the number of households for 2050 and 2100 were obtained by dividing the projected population numbers for the years by the mean household size of six individuals (Acornhoek household survey 2013). The estimated number of households was then multiplied by the annual resource consumption rate per household using mean water and firewood estimates to determine consumption in 2050 and 2100. The amount of firewood used for each household was derived from the use of a one tonne truck normally used to carry firewood to households a mean of four times per year, from the 200 household survey of Acornhoek. This annual figure for firewood use of four tonnes per household is similar to studies by Dovie *et al* (2002) and Madubansi and Shackleton (2007). Mariepskop future biomass projections for the same years were obtained using the mean total biomass of 312.6 t/ha from a study of two mountains by Ni (2004). The mountains in the study by Ni (2004) experience similar warm summers, cool winters, adequate rainfall to sustain a forest that is comparable to Mariepskop.

Standing biomass (tonnes) = B+ (A x Y x FRR)

Where: B = Biomass of forest, A = Total area of the forest, Y = Number of years, FRR = Forest regeneration rate

Assumptions made were that:

- the standing biomass was calculated using forest regeneration rate (FRR) of 89 kg/ha/yr ((Twine 2012).
- the population of Acornhoek would continue increasing by annual growth rate of 1% until 2100.
- Acornhoek households would continue to use 4 tonnes of firewood per household annually.

Estimated mean water use of 70 litres per day/ household was multiplied by 365 days to obtain 25 550 litres (25.5 kl) per annum used by each household. Estimated consumption rates of water for the years 2050 and 2100 were obtained by further multiplying the annual household water use for one household and with the projected number of Acornhoek households in these years.

3.3 Results

3.3.1 Review of sustainability indicators at Acornhoek

Selected international sustainability indicators and/or goals considered relevant to the Mariepskop-Acornhoek complex and local sustainability were assessed for their applicability and categorised as easy, moderate and difficult. Eight of the indicators were found to be easily applicable, five indicators were moderately applicable whilst seven indicators were difficult to apply (Table 3-1a, b, c). Of the easy sustainability indicators five were social, two were economic indicators and one was a governance indicator. The moderately applicable sustainability indicators consisted of one social indicator and four environmental indicators. The difficult sustainability indicators to apply were made up of four social indicators and three environmental indicators.

Table 3-1a: An assessment of easily applicable selected international and local sustainability indicators for studying sustainable development in Mariepskop and Acornhoek.

International indicators, goals and targets			**Assessment of local indicators (Mariepskop and Acornhoek)**			
International Sustainable Development Indicators	**MDG Indicators (2000 – 2015)**	**UN SDG Goals and Targets (2016 – 2030)**	**Mariepskop -Acornhoek indicators (Census 2001, 2011 and other information sources)**	**Local Data available**	**Relevance to the local level**	**Gaps or inaccuracies in local data**
Poverty: Percentage of population below international poverty line (US1.90 $/day) per capita (ZAR 855/month) (Jolliffe and Prydz 2015)	1.1	1.1	Poverty: Percentage of Acornhoek households with per capita income	Yes, down to sub-place level StatsSA 2011)	Poverty is cited as a threat for Bushbuckridge municipality Integrated Development Plan (IDP) 2011 -2016.	Informal economy may not be accurately recorded
Percentage of population that is unemployed Number of people, 15 years or older that is employed (World Bank 2015)	1.5	n/a	Percentage of households with other sources of income besides government grants	Yes	Unemployment listed as a threat in the Bushbuckridge IDP (2011-2016). Low employment leads to low income and higher levels of poverty	Informal or self-employment statistics may not be accurate
Percentage of population using an unimproved sanitation facility	7.9	6.2	% of Acornhoek households with basic sanitation facilities	Yes	Household access to improved sanitation facilities reflects Acornhoek standard of life	Households sometimes share sanitation facilities with neighbours limiting accessibility
Percentage of population using an improved water source	7.8	6.1	% households with access to piped potable water sources at less than 200m distance	Yes	Household access to improved water sources reflects Acornhoek standard of life	Tap or piped water supply and availability is not constant particularly during drought periods or infrastructural breakdowns
Percentage of population using solid fuels for cooking	7.3	7	Total annual firewood consumption per household	Yes	Indigenous trees are highly favoured for firewood, natural regrowth takes about 8 years for a tree to mature and currently there is a high rate of deforestation at Mariepskop	Prone to underestimation of wood use due to varying seasons and wood types. Harvesting for commercialization of wood not captured.

Percentage of population with access to affordable, reliable, sustainable and modern energy Modern energy services are household access to electricity and clean cooking facilities (IEA 2014)	n/a	7.1	Percentage of population exclusively using electricity as the main source of energy in Acornhoek	Yes	Acornhoek households use a mix of energy sources for cooking, heating and lighting	Affordability of energy is relative to a particular household and electricity from coal-fired power plants may not be sustainable by international standards.
Percentage rate of violence and related death rates	n/a	16.1	Acornhoek contact crime rate	Yes	Crime is mentioned as a threat in the Bushbuckridge IDP (2011-2016)	Under-reporting of crime
Net enrolment rate in primary education	2.1	4.1	Percentage of pupils who have completed primary school	Yes	Primary school education is important in increasing literacy levels and and improving Acornhoek households quality of life	Indicators do not include those children who never attended school due to a limited access and are therefore not captured by education system.

*Ease of application categorised as easy, moderate and difficult. This means the level of difficulty in applying the indicator to understanding sustainable development in Acornhoek.
1$ USD = R15.00

Table 3-1b: An assessment of moderately applicable selected international and local sustainability indicators in Mariepskop and Acornhoek.

International indicators, goals and targets			Local indicators (Mariepskop and Acornhoek)				
International Sustainable Development Indicators	**MDG Indicators (2000 – 2015)**	**UN SDG Goals and Targets (2016 – 2030)**	**Mariepskop - Acornhoek indicators (Census 2001, 2011 and other information sources)**	**Local Data available**	**Ease of application of the indicator**	**Relevance to the local level**	**Gaps or inaccuracies in local data**
Percentage of population with access to primary health care facilities	8.13	3	Percentage of population with access to a medical clinics in Acornhoek	Yes	Moderate – Distance to the PHC facilities affects accessibility and quality of care received is difficult to measure	Access to quality primary health care is important in improving Acornhoek households standard of living	Rural hospitals are prone to medicine shortages which may not be captured in the official data
Proportion of land area covered by forests	7.1	15	Area under indigenous and exotic forest (DAFF)	Yes	Moderate - Available data needs to be extrapolated on to Mariepskop study area	The increase and decrease of exotic and indigenous forests on Mariepskop Mountain	Subsistence farming is dependent on the availability of inputs
Area under sustainable forest management Sustainable forest management tackles forest degradation while improving ecosystem goods and services to the people and environment (FAO 2014)	7.6	15.2	Area of the mountain with restricted access A permit from DAFF is required for any activities from about 1 500m elevation	Yes	Moderate - very little sustainable management is visibly taking place and there are no records or plans for it available	Acornhoek households harvest natural resources from Mariepskop indigenous and exotic forest	Lack of enforcement of Mariepskop forest rules and conditions
Water use efficiency across all sectors	7.5	6.4	Acornhoek households water consumption rates	No	Moderate – water use is dependent on the household size and farming area for irrigation and type of crop. Water use efficiency is difficult to measure	Climate change was highlighted in the Bushbuckridge IDP (2011-2016) as a threat to water availability	Limited data on cash crops grown in the study area
Presence of faecal coliform in freshwater	n/a	6.3	Levels of faecal coliform in the Klaserie River	No	Moderate – no monitoring of faecal coliform on the river	Levels of faecal coliform in the Klaserie River	Data available on other potential pollutants in the Klaserie River

Table 3-1c: An assessment of selected international and local sustainability indicators which are difficult to apply to Mariepskop and Acornhoek.

International indicators, goals and targets			**Local indicators (Mariepskop and Acornhoek)**				
International Sustainable Development Indicators	**MDG Indicators (2000 – 2015)**	**UN SDG Goals and Targets(2016 – 2030)**	**Mariepskop - Acornhoek indicators (Census 2001, 2011 and other information sources)**	**Local Data available**	**Ease of application of the indicator**	**Relevance to the local level**	**Gaps or inaccuracies in local data**
Prevalence of major diseases such as HIV/AIDS, malaria, tuberculosis	6.5	3.3	Percentage of HIV positive people with access to Antiretroviral Therapy (ARTs) coverage	Yes	Difficult - Accessibility to data is limited. Percentage HIV infections and deaths is often linked to opportunistic diseases which cause the actual deaths(DoH)	A major threat highlighted in the Bushbuckridge municipality IDP (2011-2016)	Due to stigma people may not reveal HIV related illness or seek medical attention, resulting in an under-recording of certain health data
Access to affordable and quality technical, vocational and tertiary education	3.1	4.3	Percentage of population who have higher education	Yes	Difficult – accessibility to tertiary institutions highly subjective. Affordability is difficult to measure	Access to tertiary education increases access to better paying employment and opportunities	Gaps in tertiary enrolment. Most people move to bigger cities after attaining tertiary education or to obtain it and therefore may not be captured.
Percentage population growth rate (Agenda 21, Chapter 5.17)	n/a	n/a	Population density in Acornhoek	No	Difficult – inconsistencies in place boundaries, compromising reliability of population data	Bushbuckridge annual population growth rate and the local indicator using the Acornhoek population growth rate.	Difficulties with comparing sub-places between censuses, and also name changes complicate comparisons over time.
Land use change	n/a	12.2	Land use changes on Mariepskop and Acornhoek (Dept of Agriculture, Forestry and Fisheries, DAFF)	Yes	Difficult – data from the Kruger to Canyons Biosphere covers broad areas and may not be specific to Mariepskop Mountain	Increased land use changes over Mariepskop and Acornhoek in the last 50 years (1960- 2010) Highlighted in the Bushbuckridge IDP as a threat	Data only shows parts of the study area
Land degradation	n/a	12.2	Area under land degradation and deforestation rates the Mariepskop (DAFF)	No	Difficult – no available local data due to lack of monitoring	Mariepskop Mountain currently experiencing deforestation particularly for firewood.	Complexity in land ownership and use of land, NEMA EIA for process and results not systematically recorded in a data base and available for public and research access
Arable and permanent cropland area	n/a	2	Area of the mountain and Acornhoek under commercial and subsistence farming (DAFF)	No	Difficult – no available local data of the changes in the type of farming area	Changes in land use are important because of the effect on natural ecosystems.	Degradation may be a result of other non- anthropogenic factors such as floods

The lack of availability of long and short-term data on environmental aspects, specifically the state of the vegetation, land degradation and water quality, was a major research challenge for the Mariepskop area as no local monitoring data were readily available to assess these indicators. This situation relates to the indicator categories for the environment mostly falling into the moderately applicable and difficult to apply category developed in this study. Only fourteen of the international and local Mariepskop/Acornhoek indicators with adequate available data were then further assessed and ranked (Table 3-1d). This assessment revealed that five of the local indicators reflect high unsustainability, four of the indicators show unsustainability, one indicator reflects sustainability and four reflect high sustainability. The international indicator values were also ranked and show high sustainability, six indicators reflect sustainability, one shows unsustainability and six reflect high unsustainability.

