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ECONOMIC EVALUATION OF POSSIBLE LOSS OF PROSOPIS PODS AS A RESULT OF BIOLOGICAL CONTROL IN THE NORTHERN CAPE PROVINCE, SOUTH AFRICA

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DEDICATIONS

I dedicate this to my late great sister, “Tinevimbo Zvidza” ***lala ngokuthula dadewethu***. You will always be in my thoughts and memories.

DECLARATION

I, hereby declare that this thesis is my original work, and has not been submitted in partial or entirety for degree purposes to any other university. All the work that was written by other authors and used in the thesis is fully acknowledged.

Submitted for the Master of Science degree in Agricultural Economics at the University of Fort Hare.

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ABSTRACT

Species of Prosopis (Mimosaceae), or mesquite, are native to the Americas and introduced in South Africa as agro forestry trees to provide wood, fodder and shade in the late 1800s. In the Northern Cape Province, these trees have been particularly used for their pods by local farmers and local industry. However due to Prosopis' ability to spread rapidly there has been increasing pressure to step up control of the tree. Due to the costs associated with most control methods biological control has been singled out as the most viable control method worth pursuing.

This thesis attempts to explain and shed light on the effects that increased biological control of Prosopis would have on the farming community and Prosopis based businesses in the area. Two hypothetical scenarios were used, the first being a possible 50% reduction in available pods and the other a possible 100% reduction. In an effort to explain these effects data was collected from a series of collection activities in the form of a pilot study and two unique questionnaire surveys. Twenty-seven farmers and one Prosopis based business were interviewed at random with the data analysed and documented.

Results showed that the business community is the main user of pods incurring crippling losses in the event of a 50% or 100% decrease in available pods. Using control costs from working for water De Aar long term costs of the presence of Prosopis were estimated and compared to the estimated provincial cost of losing pods giving a cost comparison ratio of (α)270 million : Y(N(15.7million)). Only 48% of the respondents valued pods and 11% had traded in pods, the top concern resulting from the invasion was the loss of underground water. With a 50% decline in available pods, all respondents indicated unchanged effects. However empirical results showed that with a 100% decline in pods estimate losses of R 5 818 per farm are expected. The cost comparison ratio showing the losses farmers bore with Prosopis in the area and the losses they would suffer with a 100% decline in pods was R11 389 + (K): R5 818.

In light of the empirical results, policy recommendations that support the introduction of more effective biological control agents have been made with areas for further research identified and discussed.

Key words: *Prosopis* mesquite, *Prosopis* pods, Biological control, pod based businesses, farmers, Northern Cape Province, Working for Water.

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LIST OF ACRONYMS

WfW :	Working for Water.
DWAF:	Department of Water Affairs and Forestry.
NCPG :	Northern Cape Provincial Government.
CBA :	Cost benefit analysis
WTP :	Willingness to pay.
CSIR :	Council of Scientific and Industrial Research
CRC :	Co-operative Research Centre.

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CHAPTER 1

INTRODUCTION

1.1 BACKGROUND STUDY

Increased attention is being directed towards the biotic homogenisation of the earth's surface due to the anthropogenically induced breakdown of major bio-geographical barriers that have historically kept floras and faunas of the continents distinctive (Mooney & Hobbs, 2000). This mixing has resulted in aggressive species devastating the endemic biota of specific regions. These aggressive species commonly known as alien invasive species or biotic invaders exert a toll on ecosystem diversity, processes and services (Turpie, 2004b). In South Africa, for example, the first environmental problems associated with floral species that are not indigenous to South Africa were documented in the early 1900s (Macdonald, 2004). The introduction and spread of non-native species has become a global ecological and conservation crisis (Mooney & Hobbs, 2000). Invasive alien species are defined by Mack, Simberloff, Lonsdale, Evans, Clout & Bazzaz (2000) as

'Biotic invaders are species that establish a new range in which they proliferate, spread, and persist to the detriment of the environment'.

Ancient trade in domesticated animals led to the start of the introduction of non-indigenous species and parasites. Deliberate examples of the introduction of non-indigenous species include the introduction of crop, woody tree and forestry species and the introduction of fish species for game fishing or aquarium plants for aesthetic value. Accidental introductions include rats being inadvertently transported on ships to remote islands, or invertebrate marine species that are transported on the hulls of ships and in ships' ballast and deposited at new sites (Mack *et al,* 2000).

Prosopis the topic of this thesis is a perennial deciduous thorny shrub or small tree that can grow up to 10 m tall; with a trunk up to 1.2 meters in diameter; with various species distributed throughout the world (Pasiecznik, Harris & Smith, 2004). *Prosopis juliflora, P. pallida*, *P. chilensis, P. alba, P. pubescens* and *P. tamarugo* are species that are native to the Americas, but have now become established in arid and semi-arid Australia, Africa and Asia. *Prosopis cineraria* is native to India, whilst *P. africana* is native to the Sahelian belt of Africa (Dulloo, Kell & Jones, 2002)**.** Ross (1975) recognized three species *of Prosopis* in southern Africa, namely *P. pubescens* Benth., *P. velutina* and *P. glandulosa* J.

Torrey which includes two subspecies, *P. glandulosa* var. *glandulosa* J. Torrey and *P. glandulosa* var. *torreyana*. Poynton (1987) added *P. tamarugo* F. Philippi as a recent introduction that is confined to two or three localities. Harding (1987) has recognized six taxa that have become naturalized in southern Africa, namely *P. chilensis, P. pubescens, P. juliflora* (Swartz) DC, *P. velutina, P. glandulosa* var. *glandulosa* and *P. glandulosa* var. *torreyana.* All except the first two have become invasive, with *P. velutina* and *P. glandulosa* var. *torreyana* causing the most damage.

The economic impact from introduced species can be costly. It was estimated in 2000 that the in United States, total costs from invasive alien plant species was US$ 24 billion (Pimentel, Lach, Zuniga & Morrison, 2000). According to Van Wilgen, Little, Chapman, Willems, Marais & Gorgens (1997), in South Africa, based on actual costs incurred by the Working for Water Programme in the Western Cape clearing costs amounted to R1475/hectare for dense infestations of *Prosopis* species.

Without careful management, *Prosopis* can invade open areas, resulting in very high densities of small trees. As livestock have great fondness for the high-sugar-content pods, and as their chewing mechanism only serves to scarify the seeds in the pods, hundreds of seedlings may germinate from a single pile of horse, sheep, goat or cow dung (Da Silva, undated). As a result, without effective control, pastures may develop thousands of young *Prosopis* seedlings per hectare.

Studies by the World Agro-forestry Centre (W.A.C) (2007) revealed that thickets of *Prosopis* have established in grazing lands, croplands and along river courses, alarming farmers and conservationists in the Northern and Western Cape provinces of South Africa. Harding (1988) conservatively estimated that infestations of *Prosopis* covered 180 400 ha in the Western and Northern Cape, with 62% occurring in low-lying plains which are flooded occasionally, and the rest in depressions and river courses. The total area suitable for invasion by *Prosopis* is estimated at 935 000 ha in the North and Western Cape (Harding, 1988).

1.2 PROBLEM STATEMENT

Prosopis species have invaded the Northern Cape Province of South Africa, bringing with them environmental consequences. Biological control of this invasion has been restricted by the continued use of *Prosopis* pods by local farmers and industry. This conflict of interests has left the local farmers needing convincing to adopt more effective and efficient control mechanisms, which are available but have not been considered due to the suggested value of the pods.

1.2.1 RESEARCH GOALS

This thesis discusses the hypothetical possibility of biologically controlling *Prosopis* through the reduction of the amount of pods produced by the individual plants. This control possibility is accompanied by economic and environmental advantages, but losses would also be realised by the users of *Prosopis* pods, namely, local farmers and pod based businesses. The research seeks to highlight and explain the costs accruing to the different respective pod users making use of descriptive statistical tools and techniques where necessary. Thus, explaining if the introduction of the biological control agent is economically justifiable.

1.2.2 OBJECTIVES

- Determine economic loss accruing to the farmers due to a 0%, 50% & 100% reduction in available pods.
- Explain the effects of biodiversity loss due to the *Prosopis* invasion.
- Explain the effects of losing water resulting from the invasion.
- Determine the costs that could accrue to the farmers and the business community in the event that a more effective agent like a flower feeder is introduced.

1.3 HYPOTHESIS

The main hypothesis of the study is that *Prosopis* species have become invasive weeds, and there is need to control the weed and keep its negative effects on the environment in check. In the presence of flower and bud feeding agents it is possible to control *Prosopis* more effectively and hypothetically reduce the seed production by 50% or 100%. However, the reduction of pods or seed will see pod consumers or users losing out.

1.3.1 SPECIFIC HYPOTHESIS

- After the introduction of a more effective biological control agent (flower and bud feeder), the province at large is better off than in its absence.

South Africa is water scarce country endowed with immense biodiversity thus; *ceteris paribus* the environmental and economic advantages that would be realised from a reduction in pods, which are the main source of the invasion are likely to outweigh the gains from utilising pods.

1.4 RESEARCH QUESTIONS

The research seeks to answer the following questions:

- What is value of *Prosopis* pods in the study area?
- What are the economic implications of a 0%, 50% and 100% reduction in *Prosopis* pods to farmers in the area?
- What are the economic implications of a 0%, 50% and 100% reduction of *Prosopis* pods to the local business community and the province at large?

1.5 JUSTIFICATION OF THE STUDY

Antrobus & Law (2005) showed that there is increasing awareness of the importance of biodiversity for sustainable living. Firstly, at the level of individual households and firms, decisions concerning what to consume and what and how to produce goods and services can have important implications for the long-term sustainability of society. Secondly, policy makers need to be persuaded that actions to maintain, let alone that serve to increase biodiversity, are worthy of being 'on the agenda' and deserve the diversion of funds from other social and economic needs of the nation.

Van Wilgen, Richardson, Le Maitre, Marais & Magadlela (2001) observed that one of the unique aspects of invasive plant control programmes in South Africa has been the ability to leverage further benefits (mainly through employment) for the expensive control programmes from the government's poverty relief budget. This has made it possible to allocate substantial funding to a programme that would otherwise have struggled to obtain significant support.

The Working for Water Programme (WfW), was launched in South Africa in 1995 aimed at clearing and controlling alien vegetation in conservation areas, water catchments and riparian habitats and providing employment for jobless people (Turpie, 2004a). The removal of alien vegetation from catchments and river courses is a highly cost-effective way of delivering additional water. Earlier in the implementation of the programme for clearing alien trees from river courses, through mechanical and chemical means (felling and removal or burning of alien plants - most importantly, acacias, pines and eucalypts - and the prevention of coppicing by the application of herbicides), it was realised that a major weakness was the re-growth of weed populations, mainly from seeds in the soil, in areas previously cleared (Impson *et al*, 1999). This led the Working for Water authorities to place special emphasis on biological control as an essential element of any long-term integrated control strategy.

In South Africa, the control of *Prosopis* has been restricted to bruchid beetles (*Algarobius prosopis* (Le Conte), *Algarobius bottimeri* (Kingsolver), and *Neltumius arizonensis* (Schaeffer) due to conflicting interests as the tree continues to be used for its pods and other beneficial attributes (Coetzer & Hoffmann, 1997). Due to the current redirection of control efforts towards biological control, there is need to highlight and explain the economic implications of loss of certain environmental goods due to increased control. Livestock farming constitutes a main source of livelihood for farmers in the Northern Cape; harsh climatic conditions have left *Prosopis* pods as a main food source for this livestock. Hence, pod loss may compromise production of livestock. In Mexico, the increased use of *Prosopis* pods is of considerable importance under intensive livestock production systems and the scope for using innovative feeding systems in order to increase rearing efficiency is enormous (Acharya, 1990).

Prominent environmental researchers such as Zimmerman have considered the possibility of foregoing *Prosopis* pods as a food source. It is essential to consider the effect of the loss of *Prosopis* pods to the affected stakeholders in terms of associated costs and implications. WfW in De Aar has embarked on an aggressive control approach towards *Prosopis*, however, current efforts are frustrated by re-growth *(*Pillay, 2008 pers comm). The presence of bud and flower feeders like *Calliplora sextrigella* and *Asphondilya prosopidis* (Rodgers, Clarke & Burke, 1975) allows the possibility to control *Prosopis* more effectively.

1.6 METHOD TO BE FOLLOWED

Using a questionnaire-based survey, the research attempts to quantify the projected economic loss that would accrue to the pod users because of pod loss. Costs incurred by the farmers after the loss of pods would include increased animal feed costs and transport costs. Using random sampling techniques the research makes use of the sample data and descriptive statistics to estimate and highlight the economic implications and loss that would accrue to the entire study area.

1.7 STRUCTURE OF THE STUDY

Chapter 1 introduces the *Prosopis* situation in the Northern Cape and the research questions. Chapter 1 further presents the aims of the study, the basic assumptions and strives to provide a golden thread throughout the whole research work. The actual theoretical framework and evaluation work is presented at each research stage separately later on in the text; the chapter further describes the structure of the study. The specific hypothesis is also stated in this chapter.

The overview of the *Prosopis* situation is given in chapter 2 beginning with the origin of invasive alien plants. The advantages and disadvantages brought about by mesquite are discussed in this chapter together with a biological control overview. The biological control agents are classified and highlighted together with a discussion of control efforts by stakeholders in the study area. Chapter 3 gives a summary of the tools and methodologies used in the research. The analytical tools to be used are also described and explained.

The data collection process is recorded in chapter 4; the steps taken in the data collection process together with the challenges faced during the process are highlighted. The chapter also shows the results of the study after the data collection process as decoded from the data collection tools. The discussion follows in chapter 5 where the research attempts to find out if the problem set out to be solved and the questions asked have been adequately addressed. Recommendations and areas for further research are identified and the study arrives to its logical conclusions in this chapter.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

The Conservation of Agricultural Resources Act of 1983 (Act No. 43 of 1983) (CARA), makes landowners liable for clearing invasive alien plants from their land. However, the reality is that due to the high costs involved, landowners are not able to comply unless the level of infestation is very low (Turpie, 2004a). To date the act has simply not been enforced, while in some cases government has supported landowners to clear invasions through the Working for Water Programme.

Andersson (2005) noted that invasive alien plants often have negative economic, environmental and / or social impacts. These include reduction of grazing areas, reduction of crop yield, threat to biodiversity, disruption of water flow, livestock poisoning and the formation of impenetrable thickets. However, in the case of *Prosopis* species local communities tend to make use of their pods for various purposes.

Many landowners in South Africa, whose properties have been invaded by *Prosopis* species, are increasingly concerned because not only have the plants formed impenetrable thickets with minimal by-products but the trees also have a long tap root system that utilises copious quantities of the scarce underground water (Impson, Moran & Hoffmann, 1999). The incremental water use of alien invaders in South Africa and Lesotho is an estimated at 300 m^3/yr or 6.67% of the mean annual runoff (MAR) (Le Maitre, Versfeld & Chapman, 2000). This is equivalent to 190 mm/yr (1 900 m^3per ha) for a closed canopy (i.e. based on the condensed area) and 33 mm/yr when calculated using the total invaded area of 10.1 million ha. The greatest percentage impact was found in the Northern Cape where water use by invaders, primarily *Prosopis*, is equivalent to about 17% of the MAR, or the equivalent of 910m^3/ha/yr, using the condensed area (Zimmermann & Klein, 1986).

In South Africa, employees of the national Working for Water Programme physically cut down the problem species. However, South Africa, like many other countries, also uses biological control against invaders. Since the 1800s, countries have tried intentionally introducing the natural enemies of invasive pests and weeds to attempt to suppress them or control their range (Van Wilgen *et al,* 1997). According to Van Der Heyden (1999), the Working for Water Programme aims to use biological control to its full potential, bringing as many weeds as possible under full or partial biological control, and to reduce the invasive potential of as many species with commercial value as possible, without affecting the ability to utilise them for commercial gain. The programme currently spends R15 million annually on biological control research, and has budgeted to increase this value. It aims to invest as much as necessary in biological control due to the high-predicted returns on investment (Van Der Heyden, 1999). However, biological control is not always effective, with only about 10-15 percent of the natural enemies of arthropod pests that are introduced succeed at controlling their targets and about 30-40 percent of biological control agents released against weeds are successful (Hill & Greathead, 1999).

According to Zimmermann & Klein (1986), invasive alien plant invaders have been estimated to cover 10 million hectares in South Africa, which represents about 8% of the surface area of the country. How much these alien plant invasions cost the country has not been determined, except in terms of water losses due to woody invaders (Versfeld, Le Maitre & Chapman, 1998). A process for determining and ranking 'Weeds of National Significance' was developed based on expert scoring of four criteria: invasiveness, impacts, potential for spread, and socio-economic and environmental values (Nel, Richardson, Rouget, Mgidi, Mdzeke, Le Maitre, Van Wilgen, Schonegevel, Henderson & Neser, 2004). The top twenty species thus ranked were selected to serve as a test case for improved co-ordination amongst affected parties in Australia.

A similar study in South Africa sought to prioritise invasive alien species based on their potential invasiveness, spatial characteristics, potential impacts, and conflicts of interest. Species were then ranked by summed scores of expert ratings to provide a means of prioritizing species for national action (Nel *et al*, 2004). There are, however, several limitations with such ranking exercises. There is no objective criterion determining a score sufficient to qualify a species for high-priority management action (Tucker & Richardson 1995). Comparisons are also difficult between species that occur over a wide range of different habitats, with varying levels of abundance and impacts (Nel *et al*, 2004).

Sixty-seven tree species from across the world (Table 2.1) are listed as invasive alien weeds in South Africa (Henderson, 1995). Of these, 32 are formally and legally recognised or proposed for legal recognition as weeds (their removal is required by law) or as invaders (their spread has to be controlled) (Impson *et al*, 1999). Twenty species of trees that are legally recognised as weeds have been the subject of, or proposed as targets for biological control (Table 2.1).

Table 2.5 The number of tree species from the Americas, Europe and Asia Australia and New Zealand that are listed as invasive weeds in South Africa

	AMERICAS	EUROPE/ASIA	AUSTRALIA/ NEW ZEALAND
Legally recognized or proposed for recognition	10(5)	8(3)	14(12)
Others	7(1)	17(0)	11(0)

The number of these species that are legally recognised or proposed for legal recognition (see text) as weeds or as invaders is given. The numbers in parentheses are the number of species that have been subjected to, or have been proposed subjects for biological control. Source: Henderson (1995).

Prosopis species produce leguminous highly nutritious pods that are consumed by livestock and are useful in various industrial processes (Pasiecznik, Felker, Harris, Harsh & Cruz, 2001). According to Coetzee (2008 pers comm), farmers in the Northern Cape Province of South Africa use *Prosopis* pods as animal feed with local industry also making use of *Prosopis* pods for chemical industrial processes and manufacturing inputs. Abdelgabbar (1981) showed mesquite as having great potential as a multiple-use resource in dry-land areas. However, further study is needed in the areas of pod production, nutritional qualities, management and values of native stands, plantation establishment, agro-forestry and silvo-pastoral systems, and economic comparisons of mesquite with other dry-land production options. Thus, *Prosopis* can be a useful source of animal feed, substituting or reducing, at much lower costs, the use of maize, soybeans, and wheat, all of which can be produced on only a very limited scale in the semi-arid areas (Da Silva undated). A comparison of the protein content of mesquite leaves and mesquite pods with other common feeds from the arid regions of Brazil is shown in Table 2.2 which illustrates the fact that mesquite has higher protein content than most common feeds from arid regions

Table 2.6 Comparison of Protein Content of Mesquite Products in Comparison to Other Products Common in Brazil

Description	Protein
Mesquite pods (*Prosopis juliflora*)	12.9
Mesquite leaves (*Prosopis juliflora*)	13.6
Manioc (*Manihot esculenta*)	1.6
Maize (*Zea mays*)	6.0
Alfalfa (*Medicago sativa*)	14.1
Guinea grass (*Panicum maximum*)	2.6
Spineless cactus (*Opuntia ficus-indica*)	0.4

Source: Da Silva (undated)

In India, people view *Prosopis juliflora* in a positive light; they use it for different purposes such as charcoal, furniture and construction. The bark can even be used as an antiseptic medicine (Sharma, 1981). In Niger, the view of *Prosopis juliflora* as a threatening weed has now changed and it is seen as a resource, the people have learned a South American technique to process flour from the pods, which is used for human consumption and as coffee substitute (Geesing, Al-Khawlani & Abba, 2004).

However, South African research by Zimmermann & Klein (1986), Impson, Moran & Hoffman, (1999), Turpie (2004b) has shown that invasive species like *Prosopis* have a negative effect on environmental variables such as biodiversity and underground water. *Prosopis*, therefore, is a livestock feed source while at the same time its presence may exacerbate ecosystem degradation and loss of environmental goods and services. These goods and services are difficult to quantify, although a number of non-market valuation techniques do exist, sound economic valuation techniques are yet to be developed that adequately place monetary values on the structures that allow for the evaluation of environmental goods and services (Law, 2007).

According to Zimmermann (1991), the propagation of *Prosopis* throughout many of the drier parts of South Africa was encouraged by the Departments of Agriculture and Forestry until about 1960, which contributed greatly to the initial introduction of *Prosopis* over a wide area.

Prosopis species like many other woody foreign plants were intentionally introduced to South Africa with the purpose of exploiting the possible benefits derived from the plant (Zimmermann, & Neser, 1999). *Prosopis glandulosa* var. *torreyana*, was reported to be the first species introduced into South Africa (Poynton, 1987). Alston (1914) stated that in about 1880 a few seeds of *P. dulcis* were sent to him by John Marquard for 'trials' on his farm near Vanwyksvlei (30°28'S 21°56'E), but the origin of the seeds was not recorded. *Prosopis chilensis* was first mentioned in 1884 in a report of the Cape of Good Hope, Departmental Forest Commission, stating that plants had been raised in the Hanover Forest (31° 05' S 24° 27'E) (Zimmermann, 1991). According to Poynton (1987), these specimens may have been *P. juliflora.* Mừller (1985) was more confident that *P. chilensis* was introduced into Namibia in 1912, but again the origin of the seeds was not recorded. Between 1897 and 1916, the Cape and Transvaal forest, administrations obtained 63 kg of seeds, which were ostensibly all *P. julifora,* in 23 different consignments from various public and private sources in the USA, Hawaii and Mexico (Poynton, 1987). It seems, however, most unlikely that only *P. juliflora* was represented in the consignments and, with the exception of *P. chilensis,* these seeds, were probably the source of most of the *Prosopis* species and their variants that arrived in South Africa (Zimmermann, 1991).

Through the years since its introduction, *Prosopis* has proved useful in restoring degraded and saline lands and producing a variety of useful products for the local populations. Harding (1988) estimated the *Prosopis* resource in South Africa to be worth R280million annually, if fully exploited.

The continued use of *Prosopis* for its beneficial attributes has limited the biological control programmes to the use of seed feeding bruchid beetles (Impson *et al*, 1999). Although certain species have become established, limiting biological control to seed destroying bruchids may not be the solution to the problem. It may also be necessary to consider bud feeding and flower feeding agents like *Calliplora sextrigella* and *Asphondilya prosopidis* (Rodgers, Clarke & Burke, 1975).

Conflicting interests in biological weed control have been an important determinant for the direction of South African alien vegetation policies. According to MacDonald, Kruger & Ferrar (1986), biological control of deliberately introduced species like *Prosopis* will always elicit strong opposition from specific interest groups. This problem is better addressed through consultation with the relevant interest groups and through their participation in research activities concerning the biological control of such target plants (Zimmermann & Neser 1999). The seed-feeding bruchid beetles were the biological control agents selected to manage the reproductive potential of mesquites, while preserving the beneficial attributes.

It is essential to assess the effectiveness of the biological control programmes implemented against *Prosopis* species. According to Huffaker, Simmonds & Laing (1976), a commonly used procedure in the assessment of biological control projects since the early 1930s is the calculation of benefit–cost ratios. The decision rule followed in the use of this tool is that the biological control is viable so long as benefits of the programme exceed costs. Nevertheless, it should be noted that such a decision rule does not give information on the economic viability of possible alternative control projects, and these should ideally also be compared according to the same decision rule before selecting an option (McConnachie, de Wit, Hill & Byrne, 2003). It is therefore necessary to calculate the respective ratios of other control projects in order to come up with a ranking system to observe adequately the most effective control project from possible available programmes.

Headley (1985) observes that it is often difficult to compare different benefit cost ratios unless they have they have similar costs and benefits categorisations. Despite these methodological differences, benefit–cost ratios have become increasingly important in describing the success and potential of the biological control method. The continuous ambiguity existing between scientific and economic data makes it difficult to use scientific data when devising economic conclusions (McConnachie *et al,* 2003). It is thus advisable to follow studies like Chippendale (2002), where an economic assessment and perspective on the biological control of noogoora burr (*Xanthium occidentale*) in Australia is given.

2.1.1 THE WORKING FOR WATER PROGRAMME

The recognition of the economic consequences of *Prosopis* and other invasive alien plants in terms of water supply costs and the general recognition of the scarcity of water were also pivotal in the establishment of the Working for Water Programme (WfW) in South Africa. Launched and administered through the Department of Water Affairs and Forestry (DWAF), this programme works in partnership with local communities, to whom it provides jobs, and with Government departments including the Departments of Environmental Affairs, Tourism and Agriculture (DWAF, 2008). WfW currently runs over

300 projects in all nine of South Africa's provinces operating on an annual budget of about US$70 million and employing about 42 000 people (DWAF, 2008).

The WfW Programme has been hailed as highly successful in terms of its objective of restoring water supply in alien-infested catchments (Macdonald, 2004) its exemplary nature has been acknowledged by several renowned authors and researchers. Hobbs (2004) calls it one of the most successful integrated land management programmes in the world, referring to the programme's impacts on biodiversity, water and socio-economic development. Mooney & Neville (2000) described the programme as an outstanding example of dealing with invasive alien plants in a holistic manner. Woodworth (2006) calls it inspirational in terms of the restoration of natural capital. Since its inception, the programme has cleared more than one million hectares of invasive alien plants (DWAF, 2008). Marais & Wannenburgh (2008) estimate that the clearing of invasive alien plants from riparian areas between 1997 and 2006 increased stream flow by nearly 46 million m^3 per annum. South Africa, which is still a developing country, is characterised by competition amongst social development projects for funding. Thus, in the light of such costly control projects, there is a need to justify further alien control programmes run by WfW and to maximise efficiency within the programmes.

2.2 PROBLEMS BROUGHT ABOUT BY INVASIVE SPECIES

2.2.1 THREAT TO BIODIVERSITY

Biodiversity is defined by the Oxford dictionary as

" the variety of plant and animal life in the world or in a particular habitat including the number of different species, the genetic wealth within each species, the inter-relationships between them, and the natural areas where they occur ".

Evaluating the monetary impacts of alien invasive plants on biodiversity requires a clear and common understanding of the meaning of biodiversity and its economic worth. Although the term biodiversity is often used in the sense of species richness, it should also encompass ecosystems functioning in tandem with natural systems or nature.

The realisation that alien plants are a threat to the ecology and biodiversity of South Africa is not new. According to Turpie, (2004a), early botanists, including Peter McOwan in

1888 and Rudolf Marloth in 1908, raised concerns about the potential of introduced plants to replace the natural vegetation. This came with detrimental effects though the problems were only considered serious in the later part of the twentieth century. The realisation that the unique natural and diverse Cape vegetation that covered the mountain slope was being replaced by alien plants brought about the need to clear invasive alien plants (Van Wilgen, Little, Chapman, Gorgens, Willems & Marais, 1997).

Moseley (2008) considers South Africa immensely rich in species diversity. With a land surface area of 1.1 million km^2, representing just 1% of the earth's total land surface. South Africa contains almost 10% of the world's total known bird, fish and plant species, and over 6% of the world's mammal and reptile species. This natural wealth is under threat from growing human populations, changes in natural vegetation through plant invasions and their demands on the environment.

According to Zimmermann & Neser (1999), ten million hectares of South Africa have been invaded by 180 alien species, but their impacts are not fully understood, although they are undoubtedly significant. The indications are that the total costs of these impacts are substantial. Studies by Chippendale (2002) and CRC, (2001) show that invasions have reduced the value of fynbos ecosystems by over US$ 11.75 billion. The total cost of invasion would be about US$ 3.2 billion on the Agulhas Plain alone; the net present cost of invasion by black wattles amounts to US$ 1.4 billion; the invasions by red water fern have cost US$ 58 million; and that the cost to clear the alien plant invasions in South Africa is around US$ 1.2 billion. It should however be noted that the methodologies that are used to calculate the costs of invasion are not universal and may have shortcomings despite this problem on the evaluation of the costs of invasive alien plants these few examples indicate that the economic consequences of invasions are huge.

South African research by Kaiser (1999) on alien plant impacts focused on small spatial scales (plots or communities), and much of this work has been in the fynbos biome. This research showed that dense stands of alien trees and shrubs in fynbos could rapidly reduce abundance and diversity of native plants at the scale of small plots. As regards mechanisms for this, studies in dense stands of Port Jackson willow (*Acacia saligna*) have documented the decline of soil-stored seed banks of native plants, leading to the local extinction of native species. The altered feeding behaviour of native generalist birds that disperse seeds, with likely detrimental effects on native species, has also been observed.

Vitousek, D'Antonio, Loope & Rejmánek (1997) suggest that the most damaging species transform ecosystems by using excessive amounts of resources (notably water, light and oxygen), by adding resources (notably nitrogen), by promoting or suppressing fire, by stabilising sand movement and/or promoting erosion, by cumulating litter and accumulating or redistributing salt. Such changes potentially alter the flow, availability or quality of nutrient resources in biogeochemical cycles; they modify trophic resources within food webs; and they alter physical resources such as living space or habitat, sediment, light and water. Thus, invaders compromise the natural functioning of ecosystems acting as ecosystem re-engineers. According to Higgins, Turpie, Costanza, Cowling, Le Maitre, Marais & Midgley (1997), certain species have more important roles than others species under one set of environmental conditions, others become important when those circumstances change. The loss of species, for example, owing to alien invasions like *Prosopis*, is thought to undermine the buffering role played by species considered less important. Ecological impacts of widespread invaders, mesquite included, are highlighted by Van Wilgen *et al* (2001) (Table 2.3).

Table 2.7 The ecological impacts of widespread invaders

Invader	Biomes affected	Disruption	References
Acacia Cyclops (T)	Fy,fo,sa	Change in costal sediments dynamics (O), change in seed dispersal dynamics(OD), provides nesting habitat for rare African penguins(OD), out competes native plants(OD)	Fraser (1990)Knight & McDonald(1991) RMJ Crawford unpublished data
Prosopis	**Sa**	**Increased biomass(O), change in vegetation structure, reduced land access, reduced pasture access and productivity, out competes native plants, reduced diversity of dung beetle assemblages.(OD)**	**Harding & Bate (1991) Brown & Gubb (1986) Steenkamp & Chown (1996)**
Pinus radiate	Fy	Reduced stream flow(OD)	Dye 1996

Source; Van Wilgen *et al* (2001)

T =tree, SW=woody shrub, SS=shrub, fo= forest, fy= fynbos, sa=savanna, O= observation without data, OD = observation with data.

Various goods and services are offered by different ecosystems and these may be undermined by the presence of alien invading plants like *Prosopis* species. In the Indian province of Gujarat lie the once high quality grasslands of Banni. A flat tableland without any significant gradient fluctuations, Banni was known for its excellent quality of grass prior to the introduction in the early 1950s of *Prosopis juliflora* on the fringes of Banni with the aim to stop desertification (Gujarat Ecological Society, undated). However, to date, *Prosopis juliflora* has invaded half the Banni. According to Gavali, Lakhmapurkar, Wangikar & Sharma (undated), prior to the invasion the *Maldharis,* a prominent community of the region dependent on livestock used to keep high yielding herds have resorted to large scale migrations with their livestock as a result of the invasion by exotic species and due to the degradation of the Banni grassland. Banni was also home to the Haubara Bustard (*Chalmydotis indica*), *Prosopis juliflora* degraded its grassland habitat and the bird is no longer found there (Gujarat Ecological Society, undated).

Costanza, d'Arge, de Groot, Farber, Grasso, Hannon, Limburg, Naeem, O'Neill, Paruelo, Raskin, Sutton & Van den Belt (1997) showed that ecosystems have been characterised as economic commodities in terms of goods and services. Goods are the tangible products provided by ecosystems, such as timber, and services encompass benefits such as those associated with ecosystem functioning, for example, water purification. Turpie (2004a) reveals that natural systems have economic attributes, such as biological diversity, which contribute to their potential, such as ecotourism value, or sense of place, adding to overall quality of life. Antrobus & Law (2005) further highlight the increasing awareness of the importance of economic implications of biodiversity for sustainability. These implications are observed at individual, household and firm level decisions concerning what to consume and how to produce goods and services with long-term implications on the sustainability of society. The understanding of the value of biodiversity in South Africa may be paramount in the argument for funding as other social departments take precedence (Turpie, 2003).

It is the role of the resource economist to estimate the economic values associated with biodiversity or natural systems, and to estimate how these values would change if these systems were to be altered in any way. According to Turpie (2004a), in ecological economics terminology, natural systems represent the 'natural capital' that, together with man-made capital and human capital, produces goods and services which are consumed by households in the economy. Thus, while the traditional view of the circular economy portrays the production of goods and services by firms (man-made and human capital), ecological economics recognises the important contribution made by ecosystems and the environment as a well.

Turpie (2003) observed these ecosystem services as having characteristics of ‘public goods’. Specifically, it is difficult to exclude downstream users from receiving the benefits of improved water quality and consumption of most benefits is non-rival in nature. Public Goods have two distinct characteristics

- non-rivalry: several individuals can consume the same good without diminishing its value
- non-excludability: an individual cannot be prevented from consuming the good.

Given these public good characteristics, it is difficult for the private sector to market or sell these ecosystem services.

Difficulty arises where the good or ecosystem service is one from which it would not be possible to exclude someone from using it, namely a public good. In the environmental sphere, examples of public goods are public parks, fresh water, clean air and biodiversity. Private markets do not usually produce efficient amounts of public goods and services because once produced it is difficult or impossible to make people pay for them (Antrobus & Law, 2005). The remedy for an insufficient production of public goods, such as biodiversity, is for governments to step in and produce the goods or to provide incentives for their production. This gives rise to the necessity for placing a value on biodiversity in order to move a convincing debate for its production. However, in this case the government would have to act to avoid the destruction of biodiversity as producing it is not possible.

While these ecosystem services are often without prices due to the inherent difficulties and controversies in valuing the intangible non-market values associated with biodiversity, they do contribute utility to individuals and therefore have value. According to Turpie (2003), market values of resources such as forestry or fisheries are often articulated; but the non-market values could be far higher. These non-market values include existence value, which, in its broad sense, is the utility that people derive from knowing of the existence of biodiversity, and from knowing that others and future generations also might be able to enjoy it. The existence value of biodiversity, although intangible, is often realised in the form of donations towards the conservation of biodiversity. Its magnitude can also be elicited in terms of willingness to pay (WTP) by means of stated-preference (Mitchell & Carson, 1989).

The structure and composition of biodiversity services is shown in Figure 2.1 beginning with the productivity component explained by the consumptive values, which are derived from activities such as livestock grazing or resource harvesting activities like gathering firewood. In addition, ecosystem functioning and consumptive value is realised at broader economic scale in water regulation, purification, and carbon sequestration, which are processes that provide value on a broad scale (Turpie, 2003). In addition, genetic diversity and organisation contribute non-consumptive recreational value, option and existence value (Costanza, 2006). Option value is a measure of potential future use of biodiversity.

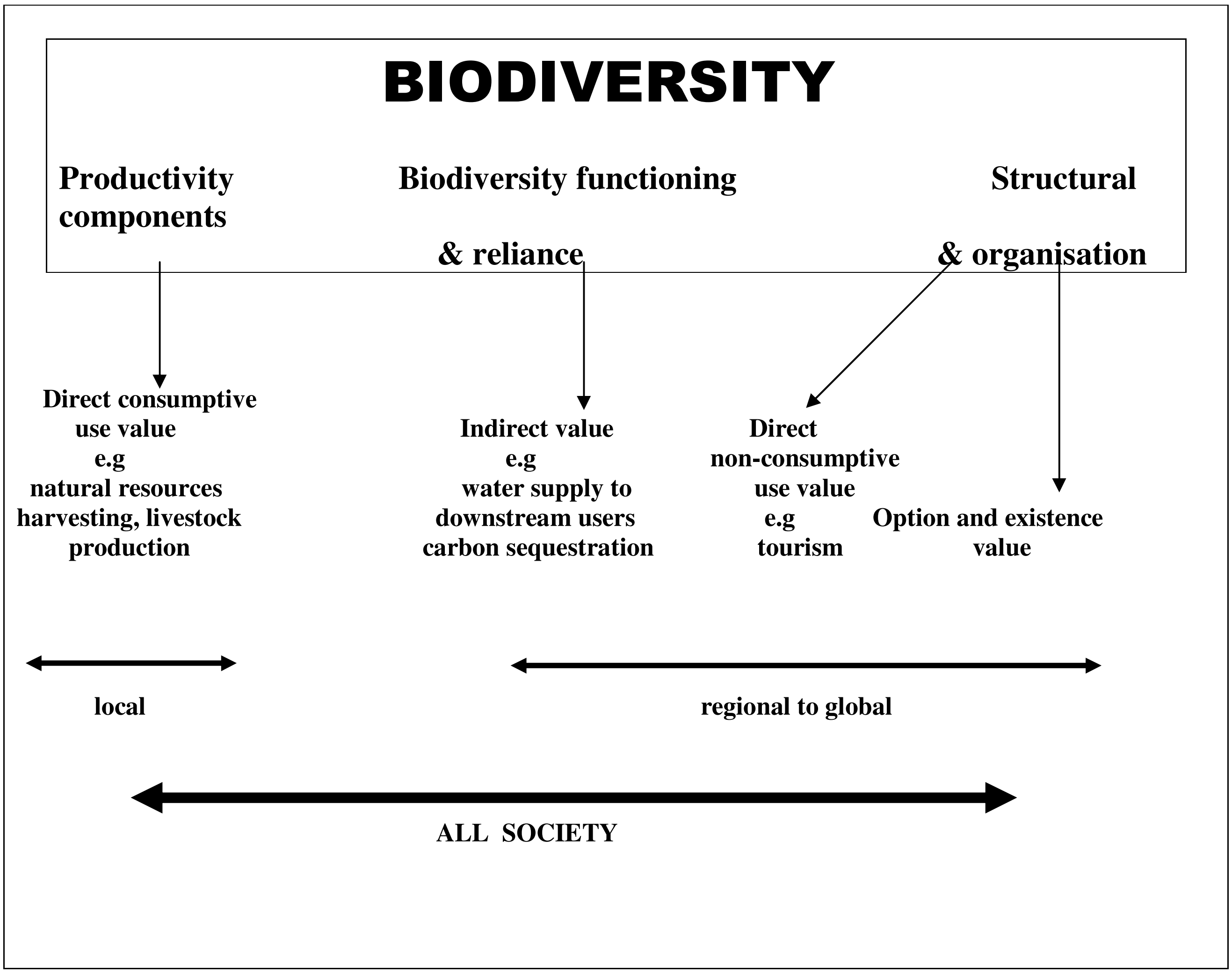

Figure 2.1 A modified view of the elements of biodiversity that contribute to Total Economic Value
Source Turpie (2004a).