A comparison carried out between the international and local indicators revealed that indicators sometimes yielded different sustainability rankings (Table 3-1d). The economic UN MDG indicator and UN SDG Goal 1.1 for poverty shows a ranking of 2 which is unsustainable for the local indicator level and 1, which is highly unsustainable at the international level because the South African monthly poverty line per capita (ZAR 501) is lower than the international monthly poverty line per capita (ZAR 855). For unemployment the international ranking was 2 (Table 3-1d) because local Acornhoek unemployment rate is high at 61.2% and the local indicator assessing the number of households with other sources of income besides government grants was ranked at 3, which is sustainable. More households with a per capita income above the poverty lines, with employment and less dependent on government grants increases the sustainability levels in Acornhoek.

Table 3-1d: Investigating the sustainability of community at Mariepskop and Acornhoek using 20 matched international and local sustainability indicators. These indicators were ranked using a ranking score system for sustainability (Evaluation Rules 1 and 2) as well as several customised ranking systems (firewood use statistics; crime and murder statistics; and population growth and population density statistics).

Ranking score system

Evaluation Rule 1:		**Evaluation Rule 2:**	
4= 0-25%	highly sustainable	1 = 0-25%	highly unsustainable
3 = 26-50%	sustainable	2 = 26-50%	unsustainable
2 = 51-75%	unsustainable	3 = 51-75%	sustainable
1 = 76-100%	Highly unsustainable	4 = 76-100%	Highly sustainable

United Nations MDG Indicators (2000-2015) and SDG Goals and Target (2016-2030) and key themes	International Indicator Definition and evaluation rule selected	Mariepskop-Acornhoek indicators (Census 2001, Census 2011 and other information sources), and evaluation rule selected	Local findings using local indicators and applying a ranking score for sustainability	Local finding using the UN MDG and SDG themes and applying a ranking score for sustainability	Indicator comparison and sustainability ranking
MDG Indicator 1.1 ***SDG Target 1.1*** Poverty	Percentage of population below international poverty line (US1.90 $/day) per capita (ZAR 855/month) (Jolliffe and Prydz 2016) Evaluation Rule 1	Percentage of Acornhoek households with per capita income (from social grants, formal employment, remittances, other economic activities) less than ZAR 501. South African Lower Bound Poverty Line (LBPL) is R501 per capita per month (StatsSA 2015) Evaluation Rule 1	74% of households have a monthly income per capita of ZAR 0 -500 (Acornhoek survey) Ranking score 2	94% of households have income per capita of less than US1.90/day (Acornhoek survey) Ranking score 1	The indicators complement each other, though they use different poverty lines. The ranking shows similar low levels of sustainability
MDG Indicator 1.5 Percentage of population that is unemployed	Number of people, 15 years or older that is unemployed (World Bank 2015) World unemployment rates 5.9% (ILO 2015) Evaluation Rule 1	Percentage of households with other sources of income besides government grants 44.5% of households in South Africa receive at least one government grant in 2014 (StatsSA 2015) Evaluation Rule 1	35 % of households in Acornhoek are solely dependent on government grants (Acornhoek survey) Ranking score 3	Acornhoek unemployment rate is 61.2% (StatsSA 2011) Ranking score 2	The indicators give different findings relating to sustainability.

MDG Indicator 7.9 ***SDG Target 6.2*** Percentage of population using an unimproved sanitation facility	Unimproved sanitation facilities do not ensure hygienic separation of human excreta and human contact (WHO 2006) Evaluation Rule 1	Percentage of Acornhoek households with basic sanitation facilities Basic provision of a toilet which is safe, reliable environmentally sound, easy to clean, well ventilated (Water Services Act 108 of 1997) Evaluation Rule 1	The local standard for basic sanitation is more stringent in terms of ventilation. Therefore, 87.2% of Acornhoek households use unimproved sanitation facilities (72.9% use unventilated pit toilets, 0.3% bucket and 14% have no toilets) (StatsSA 2011) Ranking score 1	International standard for unimproved sanitation is less stringent and therefore unventilated pit toilets are classified as improved. 21.5% of Acornhoek households use unimproved sanitation facilities (StatsSA 2011) Ranking score 4	The indicators give completely different findings relating to sustainability.
MDG Indicator 7.8 ***SDG Target 6.1*** Percentage of population using an improved water source	Improved water sources are those that adequately protect water from outside contamination (WHO 2006) Evaluation Rule 2	Percentage households with access to piped potable water sources at less than 200m distance Basic water supply is the infrastructure necessary to supply 25 litres of potable (suitable for drinking) water per person within 200 m of a household (DWAF 2002). Evaluation Rule 2	65% of households in Acornhoek have access to tap water at less than 200m (StatsSA 2011) Ranking score 3	84 % of households in Acornhoek use tap or borehole water (StatsSA 2011) Ranking score 4	The ranking reveals similar levels of sustainability using either the local or international indicators
MDG Indicator 7.3 ***SDG Goal 7*** Percentage of population using solid fuels for cooking	Solid fuel use is the household burning of biomass (charcoal, coal, firewood, cow dung) for energy (Desai *et al* 2004). Evaluation Rule 1	Total annual firewood consumption per household Mean estimated firewood consumption is 3.5 – 4 t/annum/household (Dovie *et al* 2002, Twine *et al* 2003). Therefore, we assume that this mean to be sustainable and the consumption of less firewood as highly sustainable and more as unsustainable. Tonnes/annum/household < 3.5 = 4 3.5 - 4 =3 4.1-5 = 2 >5 = 1	The mean estimated Acornhoek household firewood consumption rate is 4 tonnes/annum (Acornhoek survey) Ranking score 3	75% of households in Acornhoek use firewood from Mariepskop for cooking and heating (Acornhoek survey) Ranking score 2	The indicators give completely different findings relating to sustainability.

SDG Target 7.1 Percentage of population with access to affordable, reliable, sustainable and modern energy	Modern energy services are household access to electricity and clean cooking facilities (IEA 2014) Evaluation Rule 2	Percentage of population exclusively using electricity as the main source of energy in Acornhoek . 95% of households in rural South Africa with access to electricity still use firewood as a major source of energy (Madubansi and Shackleton 2007) Evaluation Rule 2	5.9% of Acornhoek households exclusively use electricity as the main source of energy (Acornhoek survey) Ranking score 1	93% of Acornhoek households have access to electricity (Acornhoek survey) Ranking score 4	The ranking shows that the local indicator shows a highly unsustainable situation yet the international indicator shows a highly sustainable one.
SDG Target 16.1 Percentage rate of violence and related death rates	Murder is regarded as the most serious violent crime and is the most widely collected and reported crime and hence tends to be more recorded than other crimes (HEUNI 2010) Africa region murder rate is 12.5 per 100 000 population (UNODC 2013) Mpumalanga murder rate 19.4% per 100 000 population (SAPS crime statistics 2015) 1. >20 2. 10-20 3. 5-9 4. 0-4 Murders / 100000 population	Acornhoek contact crime rate South Africa national contact crime rate is 1122 per 100 000 (SAPS crime stats 2015) and Mpumalanga province contact crime rate 754 per 100 000 in 2015 (SAPS crime statistics 2015) 1. > 1001 2. 751-1000 3. 501-750 4. <500 Contact crimes/100000	Acornhoek contact crime rate was 689 per 100 000 in 2014 (Acornhoek SAPS crime statistics 2014) Crime ranking score 3	Acornhoek murder rate is 23 per 100 000 were recorded in 2014 (Acornhoek SAPS crime statistics 2014) Murder ranking score 1	The indicators are complementary and show both contact and serious (murder) crimes in Acornhoek. However, only long term monitoring trends in these statistics would show any value in increasing or decreasing crime rates through comparisons, but on their own do not add value to monitoring sustainability
MDG Indicator 8.13 ***SDG Goal 3*** Percentage of population with access to primary health care facilities	Primary health care is the essential day to day health care provided equally and accessible to everyone in a community (Starfield 1994, WHO 2004)	Percentage of population with access to a medical clinics in Acornhoek	One Acornhoek clinic has to service 10 000 people according to the WHO guidelines (WHO 1981). South Africa aims at achieving a mean of 13 718 people/ clinic (DoH 2010)		Indicators not ranked. Long term data would be ideal in comparing past and current primary health care access