All these services contribute to overall economic wellbeing and benefit society at both a local and regional to global level thus, their production is desirable. However, despite the widespread benefits of the biodiversity services, the market would fail to produce desirable amounts of these services due to their public good nature and because individuals have the incentive to free ride thereby not paying for the benefits they receive from consuming the biodiversity services. The following example illustrates the optimal provision of a non-excludable biodiversity service, the free-rider problem, and market failure.

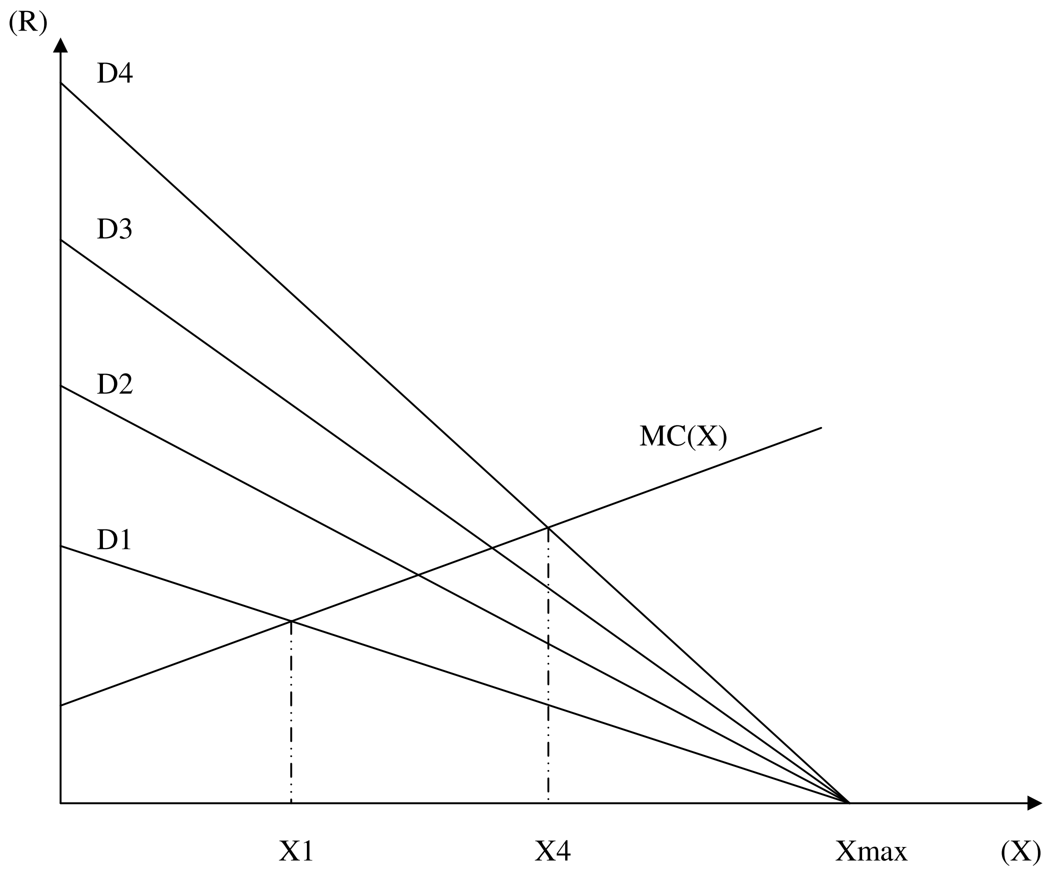

Figure 2.2 Illustration of different individual demand for a biodiversity service.

Where X represents indirect, direct non-consumptive and optional biodiversity value. (Shown in Figure 2.1) and R represents the price in South African Rands.

D1 = Demand of one individual for biodiversity service X.

D2 = Total Demand of two individuals for biodiversity service X.

D3 = Total Demand of three individuals for biodiversity service X.

D4 = Total Demand of four individuals for biodiversity service X.

MC= Marginal cost of providing the biodiversity service X.

The socially optimal level of biodiversity service X with four consumers is X4 if individual 1 decides to purchase and the others free ride, the private market will provide a level of the biodiversity service equal to X1 which is far below the social optimum. The nature of biodiversity services thus makes their evaluation difficult; hence, often their value is understated. Total economic value encompasses all the measures that affect human welfare (Turpie 2004a). Nevertheless, it is currently those values that are relatively tangible (direct and indirect use values, akin to goods and services) that carry any weight in the political arena where decisions on policies towards biodiversity are made.

South African ecosystems may be evaluated by examining the known consequences of invasive alien plants on biodiversity structure, composition and processes, which are the building blocks of biodiversity. According to Turpie (2004a), these building blocks are important and ultimately give rise to the direct consumptive use value of ecosystems (Figure 2.1). Since the Convention on Biological Diversity came into effect in 1993, there has been increasing international demand for rigorous methods for evaluating biodiversity one of the biodiversity services that sustains human life. Unfortunately, the evaluation of biodiversity is carried out in a haphazard and idiosyncratic fashion, with individual researchers and decision makers evaluating biodiversity in ways that satisfy their own research purposes and fit within the specific context of their chosen study site (Simonson & Thomas, 1999).

2.2.2 WATER LOSS

Water is essential for the development of any society; in 1992, the Dublin Water Principles claimed water as an economic good for the first time in a UN sitting (Rogers, de Silva & Bhatia, 2001). Water had however been recognised as an economic good for many centuries before 1992. Throughout Europe and the early United States private water supply companies thrived in a wide variety of settings. The sanitary revolution of the 19th century saw the demand for public ownership and management of most of these companies in the name of public health (Potier, 1996). This, of course, did not obviate the need for water to be treated as an economic good, but a heavy emphasis on the public-good nature of water and its disposal led to the development of heavily subsidised public systems (Rogers, de Silva & Bhatia, 2001). In the past, most cities and utilities in the world have provided water to their customers almost free of charge because water is considered basic, and because water was a relatively cheap and abundant resource. However, now with much larger communities requiring services, the only way to ensure that everyone has access to this basic need is to control it in some way and ensure that as little as possible is wasted.

South Africa is a chronically water stressed country with between 500 m^3 and 1000 m^3 of water available per person per year (Ashton, 2002). Surface water is heavily committed for use, water is imported from neighbouring countries, and the limited groundwater resources do not offer much reprieve (Scholes, 2001). The need for water is further highlighted by the fact that water scarcity in developing countries is closely linked to the prevalence of poverty, hunger, and disease (Falkenmark, 1994; Ashton & Haasbroek, 2002). Historically, water resource managers met rising water demands through a complex system of engineering supply side solutions, which included major inter-basin transfer across vast distances (Smakhtin *et al*, 2001). Supply-side measures of late have been generally associated with rising costs making these solutions less viable. This is underlined by the fact that 12 of South Africa's 19 water catchment areas are in deficit and receive water through inter-basin transfers schemes from the remaining surplus areas (Blignaut & deWit, 2004). It has therefore become necessary to explore other solutions to augment and conserve water supplies (Ashton & Seetal, 2002).

The National Water Act of 1998 recognises the environment as a legitimate user of water thus water available for impoundment is scarcer. Studies by Turpie (2004a) show that at least two approaches are used to measure water loss in South Africa, they are replacement cost and opportunity cost. Replacement cost entails the valuation of water or water losses in terms of the costs of buying water from national water supply schemes or in relation to the enhanced expense of supplying that water from planned future supply schemes in the area (Florida Public Service Commission, 2008). Opportunity cost entails valuing water or water losses in terms of the opportunity cost of water forgone to downstream uses, or the value that use of this water could have added to national income. This could be in terms of direct use, such as by agriculture or indirectly through provision of goods and services by downstream aquatic systems.

Alien plants have invaded significant amounts of land in South Africa. The Western Cape is the most heavily invaded at about a third of the total area, followed by Mpumalanga, KwaZulu-Natal, and Northern Province (Le Maitre *et al*, 2000). A detailed survey of the Western Cape mountain catchments showed that around 60 500 out of 1 138 million hectares (ha) (5% of the total surface area) had an invasion density of at least 25% (Marais, 1998). Initial estimates are that approximately 54% of all riparian areas also have an invasion density of at least 25%, or, effectively, some 460 000 ha (Versfeld *et al*, 1998; Cullis *et al*, 2007). The invasion of river courses and of important catchment areas is particularly problematic in terms of stream flow reduction (Versfeld *et al*, 1998). Le Maitre *et al* (2000) estimated the total incremental water use of invading alien plants (i.e. the additional water use compared with the natural vegetation) at about 3 300 million m^3 of water per year. Primary catchments in the Western Cape had the greatest reduction, of up to 31% of mean annual runoff (Le Maitre *et al,* 1996, 2000). Cullis *et al* (2007) estimate that the current loss of usable water due to invasive alien plants is 695 million m^3, equivalent to 4% of the total registered water use. If left unchecked, this could increase to more than 2 720 million m^3, or 16% of total registered water use.

Invasive alien plant research by Turpie (2004b) in four catchment areas revealed that river flow was reduced by 6–22%. It was shown that, without action, these reductions would eventually be 22–95%, and that the costs to prevent this spread (some R80 million to R200 million/catchment) were justified compared to potential impacts of alien invasion. Indeed, water is a key constraint to economic growth in South Africa, and in productive catchment areas, these costs are usually easy to justify in terms of stemming water losses.

The mesquite invasion in South Africa's Northern Cape Province is undoubtedly problematic as it is affecting the availability of water especially to downstream users (Pillay, pers comm, 2008). Van Wilgen *et al* (1997) consider catchment area management to be of extreme importance if future water demands are to be met. Studies have revealed alien plants as having a negative impact on water resources in the Northern Cape Province given that water is supplied at a cost of 59c/kl. However, with effective and efficient cost effective management of alien plants, *i.e.* the clearing of invasive alien plants from the catchment areas, would deliver additional water at 13.6% of the cost of delivery (Van Wilgen *et al,* 1997).

The incremental water use by invading species in the Northern Cape is approximately 151 million m^3/year, more than that used by the natural vegetation (Le Maitre *et al,* 2000). At a tertiary catchments scale, the top ten invaded catchments are those invaded primarily by *Prosopis* (Van Wilgen *et al,* 1997). *Prosopis* in the Van Wyksvlei area also use the equivalent of more than 15% of the mean annual surface runoff (Le Maitre, Van Wilgen, Gelderblom, Bailey, Chapman & Nel, 2002).

Mesquite due to its long root systems can manage to tap into the underground water thus depleting the underground reserves. This loss of the valuable resource water has costs attached to it, which would come in the form of deeper wells, reduced irrigation potential and depleted reserves for local farmers and their livestock. Pillay (2008 pers comm) also considers *Prosopis* as a river course damager and directly responsible for borehole pressure reduction in De Aar.

2.3 *PROSOPIS* AS A MULTIPURPOSE TREE

Prosopis wood is perhaps the most dimensionally stable of all woods in having equal radial and tangential shrinkage values of only 2-3% and in having total volumetric shrinkage values of 4-5% (Felker & Moss, 1996). Other fine woods *e.g.* oak, cherry, walnut, teak, mahogany and Indian rosewood have volumetric shrinkage values in the range of 8-15% (Felker & Moss, 1996). The result of the low shrinkage value is that furniture made from mesquite will have less expansion and contraction when ambient humidity levels change, such as from summer to winter in northern regions. Thus, furniture will not crack or split with changing humidity levels.

In view of the availability of limited number of very slow growing woody species and the high requirement of fuel, fodder, and timber, especially in arid areas, the introduction of *Prosopis* can alleviate acute energy sources. *Prosopis juliflora* is one of the species, which was introduced in India in 1877 (Muthana & Arora, 1983). In Rann of Kutch (India), it is the only tree exploited for gum, fuelwood, and fodder (pods). Estimates indicate that in the Kutch district more than 200 000 ha are covered with *P. juliflora* (Varshney, 1996). Now, *P. juliflora* is the main source of fuel-wood in larger parts of arid and semiarid regions of India (Saxena and Venkateshwarlu, 1991).

Leaves of *Prosopis* species, although not eaten by man directly as a food source, are often consumed indirectly when used as a food for animals. A minority of the species are known to have leaves, which are palatable to livestock and which are highly valued as a source of fodder or forage (D'Antoni & Solbrig 1977). All the Afro-Asiatic species have palatable foliage, while only a few of the American species have foliage that is readily consumed by all livestock (Andersson, 2005). Tender green shoots and young leaves of all species are occasionally consumed by livestock, particularly when limited alternate forage is available (Lee & Felker 1992). Immature foliage and dry, fallen foliage both have higher palatability than mature, fresh foliage on the tree. Leaves of palatable species can be eaten directly off the plant or from lopped branches (Felker & Moss 1996). There are also reports of *Prosopis* leaves being used as a soil additive, composted, added directly as mulch, or incorporated into the soil where they fall (Varshney, 1996). A large quantity of leaf material is produced and is known to have a major beneficial effect on soil quality (Singh & Singh 1993)

The original name of *Prosopis* in North America is ‘misquitl’, from the use of tree bark as a tanning agent, with bark containing 14-16% catechol tannins. The tannin content of various plant parts from different species of *Prosopis* is 6-20% (Doat 1978). According to Felger (1977), bark tannin along with that found in the wood and fruit extracts, is used in the tanning and curing of animal skins, particularly cattle hides in leather production. This generally involves the boiling of plant parts to extract the tannin. Fibres have also been made from some *Prosopis* species. Roots, with bark removed, were used in North America to make strong ropes, regarded as a valuable possession (Felger, 1977). A root extract was used to prepare a brown-purple colorant for the dyeing of cotton and other materials (Díaz Celis, 1995) and bark and gum was used to produce paints, dyes, cosmetics and hair cleanser (Felger, 1977).

In South America, preparations from fresh buds of various species are used to treat conjunctivitis, leaf preparations are used to mend broken bones or cure didropesia, liver stones, dyspepsia and venereal disease, and are often mixed with other products (D’Antoni & Solbrig, 1977). These preparations have also been recorded as treatments for mouth infections, earache, scorpion stings and snakebites (Pimentel *et al*, 2000, Díaz Celis, 1995). D’Antoni & Solbrig (1977) revealed that in North America, medicines are commonly prepared as an aqueous solution or tea from most plant parts with many tribes using infusions of leaves, buds and gum to treat eye ailments; leaves, bark and gum as laxatives, emetics, cathartics and purgatives; gum solutions to treat sore throats and respiratory afflictions; leaves, gum and bark for diarrhoea and other stomach disorders including indigestion and ulcers; and sap or gum as a disinfectant for open wounds and skin disorders (Felger, 1977).

Prosopis flowers are a valuable source of bee forage. The flowers produce copious quantities of pollen and nectar over relatively long periods, as a nutritive reward for potential insect pollinators (Lee & Felker, 1992). Larger bee species with longer flight ranges are thought to be the principal pollinating agents (Simpson, Neff & Moldenke, 1977). Large amounts of top quality honey were exported from Hawaii for several decades, based on the large woodlands of introduced *P. pallida* (Esbenshade, 1980).

However, there are records of ill effects on livestock, particularly cattle when fed almost exclusively on pods of *Prosopis* species (Silva, 1990). Symptoms such as facial contortions, an impacted rumen and constipation, occasional deaths have been reported in the USA, Hawaii, Mexico, Brazil, Argentina, and South Africa (Pasiecznik, Harris & Smith, 2004).

The fruit produced by *Prosopis* species are legume pods, high in sugars, carbohydrates and protein. Pods have been a historic source of food for human populations where *Prosopis* species are found, increasingly becoming less important as a human food and more important as a livestock feed during the last few centuries (Pasiecznik *et al,* 2001).

Pods vary considerably in size between species and even between populations and individual trees of some species. According to Wood, Willens & Willens (1975), pods of Afro-Asiatic species tend to be 3-12 cm long, while the American species are generally divided into two groups. The smaller and spiralled pods, 2-10 cm long, belong to species of sections *Strombocarpa* and *Monilicarpa*, while the most commonly utilised longer and straighter pods, 10-45 cm long, belong to species of section *Algarobia* (Mahadevan, 1954) Pods of all *Prosopis* species are composed of an exocarp, and sometimes fleshy mesocarp, fibrous endocarps and hard seeds (Felker, 1979).

The fruit also helps sustain human life by providing a valuable source of food for animal species in most trophic levels of the ecosystems in which they are found. Where *Prosopis* are common, pods are an invaluable source of food for wild animals and livestock. *Prosopis* are utilised by South African farmers in the Northern Cape Province for animal feed (Coetzee, 2008 pers comm). Small ruminant research in India by Ravikala, Patel, Murthy & Wadhwani (1995) showed that lambs fed on *Prosopis* pods gained weight faster and made higher contributions to the economic viability of the livestock project. The research also indicated that the use of the pods is essential in the diet of sheep and there was need to invest further in methods to better use the pods.

Pods from *Prosopis juliflora* species contain 7-22% protein, 30-75% carbohydrates, 11-35% crude fibre, 1-6% fat and 3-6% ash (Oduol *et al,* 1986). Analyses by Zolfaghari & Harden (1982), showed mesquite pods to be high in fibre (17% to 31%) and low in fat (1% to 4%), with the seed similar in protein to soybeans and the outer pod similar to rice or barley. Sugar content varies from 13% to 41%. Total digestible nutrients (TDN), a measure of gross energy of a food minus the energy lost in the faeces, is a good general indicator of feed value. In mesquite pods, TDN is high, ranging from 70.5% to 84.1% in whole pods (Mahadevan 1954; Campos *et al,* 1997), falling between values reported for oats and corn, but slightly higher than barley. Crude protein levels are adequate for maintenance and milk production. Studies on mesquite consumption by cattle, sheep, goats, pigs, and rabbits have shown it to be an economical feed, with varied production results, depending on the rations (Kargaard & Van der Merwe, 1976; Zelada, 1986).

Prosopis trees produce high yields of fruit compared with fruit yields from other tree species growing in similar environments. *Prosopis* trees generally initiate flowering and fruiting in the third or fourth year after germination, much earlier under optimal conditions, but often considerably later under drought conditions or very poor soils (Lima, 1990). Fruit yields increase gradually up to 10-20 years and may be expected to continue at this high level for several decades. Fruit production is, in general, inversely correlated to rainfall and, in sub-tropical climates, also to minimum winter temperatures (Lee & Felker, 1992), yields as high as 100 kg/yr, have been recorded for single trees (Pasiecznik *et al*, 2001).

Simpson *et al* (1977) termed *Prosopis* species the 'unfailing crop' since they produce fruit every year. According to Impson *et al* (1999), the deep roots accessing water tables make them less dependent on rainfall for the production of fruit. This is a very important attribute in arid and semi-arid zones, where the production of other food crops, whether wild or cultivated, is highly dependent on the rainfall.

In South Africa, *Prosopis* pods have been used by Dune Foods to manufacture pharmaceutical products and sporting supplements. According to Coetzee, (2008, pers comm), the company would grow the trees if they disappeared. Dune Foods consider the pod products extremely valuable with potential markets in Japan and the rest of Asia. The market opportunities for these products seem profitable with need for further investment. Dune Foods pay R3/kg for harvested *Prosopis* pods and harvested approximately 158 tonnes in 2007 (Coetzee, pers comm, 2008)

2.3.2 *PROSOPIS* POD BASED BUSINESSES.

In the Americas, where *Prosopis* is indigenous, it has been extensively used in industry and overall community industrialisation. In Matehuala (Mexico), the first known commercial effort to market mesquite as a feed in began in the 1940s, with an average of 300 tons of pods sold per year. In the 1950s, a second mesquite dealer began purchasing an average of 500 tons annually, with as many as 900 tons in his best year. Both businesses sold pods whole, milled, or milled and mixed with other feeds (Meyer, 1984). Government-sponsored workshops on small business management and leadership training in the 1970s sparked the idea to establish a farmers' cooperative to buy, mill, and sell mesquite pods and to develop other rural industries based on indigenous natural resources (Martinez, 1984). With government funding and organizing assistance, the cooperative initiated operations in July 1975. One of the goals of the union has been to eliminate intermediaries in mesquite sales and to allow *Ejido* farmers to gain control over prices (Meyer, 1984).

In South Africa, particularly the Northern Cape, Dune Foods has been actively involved in the harvesting of *Prosopis* pods. According to Coetzee (2008, pers comm), normally the seeds are ready for harvest from the beginning of January. Just before the harvesting starts, Dune Foods normally invites local unemployed residents in the community and contracts them to do the harvesting. After training and showing them, exactly which seeds are required and paying them per kilogram, the seeds are delivered to storage premises. This is the time of year, just after Christmas, when most disposable income has been depleted. As many seeds as possible have to be accumulated during these 3 months, because of the approaching rainy season and the need to accumulate enough raw materials to last to the end of the year (Coetzee, pers comm. 2008).

Besides the provision of employment to the local people *Prosopis* based businesses contribute to the overall Northern Cape provincial economy. Coetzee (2008 pers comm) considers *Prosopis* pods an important contributor to poverty reduction and expansion in business activities that would lead to economic growth.

2.4 THE CONTROL OF *PROSOPIS* SPECIES

Mechanical control and chemical control are control mechanisms currently used by the Working for Water programme in De Aar. However, due to the problems associated with mechanical and chemical control, these options are proving not to be sustainable over the long-term (Hill, 1999). These methods are costly and are becoming increasingly ineffective and economically inefficient (Hill, 1999). It is increasingly difficult to justify the continued investment of scarce public funds to such control programmes, which are in direct competition with other social services for funds.

At present, WfW De Aar is working with three separate contractors involved in the clearing of *Prosopis* in the study area (Pillay, 2008 pers comm). Employees wear protective clothing to avoid *Prosopis* thorns and given basic training to correctly deal with *Prosopis* shoots and a source of income. The clearing is done over specific periods at an estimated cost of R300 / hectare for sparse infestations and R3 000 / hectare for dense infestations (Antonie, pers comm. 2008). However, according to Pillay (2008, pers comm) WfW De Aar is waging a fruitless war due to the continuous need for follow up, budgetary constraints and less than full co-operation from stakeholders.

The Working for Water Programme spends between R9 and R15 million / annum on *Prosopis* alone (Antonie, pers comm. 2008), Marais, Van Wilgen & Stevens (2004) further broke down the costs of controlling *Prosopis* in the Northern Cape and Free State provinces into component cost (Table 2.4).

Table 2.8 The estimated cost associated with the clearing of *Prosopis* mesquite weed in the Northern Cape

Province	**Total costs (R million)**	**Overhead costs (R million)**	**Project expenditure accounted for on project database (R million)**	**Total expenditure accounted for on project database (excluding overheads) (%)**	**Major genera of invasive alien species treated**
Northern Cape and Free State	21.688	12.119	7.248	76	Mesquite (*Prosopis* species)

Source: (Marais, Van Wilgen & Stevens, 2004)

2.4.1 BIOLOGICAL CONTROL

The term biological control was first used by Smith (1919) to describe the introduction of exotic insect natural enemies for the permanent suppression of insect pests. It has since been applied, at times, to include virtually all pest control measures except the application of chemical pesticides: plant breeding for resistance to pests, autocidal controls, application of semiochemicals and cultural controls (Waage, 1983). The term may however be restricted to the use of living organisms (natural enemies) as pest control agents. These natural enemies include parasites, parasitoids, predators, antagonists, competitors and phytophages for weed control. The targets include weeds, plant-feeding invertebrates, plant pathogens and disease vectors.

Vail, Coulson & Dix (2005) define biological control as the use of natural enemies (parasites/parasitoids, predators and pathogens) to regulate and control pests. Two aspects of biological control are discussed: (i) classical biological control, which involves the importation and release of exotic natural enemies to control pests (usually exotic); and (ii) augmentative biological control, which includes enhancement of natural enemies through cultural techniques, environmental manipulation, and inoculative and inundative releases of beneficial insects. Examples include periodic (inoculative) releases of natural enemies with the expectation of season-long control and inundative releases of large numbers to provide immediate impact. Organisms involved in inundative releases include insect pathogens / microbial control agents and beneficial arthropods (Vail, Coulson & Dix, 2005).

The Chinese were the first to use natural enemies to control insect pests. Nests of the ant *Oecophylla smaragdina* were sold near Canton in the 3rd century for use in control of citrus insect pests such as *Tesseratoma papillosa* (Lepidoptera) (Konishi & Ito, 1973). Ants were used in 1200 A.D. for control of date palm pests in Yemen (south of Saudia Arabia). Nests were moved from surrounding hills and placed in trees (Konishi & Ito, 1973). However, the first practical attempt at biological control of weeds occurred in 1863 when segments of the prickly pear cactus, *Opuntia vulgaris*, infested with the imported cochineal insect, *Dactylopius ceylonicus*, were transported from northern to southern India (Simmonds, Franz, & Sailer, 1976).

According to Impson *et al* (1999), the biological control of *Prosopis* in South Africa has been restricted to the use of seed eating beetles due to conflict of interests. The biological control of *Prosopis* using seed-feeding insects is considered an important component in the overall control of *Prosopis*, which is also dependent on the resolution of conflicts associated with the control of *Prosopis* and the intensive utilisation of these invasive plants (Zimmermann, 1991). The potential effectiveness of seed-destroying agents in biological weed control has often been doubted (Huffaker, 1964, Harper, 1977). However, recent work (e.g. Dennill, 1990; Hoffmann, 1990) suggests that a drastic reduction in the fecundity of a weed might reduce its density and will certainly reduce its rate of spread .The action of seed-feeding insects in some cases may have to be supplemented by other measures. Where invaders, such as *Prosopis* have long-lived seed banks, the effectiveness of seed-feeding agents may not be noticeable until the seed bank is exhausted.

The use of bruchid beetles against mesquite is mainly a solution resulting from the conflicts of *Prosopis* control. According to MacDonald, Kruger & Ferrar (1986), the issue of conflicts of interest in biological weed control has been an important determinant for the direction that research in South Africa is currently taking.

According to Coetzer & Hoffmann (1997), two bruchid seed weevil species, *Algarobius prosopis* (Le Conte) and *Algarobius bottimeri* (Kingsolver), were released for biological control in 1987 and 1990, respectively. However due to the limited ability of the two to colonise tree bound pods, livestock grazing limited their ability to destroy the seed before it is grazed by the livestock and transported to geminate elsewhere. This prompted the need for the introduction of *Neltumius arizonensis* (Schaeffer), a bruchid reputed to be capable of ovipositing on immature, tree-borne pods (Impson, *et al,* 1999).

An extensive release campaign was launched again during April 1989 when approximately 10 000 net bags, each containing about 2 kg of pods with *A. prosopis* larvae and pupae, were distributed to landowners on 88 different properties throughout the *Prosopis* spp. infested regions. In addition, between July 1988 and May 1989, approximately 76 larger consignments of pods with *A. prosopis* were posted to municipalities, farmers and nature reserves throughout South Africa and Namibia. The first releases of *Algarobius bottimeri* were made during March 1990, in the Free State Province in batches of about 5000 adults on three isolated *Prosopis* infestations that up to that time had not become colonized with *A. prosopis.*

The climate at these three sites is cooler, with higher rainfall, than at most of the other sites into which *A. prosopis* was initially introduced. Studies by Coetzer & Hoffmann (1997) estimate the beetles to have reduced the *Prosopis* seed production by less than 20%, which, according to Zimmermann (1991), is not a sufficient amount to control

Prosopis effectively. Zimmermann (1991) cites reasons that may have resulted in the ineffectiveness of the beetles.

- Indigenous parasites attacking the egg or larva, this may compromise beetle populations there by reducing their effectiveness.
- Host plant preferences of seed feeding beetles may diminish their overall effectiveness if some of the taxa within the *Prosopis* species complex in South Africa are unacceptable or are only marginal hosts.
- Survival of adult beetles in winter when pods are scarce or even absent will determine how quickly the beetle population grows in order to attack the new pods in summer.

Although certain bruchid species have become established, limiting the control to seed destroying bruchids may not be the solution to the problem. Despite the destruction of seed, estimates still show that the future is bleak if all hope is placed on seed destroying agents as land that is more arable will continue to be invaded by the weed. According to Johnson (1983), it would be essential to consider the introduction of *Minosestes protructus*, a bruchid that lays its eggs on immature pods. It may also be necessary to consider bud feeding and flower feeding agents such as *Calliplora sextrigella* and *Asphondilya prosopidis* (Rodgers, Clarke & Burke, 1975).

The *Asphondylia prosopidis* complex produces four distinct bud galls on Mesquite (*Prosopis glandulosa*). Flies within this gall midge complex are being considered as potential biological agents to reduce *Prosopis* seed production in South Africa. However, before exporting this insect to South Africa, it is important to understand the relationship between members in the complex (Ik Ju Park, Beuhler & Thompson, 2008). Adult and larval specimens from the different bud galls have been considered one species due to morphological similarities (Ik Ju Park *et al*, 2008).

Preliminary estimates indicate that the ongoing biological control programmes will reduce the financial commitment of the Working for Water Programme for clearing costs by between 19.8% (R1.38 billion) and 41.4% (R2.89 billion) over the next 20 years (Le Maitre *et al,* 2002). If the impacts of invading alien plants on water and other resources are taken into account, the potential returns on investment are even more substantial. This budget is therefore not only a research investment; it is an investment into the development and implementation of one of the essential pillars of alien plant control.

It should however be considered that biological control programmes are interdependent programmes which do not start in the field. They start in labs and there are costs associated with the identification, testing and evaluation of a biological control agent. These costs are often omitted in the calculation of the total costs of the biological control projects.

Table (i) (Appendix 1) shows various aspects about control efforts in the respective areas with detailed summaries of costs, employment patterns, density and many other issues related to the control efforts undertaken by Working for Water De Aar. According to the table, the average control cost per hectare is about R300 per hectare. The table highlights mechanical and chemical control initiatives, which are usually characterised by high complementary costs like transportation, follow up, labour and labour training. Mechanical (wages) control takes up almost 9% of the budget while chemical (herbicides) take up approximately 11%. These estimations do not include transportation costs, which make up almost 14% of the budget.

The organisation spent about R55 of the budgeted R96 on a unit of labour per day. The majority of the clearing labour force used by working for water is unskilled and not employed on a regular basis (Antonie, pers comm, 2008). According to Chiang (1990), there is a positive correlation between skill and bargaining power of employees meaning that, the less educated and skilled a group of employees is the less power they have to bargain for better wages. Thus, the relatively lowly skilled clearing labour in De Aar may explain the discrepancy between the amount budgeted for wages and the actual amount paid out. The presence of an overall budget surplus of 43% may also indicate that not all is being done to contain the problems prompting the need for further research and development into better techniques.

The table also captures the general population, income and racial stratums of the Northern Cape with coloured groups making up the bulk of the labour and blacks making up the remainder. This is not to say other racial groups are not present but may probably be employed in other sectors of the economy.

2.5 SUMMARY

Prosopis pods are the source of the invasion as they are the seed carriers and may also be an important livestock feed source. However, as a result *Prosopis* invasion, it becomes necessary to consider aspects in the study area like biodiversity, water loss, grazing land and their relation to the value of *Prosopis*. There is a growing realisation the world over that a positive relationship exists between environmental conservation and economic success hence, accounting for biodiversity and water resources aims to justify continued efforts towards fighting alien invading species.

Various control techniques have been discussed in the chapter with biological control singled out as an indispensable part of control efforts. *Prosopis* species were introduced intentionally and their control would have various effects, which may be brought to light through research.

CHAPTER 3

RESEARCH METHODOLOGY

3.1 INTRODUCTION

This chapter describes the research tools used in the collection and analysis of data with respect to their application and appropriateness. Firstly, this chapter gives a discussion of study area in detail. Descriptions of the analysis techniques and data collection methods are given followed by the section on data collection methods, which explains the tools that were used for collecting data and the variables, considered.

3.2 DESCRIPTION OF STUDY AREA

The Northern Cape Province is bordering the west coast of South Africa, and is close to one-third (29.7%) of the country's surface area (Moseley, 2008). The province lies largely to the south of the Orange River, which forms the international border between South Africa and Namibia (CSIR, 2004). Being the largest province in the country at 362 000km², it is also the least populated, with an average of just two people per km² (Northern Cape Provincial Government (NCPG), 2008). Its vast plains are criss-crossed by long, deserted roads leading to isolated farms and small rural towns (Moseley, 2008). The region comprises mostly arid landscapes, including the scrub-covered plains of the Great Karoo, the red sands of the Kalahari, the Orange River, the mountain desert of the Richtersveld, and the arid soils of Namaqualand that produce the world-famous spectacular show of wild flowers in spring (DWAF, 2008). The cold waters of the Atlantic Ocean border the western coastline of the province, bringing alluvial diamonds that have washed down the Orange River over the eons (CSIR, 2004).

3.2.1 CLIMATE

The province is a large dry region of fluctuating temperature, varying topographies and January, afternoon temperatures usually ranging from 34 to 40º C (Moseley, 2008). In 1939, an all time high of 47.8º C was recorded at the Orange River while Sutherland in the Karoo is one of the coldest towns in South Africa with an average minimum is 6º C. In winter, snow often blankets the surrounding mountains (Moseley, 2008).

The Northern Cape is the most arid province in the country, with the average rainfall less than 200 millimetres per year over most of the Province (CSIR, 2004). Apart from a narrow strip of winter-rainfall area along the coast, the Northern Cape's weather is typical of desert and semi-desert areas.

Figure 3.1 Map of the Northern Cape Province

Source CSIR, 2004

Although the Northern Cape is mainly semi desert, the western areas of the Northern Cape, including Namaqualand, a small section of the Green Kalahari and Calvinia, Nieuwoudtville and Loeriesfontein in the Karoo fall into the winter rainfall area (April to September).

3.2.2 VEGETATION AND LANDSCAPE

The Northern Cape is dominated by desert vegetation and visible bush invaders such as *Prosopis* (Impson *et al,* 1999). The largest part of the province falls within the Nama-Karoo biome, with a vegetation of low shrub land and grass, and trees limited to watercourses. Change in plant species composition is a serious problem, while loss of plant cover is a minor concern compared to bush encroachment, which has become an issue in some of the eastern districts (CSIR, 2004).

The Namaqualand biome contains a number of fascinating plants, including the elephant's trunk, the landscape is characterised by vast arid plains with outcroppings of haphazard rock piles. Alien plants have invaded more than a million hectares of the Northern Cape and a serious threat in some districts for example; according to Le Maitre *et al* (2002), *Prosopis* (mesquite) may use as much as 200 million m^3 water per year, reducing the amount of groundwater available to farmers and rural communities.

3.2.3 AGRICULTURAL POTENTIAL

The economy of a large part of the Northern Cape, the interior Karoo, depends on sheep farming, while the karakul-pelt industry is one of the most important in the Gordonia district of Upington (DWAF, 2008). According to Abraham (2005), the province has fertile agricultural land in the Orange River Valley, especially at Upington, Kakamas and Keimoes, where grapes and other fruit are cultivated intensively. Wheat, fruit, peanuts, maize and cotton are produced at the Vaalharts Irrigation Scheme near Warrenton and game farming is becoming one of the fast growing activities. Because the Northern Cape is very arid, only 2% of the province is used for crop farming while 96% of the land is used for stock farming, including beef cattle in the savannah biome and sheep or goats elsewhere. The environment is unsuitable for commercial forestry and only 1% of land is set aside for conservation (Impson *et al,* 1999). Although about 98% of land in the Northern Cape is used for agriculture, mining is the prime income earner. However, some mines are closing down and workers are using their retrenchment packages to purchase livestock, which may further increase agricultural activity (Abraham, 2005).

3.2.4 INFRASTRUCTURE

Research has shown a direct link between the provision of infrastructure, income growth and human development (DWAF, 2008). Infrastructure represents a vast investment, made over many generations by both public and private sector organisations that supports the fabric of modern living in the communities (Fourie, Lievaart, Schmidt & Strachan, 2008). It is important that the very best management skills and practices are needed to ensure that services are delivered economically and sustainably. There has been a growing recognition that it is not sustainable to focus on meeting infrastructure needs through investment in infrastructure creation, without recognising the life cycle costs associated with the ongoing operation, maintenance and renewal thus, improvement of the management of infrastructure can bring major benefits (Fourie *et al*, 2008). Infrastructure has multiple links to poverty reduction i.e. it can support income generation within a household, increase productivity, decrease time needed for collection and transport of resources, and other products (DPW, 1997). Infrastructure and service delivery can also improve access to health and education.

In the Northern Cape, the growth of infrastructure is monitored through the provision of transport infrastructure, service delivery and housing (Abraham, 2005). The provincial government has made some progress in the development of infrastructure through increased economic spending towards infrastructural development programmes. According to the Northern Cape Provincial Government (NCPG) annual report of the year 2004, infrastructure development spending was relatively high at R2 billion between 1994 and 2003, compared with spending in other economic sectors. Given that this has been mainly directed at roads, it forms a good base on which to expand economic related expenditure. It is necessary to ensure that these infrastructural bases are in place because of the need to create the conditions under which economic activities such as manufacturing, mining, service industries and tourism and other economic activities can flourish.

3.2.5 ECONOMY

Although most famous for the diamond mines around Kimberley, the Northern Cape also has a substantial agricultural area around the Orange River, including most of South Africa's sultana vineyards. Some Wine of Origin areas have been demarcated (Moseley, 2008). Extensive livestock farming is the basis of the economy in the southern Karoo areas of the province. In 1994, the economy was mainly confined to primary production in the form of mining, in which diamond mining predominated. This has remained the position for most of the past decade. With the inability of this sector to yield sufficient jobs and the fact that mining has a limited lifespan, diversifying the economy is of paramount importance to the province (NCPG, 2000). Abrahams (2005) observed that, in spite of funding constraints, the province has experienced improved economic growth in 2002 from negative growth initially. However, this economic growth has not been associated with an overall increase in the number of jobs created. Herein lay major challenges for the Northern Cape Government.

3.2.6 SOCIO ECONOMIC PROFILE

The Northern Cape had an estimated population of 1 147 600 people in 2008, the population increased from about 822 727 people 2001 (NCPG, 2008). This means that Northern Cape has the smallest population of all provinces in the country, 30% of the province's population is under the age of 15 and 5% is over the age of 65. Sixty eight percent of the population speak Afrikaans with the other languages being Xhosa, Setswana and English. Education levels in Northern Cape are relatively low; about 70% of the population has not finished secondary school (NCPG annual report, 2005). The percentage unemployment of economically active people is 14.4% (NCPG, 2008). According to Abrahams (2005), these levels of unemployment may be related to the levels of education in the Province. In the Northern Cape, 17.1% of people have no annual household income and 31.2% have an annual household income less than R9 600 (NCPG, 2004).