MDG Indicator 6.5 SDG Target 3.3 Prevalence of major diseases such as HIV/AIDS, malaria, Tuberculosis	Percentage of patients with a particular disease during a given year per given unit of population (Farlex Partner Medical Dictionary 2012) The HIV global prevalence rate of people ages 15-49 was 0.8% (WHO 2014a) Global TB cases is 133 per 100 000 people per year (WHO 2015a) Southern Africa malaria incidence rate 0.13 per 1000 per year (Snow and Omumbo 2006) Evaluation Rule 2	Percentage of HIV positive people with access to Antiretroviral Therapy (ARTs) coverage This is the percentage of all people living with HIV who are receiving ARTs (WHO 2015b) Globally 37% of people living with HIV receive treatment (WHO 2015b) In South Africa 45% of people with HIV were on ART (WHO 2014b) Evaluation Rule 2	70% of people living with HIV were on ARTs at Tintswalo Hospital in Acornhoek (Otwombe *et al* 2014) Ranking score 3	Agincourt prevalence rate of HIV in people 15 year and older is19.4% (Gomez-Olive *et al* 2013) Agincourt TB prevalence rate is 212 per 100 000 (Pronyk *et al* 2007) Agincourt malaria prevalence rate 0.09 per 1000 (Streatfield *et al* 2014) Ranking score 1	The indicators are divergent and give completely different findings relating to sustainability.
MDG Indicator 2.1 SDG Target 4.1 Net enrolment rate in primary education	Percentage of children of official primary school age enrolled in primary education (UNESCO 2006) Evaluation Rule 2	Percentage of population who completed primary school The last grade in primary school education, that is, Grade 7. (StatsSA 2010) Evaluation Rule 2	12% completed primary school in Acornhoek (StatsSA 2011) Ranking score 1	16% were enrolled into primary school in Acornhoek (StatsSA 2011) Ranking score 1	The indicators give completely different findings relating to sustainability.
MDG Indicator 3.1 SDG Target 4.3 Access to affordable and quality technical, vocational and tertiary education	Every individual must be given an equal opportunity to partake in tertiary education and its benefits irrespective of income, gender, ethnicity, age, disability and language (World Bank 2009) Evaluation Rule 2	Percentage of population who have higher education All South Africans have the right to a basic education, including adult basic education and access to further education (SA Constitution Bill of Rights) Evaluation Rule 2	1 5.7% of Acornhoek population have some technical, vocational and tertiary education (StatsSA 2011) Ranking score 1	2 26.8% of the Acornhoek population completed secondary school and therefore have access to tertiary education and training (StatsSA 2011) Ranking score 2	The ranking system shows that both indicators reveal a highly unsustainable situation.
Agenda 21 (Chapter 5.17) Percentage population growth rate	The average annual rate of change of population size during a specified period (UN 2007) World population growth rate is 1.2% (World Bank 2015).	Population density in Acornhoek This the population (number of residents of a place) divided by land area in square kilometres.	Acornhoek population density is 862 persons/km^2 (StatsSA 2011) Population density ranking	Acornhoek population growth rate estimated at 1% /annum (Blewett 2016) Population growth rate	The indicators complement each other with the international indicator showing a highly sustainable population growth rate

	Optimal world population growth rate 0.5% (Coreil 2010). 1.1- 2%= 2 0.51 -1% = 3 0 - 0.5% = 4 % annual growth rate	The population density of South Africa was calculated at 45 persons/km^2 (World Bank 2014) >500 = 1 251-500 = 2 100-250 = 3 <100 = 4 Persons/km^2	score 1	ranking score 4	and the local indicator showing a highly unsustainable population density in Acornhoek
SDG Goal 15 Land use change	A process by which human activities transform the landscape by converting natural landscapes for human use (Foley *et al* 2005)	Land use changes on Mariepskop and Acornhoek (Dept of Agriculture, Forestry and Fisheries. DAFF)	36% of the subregion Kruger to Canyon experienced land cover change between 1993 to 2006 particulary in areas with dense rural populations and agricultural activity (Coetzer *et al* 2010)		Highlighted in the Bushbuckridge IDP as a threat, but long term information would be needed for a full assessment of sustainability
SDG Target 15.3 Land degradation	This is a process in which the value of the biophysical environment is affected by a combination of human induced processes acting upon the land (Conacher 1995)	Area under land degradation and deforestation rates the Mariepskop (DAFF)	Not assessed in this study		Long term monitoring information would be needed for a full assessment of sustainability
SDG Goal 2 Arable and permanent cropland area	Arable land is land under temporary agricultural crops, temporary meadows for pasture, land under market and kitchen gardens and land temporarily fallow (FAO 2005) Globally, there is 10.9% arable land and 1.3% of land area under permanent cropland (FAO 2013)	Hectares of the mountain and Acornhoek under commercial and subsistence farming (DAFF)	There was 86% increase in formal cultivation in the Kruger to Canyon Subregion between 1993 and 2006 (Coetzer *et al* 2010). This figure does not include smallholder farms and plots.		Changes in land use are important because of the effect on natural ecosystems. It would be important to measure the long term impact at Acornhoek.
MGD Indicator 7.1 ***SDG Goal 15*** Proportion of land area covered by Forests 30.8% (FAO 2015)	Forest area (% of land area) is land under natural or planted stands of trees of at least 5m in situ, whether productive or not, and excludes tree stands in agricultural production systems (World Bank 2012).	Area under indigenous and exotic forest (DAFF)	58.9% of Mariepskop forest is under indigenous trees (Schijff and Schooraad 1971).		Changes in forest area need to be monitored in the long-term for analysis of deforestation, decrease and increase of exotic and indigenous trees.

MDG Indicator 7.6 ***SDG Target 15.2*** Area under sustainable forest management	Sustainable forest management tackles forest degradation while improving ecosystem goods and services to the people and environment (FAO 2014) Evaluation Rule 2	Area of the mountain with restricted access A permit from DAFF is required for any activities from about 1 500m elevation Evaluation Rule 2	Access to 51-75% of the mountain area requires authorization (Acornhoek survey) Ranking score 3	Less than 25% of the land area in Mariepskop is being sustainably managed (Acornhoek survey) Ranking score 1	The indicators give completely different findings relating to sustainability.
SDG Target 6.5 Support and strengthen the participation of local communities in improving water and sanitation management	Community participation involves beneficiary involvement in the planning and implementation of externally initiated projects (Bamberger 1986) Evaluation Rule 2	Community participation in municipal projects in Acornhoek. The Constitution of South Africa (Act 108 of 1996) mandates local government to provide a democratic and accountable local government and encourage the involvement of communities and their organizations in matters of local government. Evaluation Rule 2	There are no listed projects for public participation and good governance and also no budget allocation (Bushbuckridge IDP 2015-2016) Ranking score 1	Acornhoek has between 26 – 50% community participation in water and sanitation projects through the NGO AWARD. Ranking score 2	The indicators give similar results in terms of sustainability, that is they both show low sustainability
MDG Indicator 7.5 ***SDG Target 6.4*** Water use efficiency across all sectors	Water use efficiency means reducing resource consumption and reducing the pollution and environmental impact of water use for the production of goods and services (UNEP 2014) Citrus crop consume 900-1200 mm/ total growing period (AFED 2010) <800 mm/season=4 900 – 1200 = 3 1201-1500 = 2 >1500 = 1	Acornhoek households water consumption rates Right per human being is 50 –100 litres of water per day (WHO 2003) <100 litres/day = 4 100-150 = 3 151-200 = 2 >200 = 1	Acornhoek households use an estimated mean of 70 litres per day and with a mean of 6 people per household the water consumption rate is 11.6 litres/person (Acornhoek survey) Household water ranking score 4	Commercial Blyde River irrigation, water consumption for citrus crops is 8500 m^3/ha which is 850 mm per season (Oosthuizen 2014) Crop irrigation ranking score 3	The indicators complement each other with the local indicator looking particularly at household water use and the international indicator assessing water use efficiency in commercial irrigation. Less water use is more sustainable.
SDG Target 6.3 Presence of faecal coliform in freshwater		Levels of faecal coliform in the Klaserie River (DWA)	Not assessed in this study.		Levels of faecal coliform in the Klaserie River. Lower levels of *E.coli* are more sustainable in terms of human well-being

The lack of availability of long and short-term data on environmental aspects, specifically the state of the vegetation, land degradation and water quality, was a major research challenge for the Mariepskop area as no local monitoring data were readily available to assess these indicators. This situation relates to the indicator categories for the environment mostly falling into the moderately applicable and difficult to apply category developed in this study. Only fourteen of the international and local Mariepskop/Acornhoek indicators with adequate available data were then further assessed and ranked (Table 3-1d). This assessment revealed that five of the local indicators reflect high unsustainability, four of the indicators show unsustainability, one indicator reflects sustainability and four reflect high sustainability. The international indicator values were also ranked and show high sustainability, six indicators reflect sustainability, one shows unsustainability and six reflect high unsustainability.

A comparison carried out between the international and local indicators revealed that indicators sometimes yielded different sustainability rankings (Table 3-1d). The economic UN MDG indicator and UN SDG Goal 1.1 for poverty shows a ranking of 2 which is unsustainable for the local indicator level and 1, which is highly unsustainable at the international level because the South African monthly poverty line per capita (ZAR 501) is lower than the international monthly poverty line per capita (ZAR 855). For unemployment the international ranking was 2 (Table 3-1d) because local Acornhoek unemployment rate is high at 61.2% and the local indicator assessing the number of households with other sources of income besides government grants was ranked at 3, which is sustainable. More households with a per capita income above the poverty lines, with employment and less dependent on government grants increases the sustainability levels in Acornhoek.

The UN SDG Goal 6 for access to improved water and sanitation received different rankings from the local indicator values, revealing inconsistency in the way indicator systems show trends. Sanitation local indicator had a ranking of 1 reflecting a highly unsustainable situation because 86% of households use unventilated pit latrines, buckets or have no sanitation facilities, whilst the international indicator is ranked at 4 reflecting a highly sustainable local situation, showing the inconsistency between different sustainability monitoring systems. The access to improved water sources indicators both showed sustainable situations with a ranking of 3 for the local indicator value and 4 for the international indicator value (Table 3-1d). Increased access to improved water and sanitation facilities results in higher sustainability.

Goal 7 of the UN SDG on the use of solid fuels by households was ranked at 2, which is unsustainable because 75% of Acornhoek households use the solid fuel, firewood, from mountain whilst the local indicator value was ranked at 3 showing sustainability (Table 3-1d), again indicating an inconsistency between different indicator systems.