3.3 SAMPLING PROCEDURE

Sampling involves selecting units from a population of interest, so that by studying the sample, the results obtained from the sample may be generalised to the population from which the sample had been chosen (Leedy & Ormrod, 2004). Thus, the characteristics obtained from the sample should reflect approximately the same characteristics as the population. Since the data obtained from a sample will be generalised to the whole population, the manner in which the sample units are selected is very important. A sample should be representative and to attain this, the sample size should be large enough to conduct reliable statistical analysis.

In this study, simple random sampling method was the method of choice. From the pilot study, it was realised that landowners in the Northern Cape are mainly sheep farmers. For this reason, simple sampling is considered the method of choice. Simple random sampling requires the use of a sampling frame (list of the population), from which the sample will be drawn (Leedy & Ormrod, 2004).

3.4 DATA COLLECTION

3.4.1 SURVEYS

Webster's New Collegiate Dictionary defines a survey as a "critical inspection, often official, to provide exact information, often a study of an area with respect to a certain condition or its prevalence. According to Kothari (1990), it requires not only skill imagination and expert planning of the study, but also accurate data collection, careful analysis, logical interpretation of the collected data, and intelligent reporting of the results and conclusions. In this research, a questionnaire survey was used with the questionnaire being the main tool of data collection.

3.4.2 THE QUESTIONNAIRE

The questionnaire was designed in order to collect both qualitative and quantitative data. Questionnaires can be administered many ways, such as face-to-face interviews, self-administered questionnaire and telephone surveys (Leedy & Ormrod, 2004). Face-to-face interviews are considered superior as they have several advantages over the other methods. According to Bless and Smith (2000), an interviewer-administered interview is an important tool of data collection because it reduces omission of difficult questions by respondents. In addition, it reduces the problem of word or question misinterpretation (misunderstandings) by respondents and can be administered to respondents who can neither read nor write. The presence of the interviewer increases the quality of the responses since the interviewer can probe for specific answers (Leedy & Ormrod, 2004). In other words, the use of interviewer-administered questionnaires ensured minimal loss of data when compared to other methods. However due to resource and feasibility limitations electronic mail interviews were used together with self administered questionnaires

Two sets of different but related questionnaires were used; the first targeted the farmers whose main use of *Prosopis* pods was animal feed. In this case, the heads of the households were interviewed and in the absence of the head, the spouse or any adult member was interviewed. The main respondent provided most of the information, but was allowed to consult other farm assistants, where necessary.

The farmer's questionnaire was finalised after a number of drafts and careful scrutiny to avoid ambiguity and to ensure as much data as possible is captured. Due to interview limitations such as, interviewer effects and pressure on the respondent, respondents were given the option of filling in the questionnaire within a specific period. The interviewer then returned to collect and verify the questionnaire ensuring that any arising issues were explained thereby maximising data collection. Due to the prevalence of the Afrikaans speakers in the area, the questionnaire was also translated to Afrikaans to ensure maximum data collection.

The questionnaire was introduced with a black and white photograph of *Prosopis*. According to Arrow, Solow, Portney, Leamer, Radner & Schuman (1993), photographs are useful tools to explain to respondents the good, which is being valued, but must not induce any bias in the process. Following the photograph is section one of the questionnaire, this section discusses *Prosopis* the plant in general. Respondents were asked if they had seen the plant before and if they consider it to bring any benefits or disadvantages to the area. The aim of this section was to establish the extent of knowledge the respondents had regarding *Prosopis* and the value they attach to it.

Section 2 considered the use of *Prosopis* pods by the respondents. Respondents were firstly asked if at all they made use of *Prosopis* pods or animal feed and if they used *Prosopis* pods, how much over a specific period in quantity terms. The respondents were then told that it was possible to reduce the amount of pods by 50% and even by 100% then asked how this would affect them. These effects were categorised into income and cost effects with a section provided for other effects as well.

Section 3 considered the control of *Prosopis*. Questions on who should be responsible for the control of *Prosopis* were asked. The respondents were also asked if they had been actively involved in the control of the plant and if they considered control necessary. If they do consider control necessary, they were then asked if they consider current control efforts sufficient.

Section 4 of the questionnaire seeks to research the biographical information of the respondent. This area considered the relationship that exists between the socioeconomic issues (age, language, race, sex, education, occupation and income) and the response consistency; this is recommended by (Arrow *et al,* 1993).

The second questionnaire targeted a business that is involved in the trade and use of *Prosopis* pods as manufacturing raw materials. This questionnaire was also a result of several edited drafts that were carefully scrutinised to come up with a final set of useful and relevant questions. The questionnaire consisted of two pages and introduced with photograph of *Prosopis* together with a summary on the aims and objectives of the research.

The questionnaire was divided into two sections, the first section seeks to find out the value the respondent attaches to *Prosopis* pods, this section also attempts to find out the possible economic losses and effects that would arise because of loss of *Prosopis* pods within the study area. The second section asked questions relating to the control of *Prosopis* and the role that the respondent has assumed in the control of the plant. Due to time and financial constraints, the questionnaire was sent via electronic mail with instructions on how the respondent was to return it upon completion. According to Andrews, Blair & Preece (2003), recent developments in communication technologies have created alternative survey methods through e-mail and web sites. Both methods use electronic text communication, require fewer resources, and provide faster responses than traditional paper and pencil methods. However, new survey methodologies also generate problems involving sampling, response consistency and participant motivation. Due to the fact that only one dominant business involved in the pod industry was identified this made the electronic survey useful and more beneficial in this situation.

3.5 PILOT STUDY

A pilot study was undertaken with its main aim being, to access the extent to which farmers in the Northern Cape utilise *Prosopis* pods and the overall state of the *Prosopis* invasion in the area. Pre-testing and careful planning is considered an essential aspect of environmental good valuation studies (Arrow *et al.,* 1993). Pilot studies are a crucial element of a good study design however conducting a pilot study does not guarantee success in the main study, but it does increase the likelihood also fulfilling a range of important functions and can provide valuable insights for other researchers (Van Teijlingen, Edwin & Hundley, 2001).

3.6 DESCRIPTIVE RESEACH

Descriptive research can take the form of quantitative or qualitative research. The former emphasises what is, and makes use of quantitative methods to describe, record, analyze and interpret the present conditions. On the other hand the latter also emphasizes what is, but makes use of non-quantitative research methods in describing the conditions of the present.

According to Kothari (1990), descriptive research studies the relationships among non-manipulated variables only. In this type of research, the investigator selects the relevant variables from the events/conditions that have already occurred or exist at present, and analyzes their relationship without introducing any manipulations to the variables. Because of its ease in use, descriptive research is the most popular and widely used method in research (Koul, 1997). The results of descriptive research provide the researcher with a platform to make important decisions and generate more research ideas to be tested by the future researchers (Kothari, 1990).

Careful planning is fundamental in any research hence various steps have to be followed even in descriptive research. According to Kerlinger (1983), the following are the steps adopted in describing and interpreting the existing conditions:

- Selection of the Problem: A researcher, from the area of his/her interest, may select any problem to study the existing conditions or phenomena. He/she should clearly state the problem and define the variables in operational terms.
- Formulation of Hypothesis: The research hypothesis guides us throughout the research process in solving the research problems. The researcher should formulate the hypotheses based on the existing theories and facts.
- Identification of Data: It is necessary to identify the appropriate type of (qualitative or quantitative) data to be collected so that the hypothesis may be correctly tested.
- Selection or Development of a Research Tool: After deciding the nature of the data to be collected, it becomes easy for us to select the appropriate measurement tool and if any standardised tool of interest is not available the researcher may have to develop his/her own tool as per research requirements.
- Selection of the Sample: While selecting the sample to be studied, one must choose a representative sample and apply randomization techniques in sample selection, if possible.
- Data Collection: After finalising the tools to be used and sample to be studied, actual data collection begins.
- Treatment or Analysis of the Data: The data collected is then treated with the appropriate statistical techniques.
- Interpretation: While interpreting obtained findings, the researcher should also emphasize the existing theories and interpret the results in their light. The researcher should also see if the findings build a new theory or conform to the old ones.

- Report Writing: It is the last and most important step of a research study, i.e. to write an appropriate and clear report of what has been done and found, so that people may also take advantage of this new knowledge.

3.7 DATA ANALYSIS

Statistical Package for Social Scientists (SPSS version 17.0) was used to run the data collected from farmers in the study area. To analyse relevant data, descriptive statistics was used; the main descriptive indicators that were employed are frequency, standard deviation and mean values of estimated costs. These are useful in data analysis as well as in analyzing the relationship between variables.

A linear equation was used to estimate the losses that the farmers would suffer because of a reduction in the quantity of pods available. Using averages derived from SPSS version 17.0 variables were computed and substituted in the linear equation,

$$(\sum (DPI + ICF + \lambda)) / n = RL$$

Where DPI direct loss of pod income

ICF increased farm production costs

λ unexplained losses

RL resulting losses to the farmer

N number of respondents.

The equation shows that the resulting loss (RL) is a function of the explanatory variable (DPI), (ICF), (n) and (λ). The explanatory variables were calculated and given as averages using the formula,

$$\sum(c) / n$$

Where (c) is the total cost / savings.

Cost comparisons ratios were also computed. Farmer's costs were compared to the environmental costs and given as a ratio. This was also the case with business costs which were evaluated against provincial environmental costs and given as a ratio as well. To estimate environmental costs the avoided cost method was used.

The damage cost avoided, replacement cost, and substitute cost methods are related methods that estimate values of ecosystem services based on either the costs of avoiding damages due to lost services, the cost of replacing ecosystem services, or the cost of providing substitute services (Wilson & Carpenter, 2000). These methods do not provide strict measures of economic values, which are based on peoples' willingness to pay for a product or service. Instead, they assume that the costs of avoiding damages or replacing ecosystems or their services provide useful estimates of the value of these ecosystems or services (King, Mazzota & Kenneth, 2000). This is based on the assumption that, if people incur costs to avoid damages caused by lost ecosystem services, or to replace the services of ecosystems, then those services must be worth at least what people paid to replace them (Wilson & Carpenter, 2000). Thus, the methods are most appropriately applied in cases where damage avoidance or replacement expenditures have actually been, or will actually be made.

According to King *et al* (2000), it is easier to measure the costs of producing benefits than the benefits themselves, when goods, services and benefits are non-marketed. Thus, these approaches are less data and resource-intensive. This makes the method readily useful as in certain situations data or resource limitations may rule out valuation methods that estimate willingness to pay. The methods provide surrogate measures of value that are as consistent as possible with the economic concept of use value, for services which may be difficult to value by other means (Clinch, 2000).

Despite the relative ease of using avoided cost method, various flaws may be realised from them. These approaches assume that expenditures to repair damages or to replace ecosystem services are valid measures of the benefits provided. However, costs are usually not an accurate measure of benefits (Wilson & Carpenter, 2000). These methods also do not consider social preferences for ecosystem services, or individuals' behaviour in the absence of those services (Clinch, 2000). It may also be argued that the goods or services being replaced probably represent only a portion of the full range of services provided by the natural resource. Thus, the benefits of an action to protect or restore the ecological resource would be understated (King *et al*, 2000). The understatement of the value of benefits was also investigated by Adams & Crocker (1991) when measuring the overall demand for environmental quality and further highlighted in studies by Arrow *et al*, (1993) on contingency evaluation techniques.

3.8 SUMMARY

In the chapter, the different data collection techniques used in the research have been discussed with the tools and methods of analysis highlighted. The study area is also discussed and highlighted in the chapter; however, the research tended to focus more on the eastern areas of the province due to income and time constraints. Questionnaires were sent out to the farming and business communities in the area. The research thus, focused on the above-mentioned users of *Prosopis* pods.

CHAPTER 4

SURVEY RESULTS AND EMPIRICAL EVALUATIONS

4.1 INTRODUCTION

This chapter analyses and discusses the results of the different data collection activities undertaken in the study area in May 2008 & 2009. The data under analysis includes data collected from an initial pilot study comprising 19 independent farmers, a field survey comprising 27 farmers in the Northern Cape and an independent private company that makes use of *Prosopis* pods as a production raw material. The chapter begins with an analysis of the pilot study that was undertaken in April 2008 followed by explanations of the demographic characteristics of the sampled respondents, with an overview of the *Prosopis* situation in the area given and analysed. It goes on to discuss economic aspects of respondents, giving special attention to aspects related to the use and value the respondents accord to *Prosopis* pods. An analysis of results from *Prosopis* based industries is also given in this chapter; descriptive statistics such as mean, maximum and minimum values was used.

4.2 THE PILOT STUDY

For the pilot study, the eastern areas of the Northern Cape were targeted with the areas of De Aar, Prieska, Bristol, Brandfontein and Rosedale observed. Personal interviews and physical observations were the method of data collection, with notes taken and recorded throughout the study.

An interview with the local WfW authorities was scheduled to acquaint the researcher with the situation in the area. The interview revealed that *Prosopis* had become problematic in the area and the authority felt that they were fighting a losing battle (Antonie & Pillay, 2008, pers comm). According to Antonie (pers comm, 2008), the authority spends between nine and fifteen million rand on *Prosopis* annually with spraying costs at over R400/hectare. *Prosopis* species in the area were also noted as the main river course damagers and responsible for the change of water pH and reduction in borehole pressure. The *prosopis* invasion has led to fundamental economic inefficiencies in the area making it profitable to move from invaded land to uninvaded land, as land prices are lower than the cost of clearing *Prosopis* on invaded land. Interviews with local farmers also revealed they generally have a negative perception towards *Prosopis,* according to Sakkie (2008 pers comm) the farmer representative, the area is better off without *Prosopis*.

During the course of the study, the researcher observed and reaffirmed observations by renowned *Prosopis* researchers like H.G Zimmermann regarding the general inadequacy of current biological control programmes targeting mesquites (Zimmerman, 1991). Pods that had been acted upon by bruchid beetles were observed but the immense *Prosopis* densities observed along river courses and on farms indicated that the beetle efforts were being reduced to bare minimums.

After meetings with individual farmers and the farmer's representative (Sakkie), the researcher observed that farmers in the area were mostly livestock oriented, specialising in sheep and mutton production. Of the 19 farmers represented in the interviews, none harvested *Prosopis*. The farmers expressed an awareness of the nutritional value of the pods but generally did not attach a high price tag to them. Sakkie (pers comm, 2008) considers a 50% or 100% reduction in pods as having a negligible impact on farm incomes and welfare. None of the farmers stored *Prosopis* pods or were heavily dependent on pods for livestock feed.

With the help of relevant authorities in the area, a *Prosopis* based manufacturing company (Dune Foods) in the Prieska area was identified and an interview scheduled. The interview revealed that *Prosopis* pods were the backbone of the company's survival. Coetzee (pers comm, 2008,) highlighted the importance of *Prosopis* pods in the local economy and the potential it had as markets were said to be developing all over the world for their products. The local economy is thought to benefit from the provision of jobs and incomes to the local residents. The interview revealed that the company valued mesquite pods and would consider developing *Prosopis* plantations if faced with a 50% or 100% decline in available pods.

4.2.1 OBSERVATIONS FROM THE PILOT STUDY

After the study observations, it became clear that there was a need to change the way questions would be set and asked in the main survey and also that there was a need to move further eastwards in the province to observe if farmers there, valued and made use of *Prosopis* pods. The questionnaire was redrafted to incorporate those farmers that simply let their livestock graze in the rangeland.

4.3 THE ECONOMIC IMPLICATIONS OF FARMERS LOSING PODS IN THE STUDY AREA

4.3.1 THE STATE OF THE *PROSOPIS* INVASION

A questionnaire survey was carried out and data collected from 27 farmers in the more western parts of the province, namely, Van Wyksvlei, Carnarvon and close surrounding areas. All respondents concurred that they were aware of the presence of *Prosopis* in the area and the tree population had been increasing at a rapid rate. However, the farmers did not all notice the *Prosopis* invasion at the same time. Figure 4.1 shows the different times at which the respondents became aware of the *Prosopis* invasion.

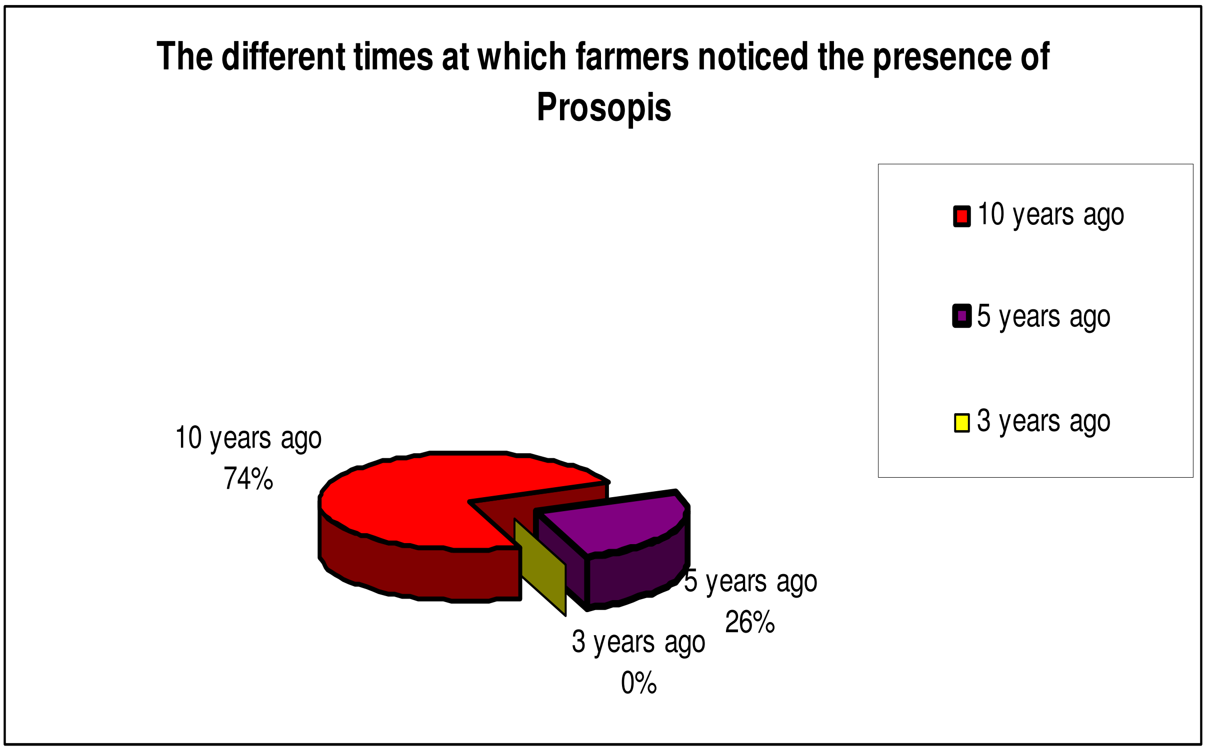

Figure 4.1 The numbers and different times at which farmers became aware of *Prosopis* *(n = 27)*

The majority of the respondents seem to have been living side by side with *Prosopis* as 74% of them became aware of the invasion 10 years ago and the remainder 26% noticed the invasion 5 years ago. This indicates that this is not a new issue but rather one that has been in the midst of the communities visited for a significant amount of time.

4.3.2 DEMOGRAPHY, SOCIO-ECONOMIC STATE AND THE LEVELS OF CONTROL

The demographic and socio-economic characteristics of the respondents were investigated and recorded throughout the study.

- Demography

Demographic data often refers to the characteristics of a population as used in research; commonly used demographics include sex, race, age, income, disabilities (Galtung, 1967). All the respondents were white male Afrikaners; their ages were thought to be a determining variable influencing the perception respondents would have towards the control of *Prosopis* species and the use of pods. Ages of sampled farmers were classified into different groups with each farmer belonging to one of the groups as indicated in figure 4.2. The majority of respondents (78%) fall between the ages of 40 and 59. with the minority (15%) and (7%) falling in the 30 – 39 and over 60 years category respectively.

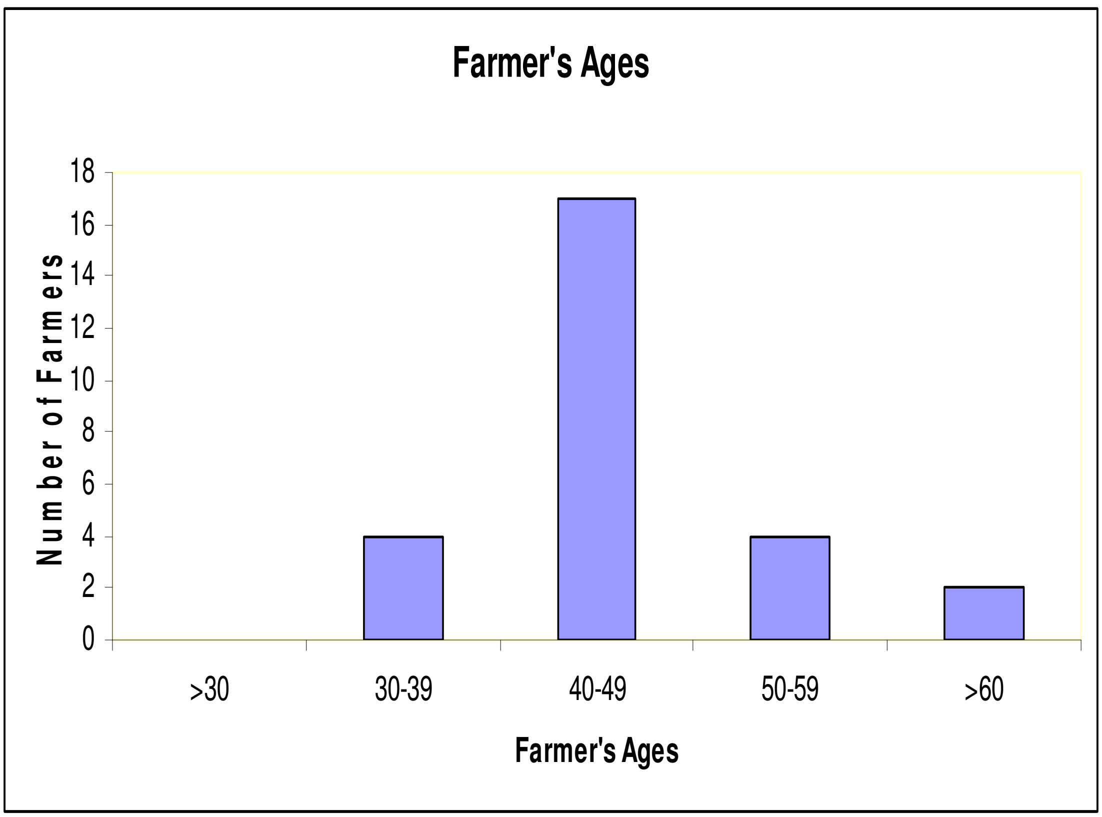

Figure 4.2 The age categories of the respondents *(n = 27)*

According to the Department Of Labour (2009), there is a general understanding that the normal retirement age in South Africa is 60 or 65. The majority of farmers are therefore below the retirement age and ceteris paribus, have the physical ability to contribute more to the control of *Prosopis* compared to their older counterparts.

- Socio-economic characteristics

The population's socio-economic characteristics, i.e. education, farm activities and income were also analysed. Table 4.1 shows the education level of all interviewed farmers together with the main farming activity carried out. The level of education may have an influence on farming activities and on the decisions made with regard to the use of *Prosopis* pods and the attitude towards control of the tree. According to Czarapata (2005), humans are the primary means for invasive species introduction, and because of this, there is need for a community education drive to identify and deal with these species. The majority (92.5%) of the farmers have undergone tertiary education with the minority (7.5%) being matriculants (Table 4.1).

Table 4.1 Education level of respondents and farming activity (*n = 27)*

Type of farming	**Grade 10**		**Matric**		**Tertiary**		**Total**	**Total**
	Number	**%**	**Number**	**%**	**Number**	**%**		**%**
Livestock	0	0	2	7.5	23	85	25	92.5
Crop	0	0	0	0	0	0	0	0
Mixed	0	0	0	0	2	7.5	2	7.5
Total	0	0	2	7.5	25	92.5	27	100

Livestock farming is the most popular form of farming in the area and this may be attributed to the low rainfall in the Karoo and the climate, which is generally hostile to crop farming. As indicated in Impson *et al* (1999), where the Northern Cape is noted as the most arid of the South African provinces, agricultural potential is dependent on functioning irrigation systems along the big rivers like the Orange River. However, 7.5% of the farmers indicated that they do grow crops, mostly vegetables for sale to the local direct community and household consumption (Malan, pers comm 2009).

Farmers' incomes are also thought to have an influence on decisions taken, including those related to controlling *Prosopis* invasion. The average monthly incomes are summarised in Table 4.2.

Table 4.2 Average monthly incomes of farmers *(n = 27)*

Average monthly incomes x (R)1000	Number of farmers	%
20 – 30	18	67
31 – 40	8	30
41 – 50	1	3
Total	27	100

The majority of the farmers (67%) belong to the R20 000 – R30 000 income group while the minority (30%) and (3%) fall in the higher R31 000 – R40 000 and R41 000 – R50 000 groups respectively.

Tables 4.1 and 4.2 show that the majority of the respondents are well educated and belong to high-income brackets. This implies that ceteris paribus, the high knowledge base and disposable income puts the farmers in a good position to engage in effective control activities.

- Levels of control

The control of *Prosopis* involving chemical and mechanical means has been practiced by both farmers and relevant authorities in the study area. However, methods for the chemical and mechanical control of *Prosopis* are dogged by limited success because they are labour-intensive and expensive, with costs of application usually far exceeding the value of the land (Vorster, 1987; Harding, 1987). All the farmers believe that not enough is being done to control *Prosopis* and they agree on the need for control due to the dire effects that have been realised in the province because of the presence of *Prosopis*. Over 90% of the farmers have actively controlled *Prosopis* at an average cost of R11 389 / annum. Two thirds of the respondents place the responsibility of control entirely on the state while remaining 33% advocate for a combined effort from the state, farmers and all relevant stakeholders.

A majority of the farmers are active controllers of *Prosopis* however; the levels of control differ from farmer to farmer. To capture and analyse the differences, the amounts spent on control by each farmer were grouped into corresponding groups shown in Table 4.3. The table shows that the modal control class is 10 – 15 thousand rand with a class mean of R12 500. The high standard deviation indicates that there are a number of respondents in the extreme classes (0 & 15 - <20) who are not captured by the overall population control cost mean. This implies that that despite the high percentage of farmers involved in the control of *Prosopis* a significant number fall below and above the average estimate of R11 389 / annum.

Table 4.3 Grouped farmers control costs

Amount spent on control in Rands (R)	Number of farmers	Mean (control cost / number of farmers) (R)
0	2	0
0 - < 10	6	7 500
10 - < 15	14	12 500
15 - < 20	5	17 500

Minimum = 0; Maximum = 17500; Mean = 11389; Standard Deviation = 4617

Table 4.4 Attitudes and levels of control by farmers (*n = 27)*

<table>
<tr><td rowspan="2">Farmers actively involved in the control of Prosopis.</td><td colspan="2">Number of farmers</td><td colspan="2">%</td></tr>
<tr><td colspan="2">25</td><td colspan="2">93</td></tr>
<tr><td rowspan="2">Average spent by farmers on control / annum</td><td colspan="2">Formula used</td><td colspan="2">(R)</td></tr>
<tr><td colspan="2">∑(c) / n</td><td colspan="2">11 389</td></tr>
<tr><td rowspan="2">Responses pertaining who should take a leading role in the control of Prosopis</td><td>State</td><td>Combined effort</td><td>%</td><td>%</td></tr>
<tr><td>18</td><td>9</td><td>67</td><td>33</td></tr>
</table>

Where (c) represents individual farmer costs of control (using class centres)

The variables age and income were further analyzed to determine their relationship with the control of *Prosopis* in the area. The survey responses relating to the variables under discussion are shown in Table (ii) (Appendix 1). The respective class centres were used to represent the different classes in the case of monthly income and amount spent on control. In the case of age,

1. Represents > 30
2. Represents 30 – 39
3. Represents 40 – 49
4. Represents 50 - 59
5. Represents > 60

A strong positive relationship between monthly income and amount spent on the control of *Prosopis* as depicted by the correlation coefficient 0.638 was realised (Table 4.5). This implies that if the amount of income realised by the farmer monthly increases the farmer's ability to control *Prosopis* also increases. However age and control are negatively related with a correlation coefficient (-0.48) (Table 4.6) meaning that the older the farmer the less his involvement in control *Prosopis* on the farm.

Table 4.5 Relationship between *Prosopis* control and monthly income

		Amount spent on controlling *Prosopis* (x R1 000)	Monthly Income (x R 1 000)
Amount spent on controlling *Prosopis* (x R1 000)	Pearson Correlation	1	.638**
	Sig. (2-tailed)		.000
	N	27	27
Monthly Income (x R 1 000)	Pearson Correlation	.638**	1
	Sig. (2-tailed)	.000	
	N	27	27

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

Table 4.6 Relationship between Prosopis control and age

		Amount spent on controlling *Prosopis* (x R1 000)	Age
Amount spent on controlling *Prosopis* (x R1 000)	Pearson Correlation	1	-.480*
	Sig. (2-tailed)		.011
	N	27	27
Age	Pearson Correlation	-.480*	1
	Sig. (2-tailed)	.011	
	N	27	27

*. Correlation is significant at the 0.02 level (2-tailed).

As earlier indicated, *Prosopis* was introduced for its perceived advantages however; disadvantages have surfaced as a result its presence in the study area. Table 4.7 indicates the advantages and disadvantages the respondents consider associated with *Prosopis* in the area. The advantages and disadvantages are listed in order of value / seriousness, which is indicated, by the number of respondents who cited the advantage or disadvantage in the survey.

Table 4.7 Advantages and disadvantages cited by respondents in ascending order (*n = 27)*

Disadvantages	**Number of farmers concurring**	**%**	**Advantages**	**Number of farmers concurring**	**%**
Depletion of underground water Reserves	27	100	Pod grazing by live stock in the veld	13	48
Reduction of carrying capacity	23	85	Soil cover	3	11
Destruction of natural vegetation	21	78	Shade in the case of single tall trees	1	4
Inaccessibility to farmland	17	63			
Sheltering undesirable animals (Black backed jackal)	3	11			

All farmers are concerned about the effect *Prosopis* has on the underground water supply this concern may be a result of water scarcity in the province. *Prosopis* species have a long tap root system, which can result in the use of large quantities of underground water resulting in the withering of most plants around the tree (Van Schalkwyk, pers comm. 2009). *Prosopis* species spread rapidly colonizing land as the spread progresses this leads to the reduction in the land carrying capacity which effectively has affected (85%) of the farmers in the study area. Over three generations, 74% of the farmers have witnessed the destruction of natural vegetation because of the *Prosopis* invasion in the area, from the survey some of the indigenous plants that were there 30 years ago have disappeared altogether from the study area. *Prosopis* species form impenetrable thickets, which 63%

of the respondents have cited as a problem. A minority (11%) argue that *Prosopis* trees provide shelter to wild animals like the black backed jackal that prey on the livestock.

About half (48%) of the farmers consider livestock grazing on pods advantageous while 11% value the tree for its ability to reduce soil erosion by providing soil cover. A minority (4%) value the shade provided by stand-alone *Prosopis* trees.

4.3.3 *PROSOPIS* PODS, THEIR VALUE AND LOSS IMPLICATIONS

Prosopis pods are a highly nutritious and useful source of fodder for domestic stock and wild animals (Simpson *et al,* 1977). Harding (1988), estimated total pod production in South Africa at about 400 000 t / annum (2t / ha) which could theoretically sustain about 500 000 sheep. The food value of *P. velutina* and *P. glandulosa* primarily lies in the sugars (16 and 19% by dry mass, respectively) of the mesocarp and in the protein (11 and 13%, respectively) of the endocarp (seed) (Simpson *et al*, 1977). However, the utilization of pods as supplementary fodder in South Africa is negligible because farmers are cautious of promoting *Prosopis* invasions on their land, a threat that is perceived to outweigh the plant's beneficial attributes (Harding, 1988).

Forty-eight percent of the respondents indicated that they valued *Prosopis* pods mainly for feeding livestock. However, none of the 48% had actively stored pods for feed but rather let the animals feed on the pods while they are on the ground. A few farmers (11%) have traded in *Prosopis* pods in the past year making an average of R2 300 per annum. However, those that traded in the pods indicated that the pods are seasonal and during pod season, they have been turned away a number of times by pod-based businesses who indicate that they have enough pods for the season (Survey). As shown in table 4.8, the majority of the respondents (85%) use commercial feed at an average annual cost of R13 750 to supplement the livestock diets.

The situation summarised in Table 4.8 is one where there is a 0% reduction in pods available hence, it may also be considered to represent the current situation at present.

4.3.4 ECONOMIC IMPLICATIONS OF A REDUCTION IN AVAILABLE PODS

The study made use of two different scenarios to analyse how the change in the available pods would affect the farmers. Firstly, the farmers were asked to indicate how a 50%

reduction in available pods would affect them economically. The second scenario posed to the respondents was a 100% reduction or rather a total eradication of pods.

Table 4.8 Value of pods and use of commercial feed *(n = 27)*

Farmers that value pods	**Number**	**%**
	13	48
Farmers that have traded in pods	**Number**	**%**
	3	11
Farmers that use commercial feed	**Number**	**%**
	23	85
Average annual cost of commercial feed	**Formula**	**(R)**
	∑(c) / n	13 750
Average income from pod trade	**Formula**	**(R)**
	∑(c) / n	2 300

Where (c) represents individual farmer costs of control (using class centres)

With a 50% reduction in pods, all respondents indicated that there would be no change in their costs, incomes, the current situation and economic activities. Malan (pers comm. 2009) considered the pods that would remain sufficient and even more than enough to supplement livestock feed.

With a 100% decrease in available pods respondents indicated that there would be certain annual changes to their incomes and livelihoods. To analyse these changes they were split into three different cost categories. Firstly, direct loss of pod income (DPI) is considered the main loss that would result from the loss of pods especially to those farmers who trade in *Prosopis* pods. Secondly, the loss of pods is assumed to lead to the need to increased supplementary feed in the form of commercial feed. The need to purchase commercial feed leads to increased farm production costs, which are termed (ICF). Thirdly, are those costs that are ambiguous and very difficult to mathematically quantify which may include the eventual eradication of the tree leading to issues such as erosion, loss of shade and other environmental positives that *Prosopis* species bring; these are termed (λ). Therefore the effect of a 100% reduction in available pods is summarised in the cost function shown in (equation 1); this cost function is then divided by the total number of respondents (n) to get the average loss resulting from the loss pods for the individual respondent.

$$(\sum (DPI + ICF + \lambda) / n \qquad \text{(Equation 1)}$$

$$n = 27$$

The respondents were asked how a total eradication would affect production costs which are in the case of (equation 1) represented by $\sum$ (ICF + λ). The costs associated with a 100% reduction in pods were ((R 3 518 / annum). Therefore, $\sum$ (ICF + λ) / 27 = 3 518. In table 4.8 the average income that farmers derived from pods was calculated and given as (R 2 300 / annum) thus $\sum$ (DPI) / 27 = R2 300.

Using (equation 1)

The average effects of a 100% decrease in pods

= (R3 518 + R2 300)

= R5 818

Therefore, estimates indicate that the average annual loss from the total eradication of *Prosopis* pods each farmer in the area can expect is R5 818. Thus, a loss in pods would result in change of income in the form of an estimated reduction of R5 818 in annual farm income. Some respondents also indicated that the total loss of pods would actually reduce their costs over time.

The effects of a 100% reduction in pods were further investigated for each individual farmer in order to assess if the general average is a good representation of the effects of the pod reduction. Using the equation

$$\sum (DPI + ICF + \lambda) = TIE \qquad \text{(Equation 2)}$$

Where TIE is the total individual effect.

Each farmer's expected changes in costs were calculated and grouped as shown in the table 4.9, while table 4.10 highlights the percentage grouped individual effects that a 100% reduction in pods had on the farmers.

Table 4.9 Grouped individual effects of a 100% reduction in pods

Cost change group (Rands (R))	Number of farmers	Mean (∑cost / number of farmers) (R)
0	5	0
<2 500	14	2 500
<7 500	5	7 500
>10 000	3	28 200

Minimum **= 0**; Maximum **=** 28200; Mean = 5818; Standard Deviation = 8413

The statistical mode is represented by the < 2 500 which represents the majority of the farmers while the minorities are represented by the two extreme groups 0 and >10 000. The presence of the extreme classes explains the high standard deviation (Table 4.9) from the arithmetic mean (R5 818) which was used to give the average effect of a total loss of pods. These extremes are a significant part of the analysis showing that pod trade amongst the farmers are concentrated on a few. However, they are not captured by the statistical tools used to come up with the farm averages.

The table also shows that the bulk of the negative effects are borne only by 11% of the farmers who are the main traders of pods. Calculations indicate that on average the active traders (11%) each make R20 700 annually in pod income. For most of the farmers (89%) who do not trade in pods DPI is zero hence the effects are all in the form of costs that would arise from aspects such as the purchase of feed and transport.

4.4 THE ECONOMIC IMPLICATIONS OF DUNE FOODS LOSING *PROSOPIS* PODS DUE TO INCREASED BIOLOGICAL CONTROL

A questionnaire was sent electronically to Dune Foods in October 2008, to obtain as much relevant information as possible after a number of deliberations and drafts. Dune Foods are the only company in the western part of the province that makes use of *Prosopis* pods as a main production raw material. The following observations were captured and recorded from the questionnaire responses.

The company values pods and considers them a potentially important resource in the province. The respondent revealed that the company does not have or actively run a *Prosopis* plantation. Pods are collected by local residents who are paid R3 / kg of pods collected; Dune Foods considers pods an integral part of the welfare of the local communities. The company currently uses 160 tonnes annually but indicated that demand is growing and the annual consumption is likely to increase and continue increasing over time.

As formerly indicated Dune Foods value *Prosopis* pods and according to the respondent this direct quotation would be the result of a 50% decline in *Prosopis* pods available;

‘Currently there will not be a huge impact, but as we are planning to expand as the markets grow, a reduction in pods could mean a loss of millions of rand for the Northern Cape Province in revenue.’

The company estimates the resulting financial loss of a 50% decline in *Prosopis* pods to be R12million.

With respect to the second scenario of a 100% decline in *Prosopis* pods the following was the response from Dune Foods;

‘Currently we use an estimated pod value of R270million in the Northern Cape and we are working towards a goal to utilize all the pods and creating much needed jobs in the process. We are propagating the management of the *Prosopis* and not total eradication.’

Thus, a 100% decline in pods is estimated to cost the province R270million and negatively affect job creation in the Northern Cape. Costs are therefore expected to rise as *Prosopis* pod quantities continue to fall between 50 and 100%.