The differences in ranking were because the international indicator assessed the general use of solid fuels whilst the local indicator went further to assess the main solid fuel (firewood) household consumption hence exposure to the toxic gases emitted. The UN SDG Goal 7 seeking to identify Acornhoek household's access to modern fuel was ranked at 4 which is a highly sustainable situation due to a high percentage of households with access to electricity in Acornhoek (93%). The local indicator assessing the exclusive use of electricity in Acornhoek households received a ranking of 1 reflecting a highly unsustainable situation with only 5.9% of households exclusively using electricity and this is unsustainable because this indirectly shows high use of other energy sources, in this case firewood (Table 3-1d).

Also showing inconsistencies, Goal 15 of the UN SDG on area under sustainable forest was ranked at 1 which shows high unsustainability in Acornhoek and 3 which shows a sustainable state using the local indicator value. The local indicator ranking took into account that 51-75% of the mountain is inaccessible to households for resource collection. The fact that local people have unlimited access to the lower parts of the mountain reduces its sustainability at the international level. Water use efficiency (UN SDG Goal 6.4) was ranked at 3 which shows a sustainable state and at 4 reflecting high sustainability using the local indicator which was assessing households consumption rates (Table 3-1d). This is because Acornhoek households use a mean amount of 70 litres/household/day, which is less than the 50-100 litres/person/day prescribed by the UN (2010), making it sustainable by international standards. The lower local sustainability ranking is also a result of the effect of water availability and accessibility.

A total of six sustainability indicators were not comprehensively assessed for ranking, of which five of them were environmental indicators and only one was a social indicator (Table 3-1d). This was primarily due to difficulties in accessing available local Mariepskop/Acornhoek data.

3.3.2 Demographic and resource use patterns in Acornhoek

Challenges with the assessment of accurate population data were compounded by boundary and name changes of sub-places (census areas) between 2001 and 2011 which created inconsistencies in total count population data for Acornhoek. The 2001 census primarily used villages as the sub-place areas in population counting and by 2011 most of these village names had changed and boundaries shifted. These sub-places had further been fragmented into numerous sub-places within a single village creating major area inconsistencies.

Data from 2001 and 2011 were used to calculate the annual population growth rate for the study area in the 10 year period calculated using the total population counts of 38 315 under 58.63 km^2 in 2001 and 61 059 under 71.7 km^2 2011. This calculation resulted in 5.9% growth rate estimation for Acornhoek, a figure which was considered to be too high compared to the 0.79% growth rate for the surrounding Bushbuckridge municipality (StatsSA 2011). This inaccuracy may have been caused by changes in the naming of sub-places and creation of new sub-places between census events.

The Eskom study on the number of dwelling counts in the greater Acornhoek settlement revealed a 1% annual dwelling number growth rate between 2006 and 2011 (Blewett 2016). This dwelling growth rate was assumed to correlate with annual population growth rate. A major advantage of using actual dwelling count is that, it is less likely to be influenced by factors such as village boundaries and name changes as the study used Global Positioning System (GPS) coordinates to mark its boundaries. Consequently, the 5.9 % annual population growth rate for Acornhoek was not used since it would lead to an over-estimation in the future household and natural resource use, projections and estimates.

UN World Population Prospects (2015b) for future population projections for 2030, 2050 and 2100 for the whole of South Africa were also considered in an attempt to calculate an annual growth rate for Acornhoek and create future household number and population projections. The population projections of the UN (2015b) for South Africa include future changes in the annual population growth rate estimates were 0.68% between 2015 and 2030, 0.46% between 2030 and 2050, and 0.005% between 2050 and 2100. The UN projections may be less accurate at local level because they do not capture other issues such as migration which can have a marked effect on local population growth rates, but the UN projections are essentially a benchmark for other estimates.

For the final population growth estimate, this study used the Eskom dwelling count annual growth rate of 1% as an upper limit to project the numbers of future households in Acornhoek. The Eskom study area included densely inhabited Acornhoek, and less densely inhabited Mariepskop and large tracts of farmland. A mean household size of six which was used in the estimation of future household projections in Acornhoek, based on the household survey.

The Acornhoek household survey provided data on the resource use patterns and showed high rates of water and firewood use in the Mariepskop households surveyed and across all total income categories (Figure 3-1a). Households which earned the least income, in the range of less than ZAR 1 000/month tended to use the largest amount of wild vegetables (30%) and herbs (39%) (Figure 3-1a). The higher income earning households earning between ZAR 3 001 - 11 000 per month used more of the non-essential goods and services provided by the mountain and surrounds, including sand, scenic beauty, livestock grazing and reeds (Figure 3-1a).

The number of people who have received education in Acornhoek (Figure 3-1b) has increased between 2001 and 2011, while the percentage of people with no schooling has decreased from 33% in 2001 to 16% in 2011 (StatsSA 2001; 2011). The percentage of people who received some secondary education rose from 26% in 2001 to 34% in 2011 and those having reached Grade 12 increased from 15% in 2001 to 26% in 2011.

Acornhoek households use different sources of water depending on availability and distance to the water source (Acornhoek household survey 2013). Households use more than one water source at a particular time. Nearly 50% of the households in Acornhoek had piped water either inside their houses or in the yard (Figure 3-1c). The percentage households with taps inside their dwellings increased from 2.6% in 2001 to 8% in 2011 (StatsSA 2001; 2011). Also, households in Acornhoek with access to shared taps less that 200m away increased between 2001 and 2011 from 13% to 19% and household access to borehole water increased from 9% to 22% during the same period (Figure 3-1c). Piped water is largely the preferred water source as it is purified to potable quality, however, most taps in Acornhoek only have water in the wetter season or at particular times of the day.

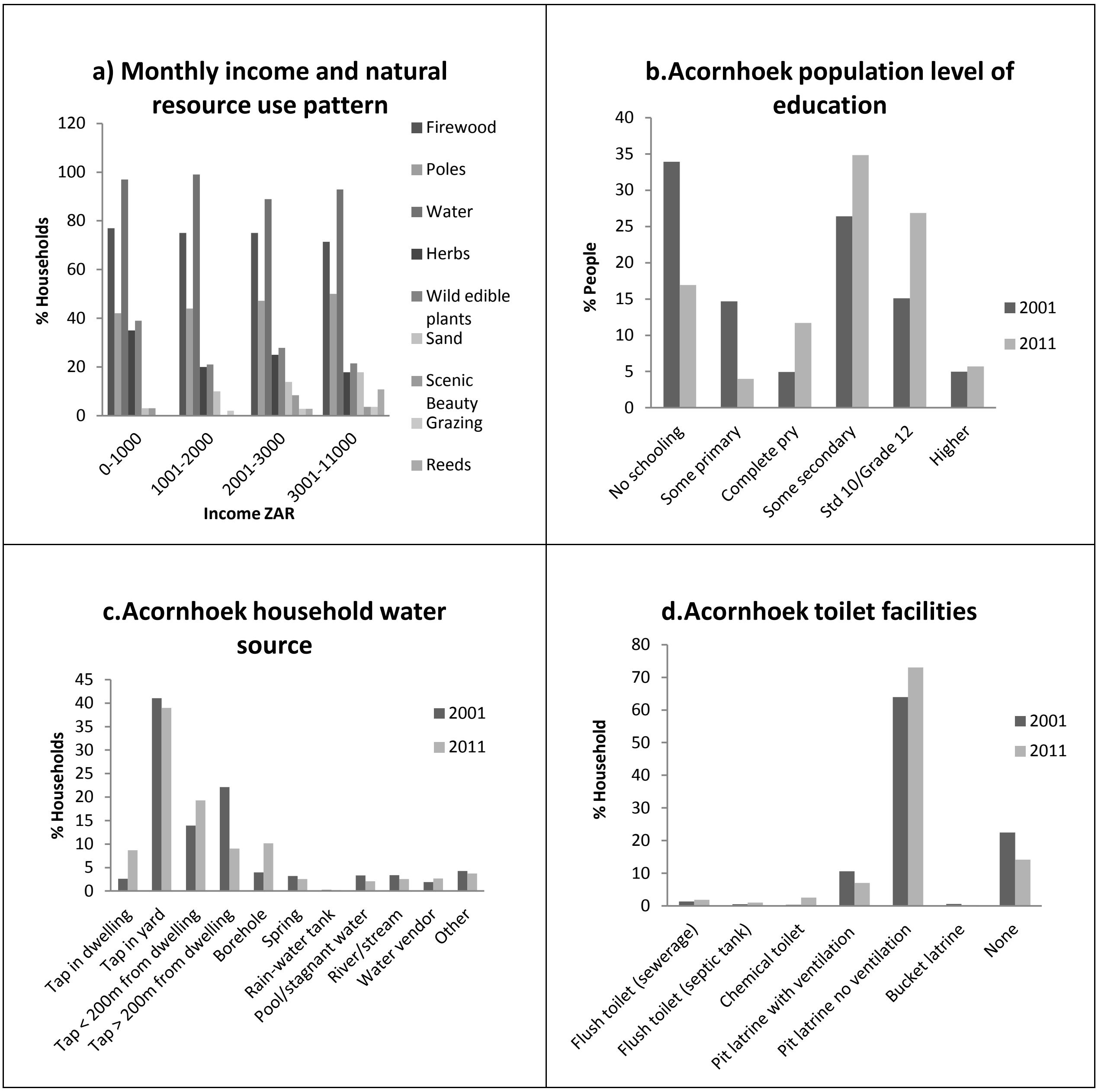

Figure 3-1: Acornhoek households showing monthly income and resource use patterns, levels of education, access to water and sanitation facilities.

Most houses in Acornhoek have access to pit toilets with no ventilation (72%) in 2011 which is an improvement from the 2001 figure of 63% (StatsSA 2001; 2011) (Figure 3-1d). The number of households without any sanitation facilities in Acornhoek decreased from about 22% in 2001 to 14% in 2011, meaning more households now have access to improved sanitation facilities. Of the households, 83.6% in Acornhoek receive government child grants and pensions, contributing to the sources of income in these homes.

3.3.3 Future sustainability of the Mariepskop Mountain ecosystem services

Firewood

An estimated firewood use for 10 000 households is 40 000 tonnes/year, and 60 000 tonnes/year for the projected 15 000 households in 2050 and 80 000 tonnes/year for the projected 20 000 households by the year 2100, at a consumption rate of 4 tonnes per household per annum.

Table 3-2: Estimated current and future collection events and future projected use for firewood, wild edible plants and water for the year 2050 and 2100.

Number of households (future projected)	**Collection events/week for firewood (mean of 7 events/week/household)**	**Collection events/week for wild edible plants (mean of 3 events/week/household)**
10 000 (Year 2011)	70 000	30 000
15 000 (Year 2050)	105 000	45 000
20 000 (Year 2100)	140 000	60 000
Number of households (future projected)	**Daily water use (kl)**	**Annual water use (kl)**
1	0.070 (70l)	25.55
10 000	700	255 500
15 000	1 050	383 250
20 000	1 400	511 000

The total number of collection events are projected to double as the number of households also doubles increasing from 70 000 in 2011 to 140 000 in 2100 (Table 3-2). A key assumption is that firewood demand in Acornhoek will increase with the increase in the number of households until it reaches a point where demand outstrips supply, estimated to be around the year 2050 (Figure 3-2).

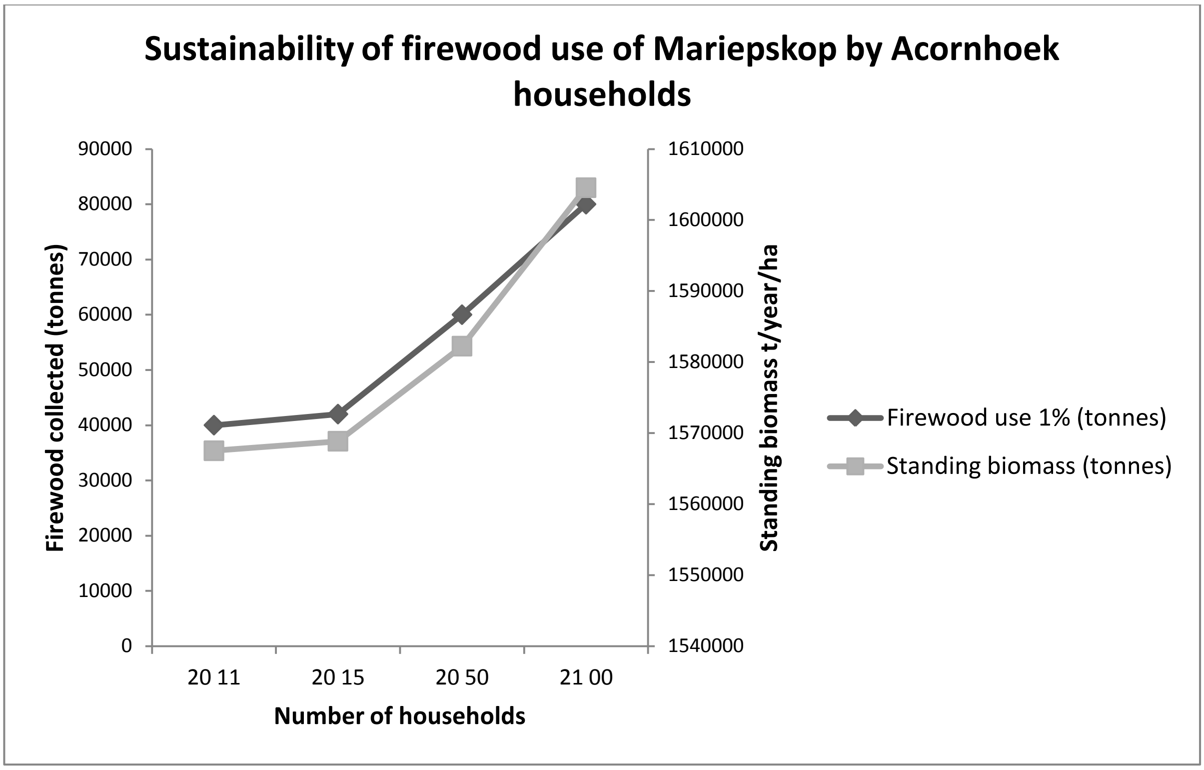

Figure 3-2: Current and future projected supply and demand trends of Acornhoek firewood (standing biomass) collected from Mariepskop Mountain given present population densities and applying an annual population increase of 1%.

Water

The water currently used by Acornhoek households is from both protected and non-protected sources. Future water projected use in Acornhoek households in 2050 and 2100 will increase proportionately with population increases and an increased number of households to a total of around 380 000 kl and 530 000 kl respectively. Rainfall trends on the Mariepskop and flow rate along the Klaserie River are highly variable but do not reflect any major changes in the last 60 years (Figure 3-3) though future trends may change. This study therefore concludes that the Acornhoek community will be able to continue to derive water from the different water sources in their environment as the population grows until 2100.

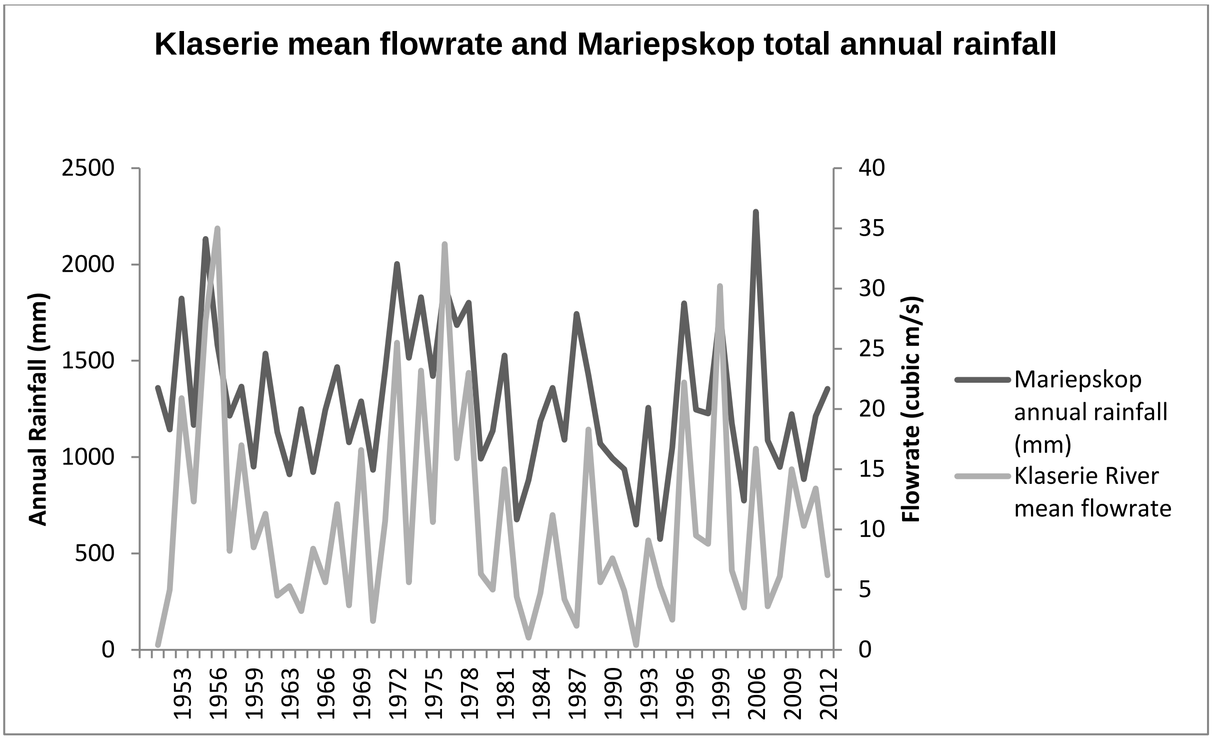

Figure 3 -3: Mariepskop annual rainfall trends and Klaserie River annual flow rate. Source data: South African Weather Services (SAWS 2013) and Department of Water Affairs (DWA 2013).

Wild edible plants

Wild edible plant collection events were three times per week (household sample survey) and projected to increase from 30 000 for 10 000 households in 2011 to 45 000 in 2050 and about 60 000 collection events in the year 2100 (Table 3-2). The consumption rate of wild edible plants by households in Acornhoek may decrease over time due to the availability of more alternatives and increased use of modern medicine synonymous with urban transitioning settlements.

3.3.4 Social cohesion and well-being

Acornhoek has a number of registered clubs and associations which include football clubs, burial societies, women's groups, home-based care groups, a Moringa growers association, community work programmes and youth empowerment clubs. Membership numbers in these groups range between 19 and 102 people of all ages (Sethlare Tribal Authority). No natural resource use committees were recorded for Acornhoek, possibly indicating that there are no local concerns about natural resource depletion.

3.4 Discussion

3.4.1 The applicability of sustainability indicators at Mariepskop/Acornhoek complex

Not all high level international indicators readily apply to local South African conditions due to differences in the biophysical and social circumstances (Cole *et al* 2014). This is because these indicators were developed to primarily fulfil international SDG agendas and national sustainability strategies, such that their measurement was broadly based on international standards and recommendations and consistent with national systems (SDSN 2014). For local evaluation, selected international indicators had to be customised to incorporate local conditions or metrics. Similary, the South African case study by Cole *et al* (2014) found that the downscaling of global indicators which measure social deprivation requires that the development levels of the country be taken into account. For example, the UN SDG Goal 1 highlights poverty reduction as an important goal, and as an indicator uses the international per capita poverty line of $1.90/day or ZAR 855/month at current exchange rate. Poverty reduction is an important strategic development consideration in South Africa, and a local poverty line (ZAR 501/month) is in place. The applicability of indicators was assessed on the basis of the availability, accessibility and reliability of data. The data assessed using sustainability indicators can directly reflect the state of environmental resources, for example, area under sustainable management or indirectly reflect natural resource use patterns using household demographic and socio-economic data.