The company considers increased biological control undesirable, as it is very costly in terms of pod loss. However, the respondent acknowledges the fact that *Prosopis* has become a threat to the environment and biodiversity of the Northern Cape. In addition, Dune Foods have been involved actively in the control of the tree and have considered the need for better environmental management in the form of techniques that do not compromise the availability of pods. A holistic approach is what the respondent advocates for one that actively requires the participation of all relevant stakeholders namely, the Department of Water and Forestry (DWAF), the local municipalities and the individual farmers in the province.

The Dune Foods interview revealed that *Prosopis* might be profitable if well managed. In the Americas, where *Prosopis* is indigenous, a combination of natural and unnatural management has led to the growth of a profitable mesquite pod industry. According to Silva (1990), a 1965 survey of nine Mexican states recorded a collection of 43,000 tons of mesquite pods, with a total value of 14 million pesos or more than US$1,000,000. In San Luis Potosí, total commercial value of pods surpassed that of mesquite wood products by 70 times. Thus, the responses support the view that if *Prosopis* is so profitable in the Americas then it should do as well in South Africa with better management.

Estimates of *Prosopis* pod yields from natural and deliberately planted *Prosopis* have been previously reviewed ranging from 14 – 12 000 kg / ha / year and up to 140 kg / tree (Felker, 1979). Harding (1988), estimated total pod production in South Africa at about 400 000t / annum (2t / ha). In South Africa, more than 2 million hectares have been invaded to some degree by *Prosopis* and it is continuing to expand its range (Henderson, 2001). Assuming the estimated Dune Foods loss of R270million is entirely for wage payments to the harvesters of *Prosopis* pods then this implies that Dune Foods uses 90 000 tonnes[1] of *Prosopis* pods which is almost 562 times the size of Dune Foods which uses 160t / annum as indicated in the questionnaire interview. This makes the indicated figurative loss of R270million high questionable and arguably a 'business man's over-estimate'. Using the yield estimates by Harding (1988), this amount of pods is harvested on an estimated 45 000ha[2]. This implies that Dune Foods does not utilise all pods as the amount of land that corresponds to the pods used is only but a small fraction of the land that has been colonised by *Prosopis* in the area. This is further highlighted by the fact that some farmers who harvested the pods have been turned away as the company indicated that what had been collected was sufficient for that period (survey).

The initial indication from the Dune Foods responses is that the province loses a vital income source if the pods were eradicated with losses estimated at 270 million. However if this loss was avoided by keeping control constant there would be surplus unutilised pods that would fuel the *Prosopis* invasion further colonising land and creating more environmental problems which the province would have to deal with. These problems include the loss of underground water, infrastructure (e.g. redundant boreholes),

[1] R270 000 000 / R3 000 = 90 000t

[2] 90 000 / 2 = 45 000h

biodiversity, grazing land and costs associated with the control of the invasive tree. In comparison, the resulting environmental losses that the province is likely to face attempting to salvage the loss of the Dune Foods income would most probably outweigh the business income loss over time.

The indicated amount lost by Dune Foods is also highly unrealistic and technically not feasible. As indicated earlier the company would have to grow an estimated 562 times in order to make use of the amount of pods indicated in the questionnaire survey. This implies that in reality the business actually uses a very small proportion of the pods further fuelling the resultant environmental costs. From the individual farmer effects shown in the Table 4.8, 11% of the farming community supply industry with over one third of the total pods Dune Foods claims to use. Given the feasibility factors surrounding the survey figure one may argue that the farming community provides the bulk of the pods used by the company. This is further brought to light by the fact that most of the *Prosopis* pods are found on private farms rather than in dense human settlements of Prieska where Dune Foods is located. It therefore would not make sense for local residents to risk the effects of trespassing on private property to receive the relatively low remuneration for pods. The presence of large individual suppliers undermines the employment provision and creates claims that are indicated in the questionnaire interview. Factors such as location of dense *Prosopis* thickets, private property laws and equipment used in pod collection would likely limit the employment creation opportunities to a minimum.

4.5 COST COMPARISONS

In the event of a loss of pods various changes may take place in the stakeholder environment, these changes, may be summarised as expected costs and benefits to stakeholders. The main stakeholders in the study area are namely the environment, farmers, business community and the local authorities.

The survey revealed underground water to be the single most problematic factor that is associated with the *Prosopis* invasion (Table 4.8). According to Marais & Wannenburgh (2008), very scattered (1–5%) invasions of selected species for example were between 3 and 25 times cheaper to clear than closed canopy stands (75–100%). On the other hand, unit reference values used to compare clearing operations in terms of cost efficiency in generating extra water yield were much higher for low levels of invasion than denser invasions, to the extent that the former's viability could be questioned by the uninformed. However, this was only assessed in terms of extra water generated and not in terms of volumes of water secured, as invasive alien plants spread and become denser if not actively controlled. Overall, Marais & Wannenburgh (2008), estimated that around 7% of riparian invasions have been cleared, resulting in significant yield increases of 34.4 million m^3 which is about 42% of the yield of the new Berg River Scheme in the Western Cape (81 million m^3). Thus, it is expected that in the long-run with an eradication of pod there will be a significant increase in available water to each individual farmer. A total eradication of pods would lead to a trade off between the loss of pods to the individual farmer versus the saving of control costs and underground water.

This trade off may be expressed in ratio form however, due to data limitations the expected increase in available water is given as a constant (K). The assumed benefit to the farmers is a reduction in control costs (C^c) (given in table 4.5) + increased water (K). However, to enjoy this benefit the farmer has to forego *Prosopis* pods, which according to the data analysis are valued at R5 818. This gives a comparative ratio of,

R11 389 + (K): R5 818.

The immediate cost of having pods on the farm is higher than the value attached to the pods by individual farmers. Thus, rationally the farmer aiming to maximise utility is better off without the pods than with them and would choose to lose the pods, as there is more benefit in foregoing them.

The eradication of pods also leads to minimal industrial losses and losses to the provincial economy at large. However, at provincial level the main benefactor from the absence of pods is the environment. To value environmental benefits, the avoided cost method is used. Specific strategies allow society to avoid costs that would have been incurred in the absence of those actions. For example, the clearing and chemical control of *Prosopis* in the Northern Cape avoids further environmental damage that may be caused by the plant. These cost avoidance strategies, can be used to estimate economic value of the environmental services based on the cost of implementing the strategies. The environmental threats posed by *Prosopis* would include the loss of bio diversity (LB), the loss of valuable grazing land (LGZ), the loss of underground and surface water (W), cumulative costs of water loss (e.g. low borehole pressure) (CW), soil chemical component loss (S) and other multiple losses that are mathematically immeasurable (β), like the utility one derives from knowing that the indigenous vegetation is unharmed. Therefore total environmental costs (TE) posed by the presence of *Prosopis* in the area may be given as,

$$TE = cAC = LB + LGZ + W + CW + S + \beta \qquad \text{equation (3)}$$

In this case, cAC represents the strategies and the associated costs that the province has implemented to avoid TE. The main components of cAC are assumed to be directly linked to costs accrued by the local DWAF through the WfW organisation. The cAC is in this case given by the amounts spent on *Prosopis* and *Prosopis* related problems in the area. According to the information in Table (i) (Appendix 1), the WfW De Aar office spent R15, 7 million annually towards the control of *Prosopis* in 2008. These control efforts have been taking place over a period of time in different areas and are likely to continue taking place till the invasion is under control hence the annual amount is multiplied by the possible number of years (Y) it would take to bring the invasion under control. Therefore

$$cAC = N(Y(R15.\ 7\text{million}))$$

where N represents the number of running projects in the area.

To analyse the provincial economic benefit of *Prosopis* pods the assumption that Dune Foods has the ability to grow 562 times over time is made. This assumption is highly unlikely and unrealistic but is made with respect to the questionnaire interview and for the purposes of analysis. Thus, the provincial loss is given by the assumed income lost by Dune Foods in the event of a total loss of pods. This gives a comparative ratio of

$$\alpha\ (270\text{million}): N(Y\ (15.7\text{million})).$$

With the pod income from Dune Foods untouched by reduced pod production, the company would not be utilising all available pods resulting in a further accumulation of environmental costs. Therefore, the Dune Foods estimated income is discounted by a factor (α) to get a true reflection of the actual derived income. Issues formerly discussed in section 4.4 indicate that due to small fraction of pods arguably utilised by industry the resultant environmental cost are still very high hence, the discount factor is likely to reduce the derived income by a highly significant margin. Thus depending on the discount factor and making use of available literature that indicates that using current techniques, it can take many years before the invasion is under control it becomes apparent that rationally the alternative to eradicate pods is on a higher provincial indifference curve.

In reality, the cost comparison is likely to favour the eradication of pods by an even larger margin as the actual incomes realised from the *Prosopis* industry may be much lower. This leads the question; if *Prosopis* benefits only but a few but affects many, should the government not make a decision for the good of the state?

4.6 CONCLUSION

Most of the farmers are well educated and have a general understanding of the extent of the *Prosopis* invasion. The results show that there is a single dominant private company involved in pod based production activities but without any alternative source to *Prosopis* pods other than the environment. Analysis also revealed that a 50% loss in pods did not affect the farmers at all and would most likely have minimal effects on business incomes given the critical conclusions in the chapter. At a 50% pod reduction however, levels of environmental costs are likely to outweigh the minimal business losses. Using information in this chapter, one may also argue that the loss of pods would affect the business more than it would affect the farming community. This is based on evidence that the majority of farmers do not value *Prosopis* pods highly and their loss would not seriously erode their income. On the other hand, the loss of pods would adversely affect the business' private income but would have immense overall environmental benefits that outnumber the benefits of *Prosopis* pods by a staggering margin hence; introduction of a more efficient biological control agent is likely to have more positive than negative effects in the province.

CHAPTER 5

SUMMARY AND POLICY RECOMMENDATIONS

5.1 INTRODUCTION

Prosopis species are classified as weeds in South Africa and their removal from the environment is deemed necessary and with beneficial results. Environmental goods and services have been lost due to the presence of the plant in the Northern Cape province of South Africa and without adequate control; these may continue to be lost with negative consequences to the population of the Northern Cape at large. However, as intentionally introduced tree species, *Prosopis* have become useful to some members of the local community and their control needs to be done cautiously.

Firstly ordinary sheep farmers in the province let their livestock graze on the highly nutritious *Prosopis* pods, which may prove to be very important given the climatic conditions in the area. The subsequent removal of these pods may result in farmers needing to supplement with costly commercial feed. Secondly due to the scientific realisation that *Prosopis* pods had chemical attributes that could be harnessed, mass produced, marketed and sold at a profit, one major dominant *Prosopis* pod based business has been set up in the study area. Businesses such as these are heavily dependent on the availability of high-grade *Prosopis* pods for their survival. Therefore, research has been carried out before implementation of pod eradication or reduction techniques in order to access the extent to which ordinary farmers and business would be affected economically.

Various pod eradication strategies are available with biological control amongst them. Biological control of *Prosopis* species in the Northern Cape has been confined to seed feeding beetles however; research and various studies consider the beetles inefficient hence the need for the introduction of more effective biological control agents. The introduction of more effective agents would mean a significant reduction of pods available but not necessarily the hypothetical 50% / 100% reduction. This would result is *Prosopis* based businesses experiencing production strains which could compromise their operational ability. This study acted as a fact-finding mission heralding the possibility of increased, more effective biological control techniques. Primary attention was given to the possible economic losses that would accrue to the ordinary farmers, the environment and *Prosopis* based businesses. The possible economic losses are documented and are explained using various descriptive statistical tools in the study.

5.2 RESULTS SUMMARY AND INTERPRETATION

Results from the pilot study, which was carried out in eastern parts of the province with its research centre being De Aar are summarised as follows:

- Most farmers in De Aar and surrounding areas do not harvest or value *Prosopis* pods and their absence will have negligible economic impacts on their farming activities.
- Some farmers have been actively involved in the control of mesquite but a considerable number have left control in the hands of the responsible authorities.
- Farmer would rather have no *Prosopis* at all on their arable land.
- The business community values pods highly and considers them indispensable and their absence would seriously affect business operations.
- The environmental benefits after the introduction of the biological control agent are likely to be higher than the value of the pods to the province before the agent.

5.2.1 SURVEY SUMMARY

Further research using questionnaire surveys revealed that the majority farmers further east did not harvest *Prosopis* pods but rather let livestock feed on the pods freely in the veld. Farmers are noted to be concerned about the *Prosopis* invasion more than they value the pods. Survey results also showed that the business community is highly dependent on pods and consider the loss of pods as a serious compromise to their ability to operate.

Analysis showed that the farmers do not highly value the pods and losing them would not lead to significant economic losses. However, the business community has serious 'private' income and economic concerns that would result from pod eradication techniques involving increased biological control. After analysis and comparisons, the overall provincial benefits that would arise from more effective biological control (introduction of a bud and flower feeder) was shown to exhibit a higher provincial utility compared to the utility derived from business private incomes. It is therefore worthwhile and economically justifiable to introduce more effective biological control agents in the province and environment at large have been shown to be better off without *Prosopis* pods.

5.2.2 SUMMARY OF DESCRIPTIVE STATISTICS

Data was collected from 27 farmers in the more western parts of the province namely, Van Wyksvlei, Carnarvon and close surrounding area. All responds interviewed were well-educated white males (over 90% of the farmers had undergone tertiary education) and spoke Afrikaans as a first language; with the majority of respondents (78%) falling between the ages of 40 and 59. (74%) of the respondents indicated that they had noticed the invasion more 10 years ago and their main concerns resulting from the invasion in order of importance were depletion of underground water reserves, reduction of carrying capacity, destruction of natural vegetation, inaccessibility to farmland and the sheltering of undesirable animals that harm livestock (Black backed jackal). All of the farmers believe that not enough is being done to control *Prosopis* and they agree on the need for control due to the negative effects that have been realised in the province because of the presence of *Prosopis.* Over 90% of the farmers have actively controlled *Prosopis* at an average cost of R11 389 / annum however, (67%) of the respondents place the responsibility of controlling entirely on the state.

The majority used commercial feed and indicated that the main uses of *Prosopis* in order of importance were pod - grazing by livestock in the veld, soil cover and shade in the case of single tall trees. (48%) of the respondents indicated that they valued *Prosopis* pods mainly for feeding livestock. However, none in the 48% had actively stored pods for feed but rather let the animals feed on the pods while they are on the ground. A few farmers (11%) have traded in *Prosopis* pods in the past year (2008) making an average of R2 300 per annum. With a 50% reduction in pods, all respondents indicated that there would be no change in their costs, incomes, the current situation and economic activities. However, with a 100% reduction in available pods estimates indicated that the average annual loss each farmer in the area could expect is R5 818.

5.3 POLICY RECOMMENDATIONS

Throughout the research, a number of observations were made concerning the value of *Prosopis* pods in the Northern Cape and the state of the *Prosopis* invasion in the area. With these observations in mind, policy recommendations and options that may alleviate the situation are given.

- **Commercialisation of *Prosopis***

Prosopis trees already play a vital part in the ecology and the economy of many arid and semi-arid zones where they are found. In the Americas, they play an integral part in several sustainable land use systems that are improving the livelihoods of rural desert populations while preventing further soil degradation and assisting land reclamation (Pasiecznik *et al*, 2001). Most of the cultural constraints to arid zone development have already been overcome, particularly through nursery and plantation establishment (Lee & Felker, 1992),

Prosopis species in South Africa grow wild and free, this implies there is no individual group that is responsible for the costs and benefits that accompany mesquite. Therefore, because *Prosopis* grows in the broader environment it is difficult to manage or apportion responsibility to the users of the plant who stand to lose. One way to deal with this issue would be to commercialise mesquite such that those that use the plant invest in well managed plantations for which they would be directly responsible. In this way, the benefits from the tree may be adequately harnessed while the detrimental environmental effects are minimised due to presence of property rights.

The study revealed that most farmers do not actively harvest pods but rather let livestock freely feed on them in the veld. This implies that the dominant harvester and user of *Prosopis* pods is the local business. Thus, to minimise the negative externalities that results from the demand for pods by local business it would be necessary to push business to bear and turn most of the arising social costs into private costs through active planting and management of privately owned plantations.

- **Introduction of the flower and bud feeding agent**

Related to the commercialisation of the tree, is the eventual introduction of the flower-feeding agent to deal with the aggressive invasion and leaving those who derive utility from the presence of the plant to protect it with insecticides, as is the case with other valuable crops. From the results and analysis, the private costs likely to be incurred by *Prosopis* pod users are likely to be significantly lower than the environmental costs associated with the current state of affairs.

- **Increased consultations**

Unemployment and poverty are issues that are not new in the study area and the presence of a supplementary income from pod collection is very much appreciated by the locals who harvest pods for local business. A reduction or a total eradication of pods will compromise this supplementary income; the policy may therefore illicit strong negative responses from locals who consider this income in their annual budgets.

Prosopis grows wild in the Northern Cape hence the effects that are borne by the environment are not directly visible to the local community's poor who may not have the extensive knowledge in environmental effects of invasive aliens. However, responsible authorities like the DWAF find it necessary to bring the plant under control due to evidence from expert analysis. This state of different mindsets puts the two parties on two different paths headed for inevitable conflict.

Like many other intentionally introduced species the eradication of *Prosopis* would undoubtedly face a credible degree of resistance from users of the plant. There is need therefore for wide ranging consultations with parties involved in order to come up with a solution understood by all. Such consultations would take the form of conferences and group meetings with concerns and suggestions aired in public by all the parties concerned. This action reduces the possibility of future conflict as all involved parties are represented and whatever outcome results is binding on all that were involved in the consultations. Through extensive review of literature it has become evident that consultations of this sort have began to take place, however, results from the study indicate that a credible binding solution is still elusive meaning that there is need for continued consultation.

- ***Prosopis* education**

There is need to educate stakeholders on the effects *Prosopis* species have on the environment of the Northern Cape. Research results show a number of farmers do not actively participate in the *Prosopis* control programmes. Indications of a free rider tendency are also highlighted as a percentage of respondents push the bulk of control costs to the public authority representing the government. Responses indicated that some farmers were not aware of the fact that in South Africa, *Prosopis* is classified as a weed and by law an owner of private property is obligated to control it to satisfactory levels so long it is on their property. Extensive literature review has shown that with education of stakeholders, *Prosopis* can be better managed reduced environmental impacts.

In view of these observations, it would be essential to send out field teams to make farmers aware of the damages and disadvantages mesquites exhibit. There is a need to make respective stakeholders aware of their legal obligation and their duty towards the environment. Field teams are however not the only possible method of education use of print and electronic media may prove indispensable when it comes to getting the message to as many stakeholders as possible in the shortest possible time. The use of local schools may also help inform the youth about the *Prosopis* story in the province at an early age.

The use of the education institutions to further the *Prosopis* education to the youth may translate to information moving from youth to parents who may be active participants in the harvesting of pods for use by local business. It may then be suggested or encouraged that the profitable users of *Prosopis* pods like Dune Foods step in and actively fund such initiatives.

The main challenge that comes after education is the implementation of the proposed strategies in order to achieve the expected goals. Education alone however may not solve the *Prosopis* problem but lays a solid foundation for the development and implementation of successful control programmes that are more goal-oriented and binding to the study area.

- ***Prosopis* SME support**

Supporting the establishment of viable, small industries in order to encourage maximum pod utilisation would reduce the environmental effects that would result from surplus pods and simultaneously ease employment concerns raised by *Prosopis* industry beneficiaries.

5.4 AREAS FOR FURTHER RESEARCH

Survey observations revealed a lot of insightful information and opened up other issues and doors, which may need further consideration, and possibly, concise focused researches, some of these issues are discussed as follows.