The application of the social sustainability indicators was mostly categorised as easy when there was availability and accessibility of data from various sources such as, the Acornhoek household survey, SAPS and StatsSA. The application of economic indicators was also dependent on the Acornhoek household survey and census data hence categorised as easy because most of the data was readily available and reliable.

The health indicator, UN SDG Goal 3 (Target 3.3) was difficult to apply in Acornhoek because Acornhoek health data are difficult to access at local level. This is likely due to the sensitivity and stigma of certain health issues and thus under-reporting associated with diseases such as HIV/AIDS. Also, government clearance must often be obtained via the Promotion of Access to Information Act (Act 2 of 2000) to access the data on disease and health care in Acornhoek.

Access to tertiary education was difficult to assess because of its subjectivity in terms of young people who may theoretically have access to tertiary institutions by having good matric passes, but lack the finances for further studies. However, in South Africa, people can be accepted into tertiary institutions for further studies depending on whether the individuals achieve adequate academic passes at secondary school and if they have the desire to do so. Students who excel in their academics and come from financially disadvantaged backgrounds have the opportunity to apply for financial aid or funding. Access to higher education could be seen as an indicator of local well-being.

Economic indicators assess poverty, income and employment levels and their social sustainability. High poverty and unemployment reflect unsustainable economic development which is likely lead to increased pressure on natural resources particularly firewood and wild edible plants harvested for sustenance use, substitution for other bought items, livelihoods and as a safety net, thus eventually compromising environmental sustainability (Wunder *et al* 2014). The economic indicator for assessing poverty using household per capita income, showed the Mariepskop/Acornhoek situation as unsustainable, because more Acornhoek households earn low incomes which eventually translate to high direct reliance on mountain natural resources, ultimately resulting in ecological changes on the mountain.

Social and health indicators which address aspects of social sustainability include access to decent sanitation and potable water are influenced by population growth rate and the provision of social infrastructure is highly associated with human well-being. Households with higher social sustainability tend to experience less poverty because they have increased levels of support network in the community and are therefore less directly dependent on the environment. Quality of life can also be determined by the level of social sustainability using social cohesion, access to water and basic sanitation as indicators. These linkages can be effectively revealed where adequate local social data are available, accessible and reliable. Low social sustainability can promote a lack of consideration for the environment by households through pollution resulting in the degradation of natural ecosystems.

Environmental indicators incorporate the state of ecosystems including the flow and quality of ecosystem goods and services flow and quality and are vital in the assessment and monitoring of ecological changes on the Mariepskop. Disturbed and degraded ecosystems reduce the quantity and quality of ecosystem services available to humans (Department of the Environment 2009). Many social and economic systems heavily rely on the benefits of these ecosystem services such as provision of clean water, air, food, regulation of soil nutrients and waste assimilation (Costanza *et al* 1997). Globally, deforestation has been identified as a major cause of environmental change (Helmut *et al* 2002). Resource use patterns and climate changes are likely to be the main driving forces of ecological change on the Mariepskop Mountain, thereby influencing the flow of ecosystem services in the future.

3.4.2 A comparison and ranking of international and local sustainability indicators

3.4.2.1 Economic sustainability indicators

In general, local indicators capture the spatial and social dynamic differences of an area that would otherwise be overlooked by international indicators. This is because they often use a finer sampling scale, for example collect data at the household level. Customising international sustainability indicators that are part of the global debate on sustainable development, and thus vitally important for developing nations, formed the main aim of this study. However, matching the data from international and local indicators is not straightforward for a variety of reasons.
These include diverging international and local sustainability indicators, different scales and units of measurement, composite versus single indicators and their varying standards which were the main reasons for applying a ranking system to quantify sustainability.

The local economic indicator value for income had an unsustainable ranking of 2 due 74% of Acornhoek households having a monthly per capita income less than the national poverty line (ZAR 501/month). The international indicator value reflected a highly unsustainable state hence a ranking of 1 because 93% of households at Acornhoek have a monthly per capita income less than the international poverty line of

US$ 1.90/day (approximately ZAR 855/month) (Table 3-1d). The local indicator value gives a more precise reflection of the level of poverty because it uses the local poverty line which takes into account the local economic situation. Both indicator values received low sustainability rankings because most households are living below both local and international poverty lines. The unemployment international indicator value received an unsustainable ranking, due to high rates of unemployment (61.2%) when compared to the international rate of 5.9%. However, the local indicator had a sustainable ranking since it was assessing households which have other sources of income besides government grants (65%). The local indicator is more comprehensive in its assessment and approach by including the different types of income sources for Acornhoek households.

3.4.2.2 Social sustainability indicators

The application of UN SDG Goal 6 dealing with the use of improved sanitation facilities reflects higher sustainability ranking because it has less stringent standards than the local indicator (Table 3-1d). The international definition of "improved" sanitation, according to WHO (2012), is a sanitation facility that separates human excreta from human contact, while the local "basic" sanitation definition for South Africa is more specific, that is, it includes facilities that are safe, reliable, environmentally sound, easy to clean and well ventilated (Water Services Act 108 of 1997).The international indicator therefore reflected a highly sustainable situation for access to improved sanitation facilities in Acornhoek because 72% of households using unventilated pit latrines, flush (3%), chemical toilets (2.5%) were classified as improved facilities (Table 3-1d).

The accessibility to improved water sources international indicator value reflected high sustainability with a ranking of 4 because 84% of Acornhoek households use tap and borehole water which are classified as improved water sources. The local indicator value received a lower ranking of 3 reflects sustainability, it factors in the element of distance from the household to the tap (Table 3-1d). Distance to the improved water source is an important aspect of accessibility because of the time and energy spent during water collection. When distances to the improved water sources increase households may prefer to use closer unimproved water sources such as rivers. The direct use of river sources is likely to occur particularly during years with high rainfall and increased river flowrates (Figure 3-3), thus increasing river water availability.

The application of UN SDG Goal 7 on solid fuel energy use shows low sustainability levels with a ranking of 2 because of the wide use (75%) of the solid fuel, firewood, as a main source of energy in Acornhoek. The use of solid fuels is considered unsustainable due to toxic fumes expelled from them, for example, carbon monoxide, contributing to respiratory diseases (WHO 2004). The local indicator estimated the actual firewood consumption per capita and received a sustainable ranking of 3. The local indicator seeks to reflect the solid fuel, that is, firewood consumption rates. The local sustainability indicator is therefore more effective in depicting the interaction or relationship of energy resource use patterns and household health.

The international UN SDG Target 7.1 assessing access to modern energy was ranked at 4, which is highly sustainable since most of the Acornhoek houses use electricity (93.5%). However, the local indicator value received a ranking of highly unsustainable because only 5.9% of Acornhoek households exclusively use electricity. The local sustainability indicator value gives a much clearer picture on the use of modern fuel, electricity, in Acornhoek whilst also depicting the wide use of firewood by households with access to electricity. Since the Acornhoek households are still heavily dependent on firewood, its use is likely to increase as the number of households increase to unsustainable levels in the medium and long-term (Figure 3-2). These results are comparable with the results from a study by Crabtree and Bayfield (1998) which found that local indicators are more specific than the international indicators because of their varying goals which are for local policy planning and monitoring and for national comparisons respectively. The study also found that the objectives of the local and international indicators were divergent which is dissimilar from this study where they mostly complement each other.

3.4.2.3. Environmental sustainability indicators

The UN SDG Target 15.2, assessing area under sustainable forest management had a highly unsustainable ranking of 1, due to the lack of regulation enforcement by the Department of Agriculture, Forestry and Fisheries (DAFF) on the mountain. The local indicator assessing the proportion of the Mariepskop with restricted access was ranked at 3 because the restriction has conservation benefits for the plants and animals in that portion of land making it sustainable.

The environmental indicators were the most difficult class of indicators to apply in the Mariepskop/Acornhoek complex particularly because of the difficulties in accessing relevant local long-term environmental data. Ecosystems are important to human beings though their management, conservation and monitoring issues are often neglected. This is largely because the environment is viewed as an infinite supply of natural resources and unless environmental issues directly affect people they tend to get overlooked. Furthermore, environmental information is complex to collect and requires skills which may be lacking in most local government departments. The environment is constantly evolving naturally and as a result of anthropogenic interactions, and therefore has to be consistently monitored in order to capture all these changes. Lack of suitable information therefore prevents the application of most environmental sustainability indicators.

3.4.3 The inapplicability of some sustainability indicators to the Mariepskop/Acornhoek complex

Six sustainability indicators were not comprehensively assessed for ranking due to difficulties in accessing local Mariepskop data from the local data sources. These indicators included a social indicator on primary health care and five environmental indicators (land use change, land degradation, arable area, area of land covered by forests and levels of faecal coliform in the river). Primary health care is freely available to all people in South Africa, however the difficulty in applying the indicator emerged in assessing the accessibility to the health facilities particularly with increasing distances. Also, access to a primary health care facility does not guarantee access to quality care from skilled health professionals, and treatment and this information would have to be obtained from thorough surveys.

These environmental indicators are particularly important for researchers and decision makers in the sustainability assessment of Mariepskop Mountain. These environmental indicators are vital in the assessment and monitoring of ecological changes on the Mariepskop as they depict the human-environment interactions, act as early warning systems as well as reflecting past and future trend analysis. To some extent, these are the data sets that would have to be collected independently and specific to the local conditions of Acornhoek/Mariepskop area.

Land use change is also particularly important because it impacts socio-economic sustainability of rural communities relying on the mountain for ecosystem goods and services, employment and livelihoods (Vidal-Legaz *et al* 2013). The study by Vidal-Legaz *et al* (2013) also found that land use changes usually involve trade-offs between the socio-economic development and some aspects of the environment, for example, through water pollution by employment creating industries. Land and water degradation from human activities leads to ecological changes that reduce the quality and quantity of ecosystem goods and services available to mountain communities.

3.4.4 Limitations of sustainability indicators

There are many gaps in understanding what sustainability indicators reveal, for example, just collecting readily available income and employment as an indicator, may not give holistic poverty levels (Lipton and Ravaillon 1995; Magombeyi *et al* 2015). This is because poverty has multiple interacting and interlinked dimensions increasing its complexity (Smith 2004). Analysing poverty through independent indicators such as education, health, crime and social cohesion give more valuable indication of local poverty in all its dimensions (Dahl 2012; SAEON 2007). Though economic international and local economic indicators are important in determining levels of dependence on natural systems they do not holistically reflect or measure household quality of life. Human well-being and quality of life are also dependent on factors other than income. Sustainability indicators provide limited information and understanding when applied in isolation and therefore need a multi-disciplinary approach which assesses the socio-economic and environmental aspects of an area to fully grasp its level of sustainability. This can result in the indicator application process becoming challenging and costly.

3.4.5 Projected sustainability of mountain resources

The water-energy-food nexus ideally identifies the interconnectedness and linkages of ecosystems and their services (Keskinen *et al* 2015). Higher rainfall around the Mariepskop ensures denser vegetation for energy, wild edible plants and better access to water compared to areas further away, and thus draws natural resource users to the area.

Even given the resilience of most natural resources, over-exploitation eventually results in resource shortages and stresses. Unless other means of accessing food, water and energy are found for future Acornhoek households, the use of natural supplies of firewood, water and wild edible plants will intensify (Table 3-2) placing the mountain resources under pressure. Estimated firewood use by Acornhoek households is currently sustainable and is likely to remain so till the year 2050 (Figure 3-2). The estimated future levels of sustainability depend on the current estimated consumption rate of firewood and the population growth rate remaining constant or decreasing. The weaknesses of this projection are that, random events such as changes in human migration (inward and outward), droughts, land use change patterns and increased settlements and their formalization may lead to associated changes in natural resource consumption rates. There is also a level of uncertainty with the long-term projection (year 2100) of natural resource use due to socio-economic, technological, political and environmental change. The use of firewood as a fuel has not diminished in South Africa inspite of increases in electricity supply and changes in the political landscape (Madubansi and Shackleton 2007, Matsika *et al* 2012). This is largely due to the initial and maintenance costs in purchasing appliances and continuous monthly payments (Williams and Shackleton 2002). These costs are unaffordable particularly to rural households who experience high unemployement rates and are largely dependent on government grants and remittances. In comparison to electricity, firewood is relatively cheap because it is freely or cheapely available from the forest and remains the primary fuel for cooking and heating in rural areas (Madubansi and Shackleton 2007, Giannecchini *et al* 2007). The assumption therefore that low income households will continue to use firewood as long as it is available stands. However, annual household use may decline since 93% of Acornhoek households now have access to electricity and more people may slowly begin to use it particularly for cooking and heating.

The use of sustainability indicators linking population growth and firewood use is limited by a lack of futuristic forecasts of changes in energy use as the Acornhoek population evolves into a more settled urban society. Customised indicators could be developed to investigate this situation and this data collected independently. The use of population growth/firewood use in isolation provides a rather simplistic view of issues that affect natural resource use patterns at Mariepskop.

3.5 Conclusion

Using international indicators to guide the creation of local indicators is an assessment approach that can be easily applied to other small mountainous areas to get an understanding of the level of sustainability. This approach could particularly be useful where there are time, budget and capacity constraints. Using this approach, a better understanding of sustainability issues in the study area was attained at Mariepskop. In this case, because international indicators were matched with, simple local indicators (water and firewood use) which were easily applied to analyze the level of local sustainability. Applying international indicators to local situations is, however, not always straightforward because of spatial differences, varying scales, social and economic dynamics and data availability. Selecting the international indicators to apply at local level can result in delays because a comprehensive evaluation is needed to probe the quality of information resulting from data analysis. Inconsistencies between the results of different types and levels of indicators must therefore be noted.

Local indicators are more effective than international indicators at probing sustainability at the local level because local indicators can be designed to be highly relevant to local people and make use of locally available data. In the end, actual data has to be collected independently of government, as government data may not be available, accurate or at the correct level. For more complex analysis of local situations, it is suggested that well-designed local indicators, rather than international (or even national) indicators, are used to monitor sustainability at the local level, using local data that is collected in the medium to long term. Household and landscape surveys and water assessments can be used to complement situations where existing national or local government data is not available. The development of specific local indicators along with independent data collection is key to developing long-term local monitoring systems and databases for localities like Mariepskop/Acornhoek since data collected by government on environmental sustainability data is difficult to access or often unavailable. Furthermore, local community participation is important in the development of these local sustainability indicators so that the pertinent issues in the area are adequately presented and monitored using the indicators, particularly those relating to well-being. Long-term monitoring and data collection will ultimately result in actual trend analysis and the development of more precise future projections.

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4

Conclusions and Recommendations

4.1 Socio-economic characteristics have been important drivers of environmental change at Mariepskop

One of the objectives of this study was to analyse the Mariepskop Mountain resource use patterns of Kampersrus, Acornhoek and commercial farmers and how these vary due to socio-economic status. The results revealed definite differences in the three communities' resource use patterns as a result of socio-economic characteristics. The Acornhoek households relied more on a wide range of essential ecosystem services such as water, firewood and wild edible plants whilst the commercial farmers depended on the water mainly for irrigation. On the other hand, Kampersrus community was largely dependent on the mountain for cultural ecosystem services such as recreation and aesthetic beauty.

The nature of socio-economic and ecological systems interactions is that of interdependency. Changes in the socio-economic status and characteristics of households link to alterations in natural resource use patterns and ultimately in the state of ecological systems. The socio-economic characteristics of a household or community determine the type of relationship or interaction that develops with its environment. These interactions are usually complex and multidimensional due to the complex nature of socio-ecological systems (Vidal-Legaz *et al*. 2013).

The second objective of this study was to identify the major drivers of this study, their interactions and the estimated value of Mariepskop ecosystem goods and services. Poverty has emerged as one of the main drivers of elevated use of essential natural resource, including, firewood, poles, and wild edible plants from studies by Twine 2011 and Debela *et al.* 2012. Our study found that though poverty did have a significant influence on most resource use patterns, it had little influence particularly on the use of firewood and water. The use of these two natural resources was found to be high across all income groups in Acornhoek. Given that the Acornhoek survey found that 93% of the households had electricity, this basically means firewood is still the preferred source of energy probably because it is primarily cheaply available from the mountain and the overall prohibitive costs of using electricity. The Mariepskop Mountain is the main source of firewood for the Acornhoek community and an increase in the number of households in Acornhoek can eventually lead to increased pressure on firewood resources from the mountain threatening overall sustainability levels. The assessment of current and future sustainability of the Mariepskop Mountain and Acornhoek and the value of using international and local sustainability indicators was the third aim of this study.

The cumulative effect of increasing numbers of Acornhoek households harvesting forest resources is likely to reach unsustainable proportions by increasing pressure on ecosystems. What is sustainable for a 1 000 households may not necessarily be sustainable for 50 000 households at Mariepskop. The impacts of scale increase as population increases because of elevated resource demand, waste generated and impacts of resource extraction on the environment, hence the importance of monitoring population growth in the mountain area and finding alternate livelihoods for people.

Currently, extraction of resources particularly through deforestation on the Mariepskop could be the main contributor to short and long-term ecological changes on the mountain in the future. Consequently, long-term ecological changes would affect the ecosystem goods and services flow and quality including the availability of livelihood opportunities. Through an analysis of some of these interactions, this study highlighted the undeniable relationships between socio-economic characteristics, resource use and sustainability levels on and around Mariepskop Mountain.

Livelihoods, food security, income and natural ecosystem linkages are important in assessing resource use patterns and ecosystem sustainability. This is primarily because households do not only use mountain landscapes as natural safety nets, and natural insurance, but in order to diversify their livelihood portfolios (Debela *et al*. 2012). The value of natural resources is evident in Mariepskop where some Acornhoek households are engaged in the commercialisation of firewood, poles and sand since the mountain ecosystem services have high monetary values in this local economy.

A study by Minja (2015) in Tanzania showed that in a community living adjacent Mt Kilimanjaro, education was identified as a climate change adaptation strategy (Minja 2015). Though the levels of education are improving in Acornhoek, only 26.8% of the population who had left school had written their Grade 12 examinations and only 5.6% had continued with tertiary education (StatsSA 2011). The study by Twine and Hunter

(2011) shows that during difficult times, households are likely to replace purchased goods for non-purchased natural goods and also reduce investment in human capital, for example, education, to save money. In terms of both climate change preparation and sustainable development, education levels must improve. Poor investment in social capital coupled with lack of access to basic sanitation facilities and potable water reduces the level of human dignity and social cohesion, negatively affecting both social and ecological systems (Adger *et al*. 2003).

4.2 Spatial interdependency and sustainability

According to Banks *et al.* (1996), households with limited access to resources resort to purchasing firewood from vendors, whilst consuming fewer wild edible plants (Shackleton *et al.* 1998). Similarly, people living near the Mariepskop Mountain have greater access and use of the mountain resources in comparison to those that live further away. The collection of firewood, poles and wild edible plants from the Mariepskop decreases significantly as distance of households from the mountain increases. After 15km from the mountain the number of households collecting mountain resources markedly decreases. As a result the overall benefit from the mountain as a source of energy, livelihood and safety net is largely determined by the distance of the household from the mountain. Due to the ease of access, households close to the mountain tend to frequent the mountain more, increasing their ecosystem goods consumption rates. Those living further away are likely to make fewer trips because of the time and effort it takes to access the mountain.

Due to the factor of distance from the resource, it is those households nearest to natural resources that are likely to be part of cooperative structures responsible for managing natural resources described by Komakech (2013*).* The idea of cooperative structures created by the communities with vested interests in certain common pool natural resources to manage the extraction and use of resources more equitably and sustainably is not new (Gillitt *et al*. 2005; Komakech 2013). The establishment of these structures usually occurs when resource users begin experiencing water stresses threatening their economic developments and livelihoods (Muchara *et al.* 2015). In the past, such initiatives would in most instances fail due to external influences usually through funding, poor financial management, and poor communication (Ndou 2012).

These particular types of cooperative structures are more likely to become successful as they are initiated and managed by the affected stakeholders and rarely have external interferences. The specific natural resource and its value is important to the livelihoods of all stakeholders who have to participate in the planning and decision making processes in order to benefit.

4.3 The importance of long-term mountain research and data

The application and use of customized local sustainability indicators is a useful management and decision-making tool to identify areas or resources under threat, and develop early warning systems to counter the negative impacts of over-use. This can also be part of an overall climate change adaptation strategy. An assessment of the usefulness of selected sustainability indicators to Mariepskop and Acornhoek was made possible by data from included in SAEON studies.

One way of countering the poor quality of local data is to work with local government structures to inform them of the types of data that are needed for long-term monitoring and determine the most practical monitoring methods to gather this data, including who must collect the data. In some situations, citizen science, which is where environmental data is collected analysed by community members, can help gather certain types of data (Cohn 2008), but in other situations, scientific methods and equipment are needed to provide data of a reasonable quality. The advantage of monitoring and the establishment of long-term monitoring and database systems can then be explained to local governance structures, allowing for the investigation and analysis of all possible trends, linkages, interactions and processes. Long-term data helps monitor ecosystem changes as a result of anthropogenic activities, human behaviours and attitudes, and can determine whether society is sustainable or not.

Social, economic and environmental aspects of a society are dynamic and ever changing. Therefore, to get a holistic picture of the local sustainability issues, problems and challenges, these aspects have to be monitored consistently through the use of localised sustainability indicators and a long monitoring period. The successful application and monitoring of sustainability indicators requires support from local institutions such as the municipality, in the form of financial resources and expertise in order to facilitate good quality data collection. This type of assessment, using local indicators to probe sustainability at Acornhoek, also highlights the role or lack thereof of local institutions such as the municipality, tribal councils and the government departments. The use of relevant local sustainability indicators is a sound method of determining the state and future sustainability trends in ecosystems and development through analyzing resource use patterns and actual trends.

This study has revealed that international sustainability indicators may not necessarily be adequate or relevant for application at the local level, although they may guide the development of local indicators. Although the international indicators for the MDG and SDG (still under consideration) were developed using high level international stakeholder and specialist consultations, they may not necessarily reflect the needs and issues of individual communities, which may limit their use at a local level. This means that a thorough assessment or localization of the selected international sustainability indicators which may include economic, environmental, socio-cultural and governance indicators, needs to be done prior to their local application. This customisation process may also lead to the development of other sustainability indicators that are more specific and relevant to that area. The involvement of stakeholders, communities and decision makers in the process of indicator customization and sustainable development monitoring is of paramount importance in holistically addressing sustainability challenges. As well as local needs assessment and stakeholder opinions, there is a need for both local knowledge and scientific information from research on natural resource use to make better local decisions relating to long term sustainability in society.

4.4 Ecological changes at Mariepskop

In most rural areas, household livelihoods are closely linked to the landscape and its resources and in the long-term household resource use patterns shape landscapes and the resulting environments. Most landscapes and ecosystems are under threat from over-utilization and the state of stressed landscapes may be exacerbated by climate change. The rainfall gradient shows higher rainfall towards the Mariepskop Mountain, and this increases wild edible plant availability (Shackleton *et al*. 1998). There are concerns that climate change will impact rainfall distribution and availability, negatively impacting vegetation density and affecting the households dependent on it. It must be said that human beings have adapted to natural climate variations for centuries (Adger *et al*. 2003), but contemporary increments in temperatures due to anthropogenic global warming are unprecedented (IPCC 2007). South Africa has been projected to have increased flooding and drought events as a result of warmer temperatures (DEA 2013).

Resource use monitoring as an input into future projections of the sustainability of mountain resources at Mariepskop are important because Mariepskop is a vital source of natural resources for the Acornhoek community (wood, water and vegetables from the wild) and commercial farmers (water). Monitoring of a wide range of issues and determining trends will also be important for any local climate change adaptation efforts at Acornhoek and Mariepskop.

The survival of rural households depends on their ability and capacity to adapt to environmental change by devising coping mechanisms to buffer them from shocks (Debela *et al.* 2012). Since climate change may diminish or eliminate the capacity of the ecosystems to continue forming a substantial part of rural livelihoods and safety nets, it is important that new coping strategies be employed (Debela *et al.* 2012). Households will have to alter their resource use patterns by for example, using firewood more efficiently, embarking on reforestation programmes and shifting towards cleaner renewable sources of energy. This would require a multidisciplinary and participatory approach to mobilize environmental awareness, initially to transform the attitudes and behaviour of local households towards adoption of alternative sources of energy (Liu *et al.* 2010) and implement cleaner energy programmes. This is also an activity that is the responsibility of municipalities as energy providers to their residents. The support of business sectors to provide alternate energy would also be necessary, particularly in developing countries where governments are constantly experiencing cash flow problems and cannot provide energy infrastructure (Liu *et al.* 2010).

The strengthening of environmental governance structures, whether by government, traditional councils and local communities, or NGOs, and understanding crucial local socio-ecological linkages is a primary component of improving long term sustainability levels in the Acornhoek society and ultimately maintaining the ecosystem goods and services flowing from the Mariepskop Mountain to the surrounding communities. This is likely to be true for all communities that still rely on natural resources for all or part of their livelihood.

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Appendices

Appendix 1: Official local data sources, other studies and gaps linked to sustainable development monitoring at Acornhoek and the Mariepskop river basin

Factor to be monitored	South African census data (and how the data are measured)	Other sources of data (government, academic, NGO)	Reliability, and availability of data	Information gaps for identified in this study	Contribution to attainment of sustainability?
Municipal population	Household count (2001, 2011)	South African national census 2001 and 2011	Reliable as census is done per household. However, the changing municipal divisions and sub-places , and place names makes it very difficult to compare between census sets	Unofficial migrants and transient settlers may not be accurately enumerated	Larger populations require more ecosystem services and produce more waste, may be less sustainable in total, while fewer households may be sustainable and have a low impact on environment
Household income	Household population count	Census 2001 and 2011 and household academic research	Reliable as actual household data used in census	Only households in villages closest to the Mariepskop were surveyed during the academic research	Income directly affects natural resource use patterns, with poorer households tending to use what they can harvest for free. With too many poor households, a greater impact on the natural resources will occur, and this may be unsustainable in the long term
Access to energy	Households with access to electricity enumerated in census. Alternative sources of energy e.g. fuel wood, paraffin, candles noted by census	Eskom and Dept of Minerals and Energy data, Census 2001 and 2011, academic research	Relatively reliable as Eskom sells electricity directly to municipalities	This study used household surveys to calculate of the quantities of wood households use in Acornhoek., There are also Illegal electricity connections which may not be captured in municipal surveys	Access to electricity may reduce the amount of firewood used and deforestation rate
Cultivated areas per household	n/a	Research, household survey, e.g. Studies by NGOs, municipalities	Unreliable, cultivation may not be carried out yearly due to lack of horticultural inputs	Information on crops grown e.g. maize, sweet potatoes does not seem to be collected systematically, and types of crops and yields may vary seasonally. Yields often affected by drought and lack of irrigation, but no data available on this at the subsistence level	Subsistence farming will affect natural resource use patterns as people are more self-sufficient, and successful farming may reduce dependency on mountain resources and create more human wellbeing, an indicator of sustainable development
Type and quantity of water supply to household, or collected by households	Sources of water for households – collected by census	Household research for estimated quantities of water used daily/annum. (Academic research)	Water sources and use may change due to seasonality, water availability	Little data on the informal water sources (unprotected water) for household use	Access to adequate and portable water reflects household well-being which can be considered as a measure of sustainable development. As Acornhoek expands in population, water demand will increase provision of households with potable water, necessitating a revision of the water storage and reticulation capacity in the area
Downstream water quality	Not collected by census	Department of Water and Sanitation (DWS)	Reliable if collected accurately and consistently	Data for particular areas may not be available, accurate or consistent	Levels of pollution reflects the sustainability of use of the aquatic ecosystem

Household food security	Census household data on access to adequate food	Food security studies by HSRC, AFSun and others for the Acornhoek area	Reliable if consistently done at household level, taking into account mid-season and annual droughts, households shocks (deaths, loss of jobs) and the types of persons in the household (aged, HIV patients, children)	Crops such as sweet potatoes, maize, vegetables and fruit trees are grown in a portion of the household plot to save money spent on grocery purchases, but no actual data is available on yields, nutritional value And contribution to food and nutritional security	Food security impacts natural resource use and dependence, with people harvesting more items from the wild to increase their food security, including rodents, insects and wild plants (Twine and Hunter 2011)
Governance (Social Cohesion, Social Assets - societies and associations in Acornhoek)	Not surveyed by census	Ward structures and local municipalities may have this information on burial societies, food garden projects, sewing circles, religious groups, soccer clubs, youth groups	Moderately reliable, membership does imply being active in the club	The same groups of people may be involved in many associations which may not be representative of the whole community	Social cohesion may affect natural resource governance, accessibility and use patterns and the involvement of residents in resource associations (e.g. water committees) may indicate shortages and a need for collaborative management of the resource
Land degradation and clearing of natural vegetation	Not surveyed by census	Remote sensing and academic studies	Unreliable unless verified	Lack of more recent data and verification surveys	Degradation reduces the amount and quality of ecosystem services and can hinder sustainable development, as practised through agricultural activities. Degraded landscapes can be restored
Mountain resource economics	Not surveyed by census	Academic research on the value of ecosystem services from the Mariepskop Mountain	Reliable as qualitative estimations done on household dependence on the natural resources (water, firewood, raw materials, wild edible plants)	Difficult to measure ecosystem services or their value	Decision makers pay more attention when economic value is placed on mountain resources their contribution to people's livelihoods