5.4.1 THE IMPACTS OF POD REDUTION ON LOCAL UNEMPLOYED RESIDENTS

The realisation that local unemployed make a living through the collection of pods for local businesses brings about the need for fact-finding studies on the effects that the loss of pods would have on the locals. In addition, local people may have livestock that feed on *Prosopis* pods that naturally fall to the ground, as the tree grows wild. The loss of pods is also bound to have an effect on this sector of society as well, bringing the need to access the economic effect of this loss through research.

5.4.2 A FULL COST BENEFIT ANLYSIS OF THE IMPACTS OF PROSOPIS IN THE AREA VS CONTROL COSTS

It is always important to get feedback on any course of action that was undertaken with aims and goals in mind. In the control of alien plants, the methods used need continuous evaluation in order to justify the scarce resources that they continuously use. One method that has become popular is the use of benefit – cost ratios to determine and evaluate the best alternative and its viability with respect to economic efficiency. There is need to evaluate the effectiveness of current and possible control programmes in the area with a special emphasis on mesquites.

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APPENDIX (1): PRIMARY DATA

Table (i) the operational costs incurred by WfW De Aar

#	Project Name - LIST CLEARING PROJECTS THEN OTHER PROJECTS	N Cape Total	TOTAL Boegoeberg Neusberg	TOTAL Kgalagadi	TOTAL Ongers	TOTAL Francis Baard	Total operational plus operational management
	BUDGET						
1	Budget for 2007/2008	11,044,358	3,553,255	3,437,596	2,741,630	1,311,877	15,687,435
2	Budget spend	6,305,956					
3	Percentage of budget spent.	57%	0%	0%	0%	0%	0%
4	**PERSON DAYS**						
5	Planned persondays of work (excluding training)	118809.0	39752.0	34142.0	36642.0	8273.0	
6	Actual persondays of work done.	0.0					
7	Percentage of planned persondays achieved.	0%	0%	0%	0%	0%	
8	**TRAINING DAYS**						
9	Planned training days.	1385	200	20	1123	42	
10	Actual training days done.	0					
11	Percentage of planned training days achieved.	0%	0%	0%	0%	0%	
12	Percentage of people who worked during month who received training in the month.						
13	**NUMBER OF PEOPLE**						
14	Planned number of people to work on project.	1136	430	246	350	110	
15	Actual number of people who have worked on project.	0					
16	Average number of days worked per person (persondays and training days).						
17	**COST PER PERSONDAY**						
18	Planned cost-per-personday.	R 92.96	R 89.39	R 100.69	R 74.82	R 158.57	

19	Actual cost-per-personday achieved.	R 53	R 0	R 0	R 0	R 0
20	**COST PER HECTARE (Initial + Follow-up)**					
21	Planned cost-per-hectare.	R 306.93	R 330.57	R 356.97	R 216.95	R 442.16
22	Actual cost-per-hectare achieved.	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
23	Planned cost-per-condensed-hectare.					
24	Actual cost-per-condensed-hectare achieved.					
25	**INITIAL CLEARING**					
26	Planned initial hectares.	13884	3088	5410	4087	1299
27	Planned condensed hectares.					
28	Actual initial hectares cleared.	0				
29	Planned condensed hectares cleared.					
30	Actual initial hectares cleared as a percentage of planned initial hectares.	0%	0%	0%	0%	0%
31	TRAINING DAYS					
32	Percentage of planned initial hectares that are on private land.					
33	**FOLLOW-UP CLEARING**					
34	Planned follow-up hectares.	22099	7661	4220	8550	1668
35	Panned condensed follow-up hectares.					
36	Actual follow-up hectares cleared.	0				
37	Actual follow-up hectares as a percentage of planned follow-up hectares.	0%	0%	0%	0%	0%
38	Actual follow-up condensed hectares cleared.					
39	Actual follow-up condensed hectares as a % of planned condensed follow-up hectares.					
40	Formal confirmation that hectares are actually cleared (express as a percentage)					
41	Percentage of planned follow-up hectares that are on private land.					
42	Formal confirmation that land-owner agreements are operative (express as percentage)					
43	Number of planned initial hectares not done.	13884	3088	5410	4087	1299
44	Number of planned follow-up hectares not done.	22099	7661	4220	8550	1668
45	**ADDITIONAL PERFORMANCE INDICATORS**					
46	Hectares cleared using fire.					

47	Planned budget for herbicides.	R 1,159,783.00	R 443,235.00	R 285,493.00	R 258,583.00	R 172,472.00
48	Percentage of planned amount actually spent on herbicides.					
49	Value of herbicides given out as incentives.					
50	Hectares to be controlled through herbicides given out as an incentive.	R 0.00				
51	Planned budget for transportation.	R 1,758,238.00	R 687,217.00	R 546,477.00	R 346,312.00	R 178,232.00
52	Percentage of planned amount actually spent on transportation.					
53	Planned budget for PPE.	R 878,154.00	R 243,754.00	R 225,404.00	R 345,106.00	R 63,890.00
54	Percentage of planned amount actually spent on PPE.					
55	Hectares rehabilitated.					
56	Amount spent on rehabilitation.					
57	Number of injury-on-duty cases.					
58	Number of fatalities.					
59	**EMPLOYMENT**					
60	% Black African	41%	20%	100%	12%	30%
61	% Coloured	70%	93%	30%	87%	70%
62	% Indian	0%	0%	0%	0%	0%
63	% White	0%	0%	0%	0%	0%
64	% Male	44%	38%	60%	44%	34%
65	% Female	51%	52%	40%	44%	66%
66	% 18-25 years	17%	19%	30%	2%	15%
67	% 26 years and older	81%	81%	75%	83%	85%
68	% Disabled	2%	5%	1%		1%
69	**CONTRACT TEAMS**					
70	Number of contract teams.	0				
71	Planned number of contracts.	0				
72	Most number of contracts per contract team.	0				
73	Least number of contracts per contract team.	0				
74	Average contracts per team.	0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
75	**PROJECT MANAGEMENT**					
76	Number of days on which project visited in the field by Project Manager.	0				

77	Number of days on which project visited in the field by Area Manager.	0				
78	Number of days on which project visited in the field by RPL/Implementation Manager.	0				
79	Number of times that formal monitoring and evaluation undertaken.	0				
80	Number of persondays lost to injury on duty.	0				
81	Number of persondays where workers were absent without leave.	0				
82	Overall rating of performance of project by RPL (express as percentage).					

Source (Antonie, 2008).

Table (ii). The responses to questions on age, control and age.

Respondent	(Cnt) Amount spent on control, X (R)1 000	(Y) Monthly income, X (R)1 000	Age
1	12.5	25	5
2	12.5	25	3
3	12.5	25	3
4	12.5	25	4
5	7.5	25	3
6	7.5	25	3
7	12.5	25	3
8	0	25	3
9	17.5	35	4
10	7.5	25	3
11	17.5	45	2
12	17.5	35	3
13	12.5	25	3
14	0	25	3
15	12.5	25	3
16	17.5	35	3
17	7.5	25	3
18	12.5	25	5
19	17.5	35	3
20	12.5	25	3
21	12.5	35	2
22	7.5	25	3
23	12.5	25	4
24	12.5	35	2
25	12.5	25	3
26	12.5	35	2
27	7.5	25	4

APPENDIX (2): QUESTIONNAIRES

University of Fort Hare

Together in Excellence

Resource economics questionnaire

Upon completion of this questionnaire you have contributed towards the cost evaluation of prosopis in the Northern Cape, South Africa. This survey is designed to gather information about how much you value prosopis pods and how their absence or reduction would affect you. It will take approximately 10 minutes and it would be greatly appreciated if you would complete it. It will be collected in 24 hours where it was dropped off, so if you do have any questions please don't hesitate to ask then. This survey is completely anonymous and the results will be used for research purposes only.

Please also be aware that the survey is completely non-discriminatory and the information that you are about to give merely helps in the interpretation of the results.

Met die voltooing Van die vrae, wat toegeken is an die evolueering Van prosopis in die Noord Kaap , Suid Afrika. Die opsoming is geontwerp om informasie te kolekteer oor hoeveel waarde prosopis bome en hoe hulle awesigheid of verandering jou affekteer.Dit sal om en by 10 minute vat en dit sal deeglik waardeur word as jy dit voltooi, so as jy enige vare het moet nie heiwer om te vrae nie. Die opsiming is heeltemal onder geen spesifieke naam toegeken, en sal gebruik word vir navorsing redes alleenlik.

Asseblief wees gewaar dat die opsomings nie in verband is met diskriminasie nie en die informasie wat jy nou gee Van min behulp sal wees , in verband met hierdie uitslae.

1) Have you noticed the presence of *prosopis* in your area? /
Het jy die teenwooddigherd Van prosopis in jou area gesien?

YES / **JA** ☐ NO / **NEE** ☐

1.1) If yes when did you first notice the tree? /
As ja wanner het jy die boom vir die eerte keer gesien?

3yrs ago ☐ 5yrs ago ☐ 10yrs ago ☐ more than 10yrs ago ☐

1) How has the tree population increased? /
Hoe het die boom se populasie vermeerder?

Increased and still increasing at a very high rate/ ☐
Vermeerd en nogsteeds vermeerdiring as baie hoe koers?

Increased but of late the rate has slowed down/ ☐
Vermeeder maars later die verminder koers?

Not increasing/ ☐
Geen vermeerdeing

Decreased/ ☐
Verminder

2) Do you think the presence of *prosopis* brings about any problems? /
Dink jy die teenwoordigheid Van prosopis bring enige probleme?

YES / **JA** ☐ NO / **NEE** ☐

3.1) If yes list the perceived problems in order of seriousness? /
As ja noem die probleme wat jy toegeneem het en doen dit in n volgorde Van ernstigheid?

- …………………………………………………………………
- …………………………………………………………………
- …………………………………………………………………..
- …………………………………………………………………..
- …………………………………………………………………..

3) Do you think the presence of *prosopis* brings any advantages? /
Dink jy die teenwooddighied Van prosopis bring enige voodele?
YES / **JA** ☐ NO / **NEE** ☐

3.1) If yes, list the advantages in order of importance? /
As ja noem die voodele in n volgorde Van belangrikheid?

- ………………………………………………………………………
- ………………………………………………………………………
- ………………………………………………………………………
- ……………………………………………………………………….
- ……………………………………………………………………….

Due to the continuous efforts by organisations such as Working for Water under the department of water and forestry the control of prosopis has become a priority in this area. It is hypothetically possible to use biological control against the plant however; this may see a 50% or even a 100% reduction in pod production. This section attempts to find the value you place n the pods and how the reduction in quantity would affect you.

As gevolg Van die voort gan Van moeite Van organisasies soos werk vir water onder die departement Van water en die beheer Van prosopis het n priorityd in die omgewing geword. Dit is Van belange om biologiese beheer te gebriuk teen die plant, maar dit mag 50% of 100% vemindering in vrug pdukoise bring . Die afdeling probeer om die waode Van die vrugte te vind en hoe die hoeveelheid vermindering jou sal affekteer.

4) Do you use/value *prosopis* pods? /
Gebiuk jy of waardeur jy de vrugte Van prosopis

YES / **JA** ☐ NO / **NEE** ☐

5.1) What do you use the pods for, and how? /
Waarvoor gebruik jy die vrugte voor, en hoe?. (*e.g do you use them as feed , if so how /* ***gebruik jy dit as voeding, as ja hoe***)

....
....

5.2) Do you harvest the *prosopis* pods or do the stock feed on them in the veld?/
Boer jy met prosopis vrugte of voed die diere op dit in die veld?

Harvest/ **Boer** ☐ Free range/ **Vry veld** ☐

5.3) If you harvest, approximately how much 50kg bags of *prosopis* pods do you harvest/month? /
As ja min of meer hoeveel 50kg sakke prosopis vrugte boer jy per maad ?

< ☐

5 - 10 ☐

10 - 15 ☐

15 - 20 ☐

20 - 25 ☐

☐

25 - 30

>30

7.2) If free range feeding, what percentage of the time in a day do the stock feed on *Prosopis* pods?(*answer may be given in hours livestork spend grazing in the veld in a single day*)/
As vry veld voeding, wat se persenasie Van die tyd in de dag voed die diere aan die prosopis vrugte

…………………………………………………………………………..

5) Have you traded in *prosopis* pods before? /
Het jy al gehandeldruif met prosopis vrugte Van tevoore?

YES / **JA** NO / **NEE**

7) If yes how much is your annual income from the pods? /
As ja hoevel is jou jaarlikse inkomste Van die vrugte ?

R10 000

R10 000 – R20 000

R20 001 – R30 000

R30 001 – R40 000

R40 001 – R50 000

R50 000

7.1) Have you used commercial feed before? /
Het jy kommersieele voeding Van tevoore gebruik?

YES / **JA** NO / **NEE**

7.2) if yes, what is the estimated financial cost of feed per anum? /
As ja wat is jou finasiele koste Van voeding per maand?

☐ < R5 000

R5 001 – R10 000 ☐

R10 001 – R15 000 ☐

R15 001 – R20 000 ☐

R20 001 – R25 000 ☐

☐ R30 000

8) If you harvest prosopis pods what quantity in 50kg bags of pods do you consider sufficient for a period of one month? /
Wat is die hoeveelheid 50kg sakke vrugte wat jy oorweeg as genoeg vir n priode Van een maand?

<☐

5 - 10 ☐

10 - 15 ☐

15 - 20 ☐

20 - 25 ☐

25 - 30 ☐

☐ >30

9) Have you invested in pod storage facilities (including preservations chemicals)? /
Het jy beleging in vrugte stoor fasiliteite (ingesluite gemikale)?
YES / **JA** ☐ NO / **NEE** ☐

9.1) If yes how much have you invested to date? /
As ja hoeveel belegings maak jy jaarliks en op datum?

☐ R10 000

R10 000 – R20 000 ☐

R20 001 – R30 000 ☐

☐

R30 001 – R40 000

R40 001 – R50 000 ☐

☐ R50 000

10) How much is your normal monthly income? /
Hoeveel is jou normale maandlikse inkomstie?

☐ R10 000

R10 000 – R20 000 ☐

R20 001 – R30 000 ☐

R30 001 – R40 000 ☐

R40 001 – R50 000 ☐

☐ R50 000

11) How would the following pod quantity reductions affect you with respect to production costs per anum? /
Hoe sal die volgende vrugte hoeveelheid aftrekkings jou affekteer met verwysing na die produksie koste per jaar? (*e.g would you end up supplimenting the pods with animal feed and how would this increase your costs* / ***sal jy die vrugte vervang met diere voeding en as ja hoe sal dit jou koste vermeerder?***)

Scenario 1 :50% reduction in pods / 50% vermindering in vrugte

Costs / koste increases

Unchanged ☐

Increase by < R5 000 ☐

R5 001 – R10 000 ☐

R10 001 – R15 000 ☐

R15 001 – R20 000 ☐

R20 001 – R25 000 ☐

☐ R30 000

Scenario 2 :100% reduction in pods / **100% vermindering in vrugte**

Costs / koste increases

Unchanged ☐

Increase by < R5 000 ☐

R5 001 – R10 000 ☐

R10 001 – R15 000 ☐

R15 001 – R20 000 ☐

R20 001 – R25 000 ☐

☐ R30 000

Other effects / **ander effekte**…………………………………………………………...........

……………………………………………………………………………….................
....
....
....

This section attempts to access if you consider prosopis an environmental threat that needs to be controlled.

Die afdeling is om te oorweeg of prosopis n omgewings dreigament is, en of dit beheer moet word.

12) Do you think the spread of prosopis should be controlled? /
Dink jy die verspreding Van prosopis moet gekollekteer word?

YES / **JA** ☐ NO / **NEE** ☐

13) Have you actively controlled *prosopis* before (*clearing, fencing, chemical, etc.*) ?/
Het jy al prosopis aktief beheer(*verwydering, heining, gemikale, ens.*)?

YES / **JA** ☐ NO / **NEE** ☐

13.1) If yes how much do you spent annually? /
As ja hoeveel spandeer jy jaarliks?

☐ < R5 000

R5 001 – R10 000 ☐

R10 001 – R15 000 ☐

R15 001 – R20 000 ☐

R20 001 – R25 000 ☐

☐ > R30 000

12.3) If yes, what types of control do you perform?/
As dit ja, watse soort beheer medode gaan jy gebruik?

……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………

14) Do you believe it is your responsibility to control *prosopis?/*
Dink jy dit is jou verantwoordelikheid om prosopis te beheer?

YES / **JA** ☐ NO / **NEE** ☐

15) If no, who should take the leading role in the control of *prosopis? /*
As nee, wie moet die hoof rol neem in die beheer Van prosopis?

....

16) In your opinion is enough being done to control the tree? /
In jou opinie is daar genoeg gedoen om die boom te beheer?

YES / **JA** ☐ NO / **NEE** ☐

This section of the questionnaire seeks to find out information about you
Die volgende vrae is gebaseer op informasie oor jouself

17) How old are you? / **hou oud is jy?** ______________________

18) What is your home language?/ **Wat is jou huis taal?**

English ☐ Afrikaans ☐ Xhosa ☐ Other: ____________________

19) What is your race group? / **Wat is jou ras groep?**

Black ☐ White ☐ Coloured ☐ Indian ☐ Other: ____________________

20) Are you male or female? / **Is jy manlik of vroulik?**

Male/ **Man** ☐ Female / **Vrou** ☐

21) How many years of education have you had? /
Hoeveel jaar het jy gestudeer?

(Primere skool tot graad 7 = 7)

Primary school up to grade 7 = 7 years ☐

Grade / **Graad** 8 = 8 years / **jaar** ☐

Grade / **Graad** 10 = 10 years / **jaar** ☐

Matric (Grade 12) = 12 years / **jaar** ☐

Tertiary education / **Tersiere edukasie** ☐

22) What farming activities do you undertake at the moment? /
Waste plaaslike aktiviteite onderneem jy op die oomblik?

Livestock ☐

Crop farming ☐

Mixed farming ☐

23) How many people are in your household including dependants? /
Hoeveel mense is deel Van jou huis familie ingesluite die broodwinner?

____

What types of livestock do you run and the numbers?/
Wat se soort diere gebruik jy en wat is die hoeveeel heid

Type/ Soort **Number/ Nommer**

Sheep/ **Skaap** ....

Goats/ **Bok** ....

Cattle/ **Bees** ....

Other/ **Anders** ....

24) Thank you very much for your time, any other comments are welcome /
Baie dankie vir jou tyd , ander kommentaar?
....
....
....

University of Fort Hare
Together in Excellence

Resource economics questionnaire

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Please also be aware that the survey is completely non-discriminatory and the information that you are about to give merely helps in the interpretation of the results.

DUNE FOODS QUESTIONNAIRE

1) Do you value prosopis pods? (*please boldly highlight the correct answer*)

Yes No

2) If yes do you have a prosopis plantation? (*please boldly highlight the correct answer*)

Yes No

3) If no where do you get your pods from? (*please boldly highlight the correct answer*)

Local farmers

Ordinary villagers

From a plantation

Other (specify) (*please respond on the space below in bold italics*)

4) What is the average pod quantity you use annually? (*please respond on the space below in bold italics*)

5) Is your future demand for pods likely to rise or fall? (*please boldly highlight the correct answer*)

Rise and continue rising

Fall and continue falling

Fluctuate

Other (specify) (*please respond on the space below in bold italics*)

6) Would you support the use of more effective biological control agents? (*please boldly highlight the correct answer*)

Yes No

7) How would a 50% decline in pods available for harvest affect you? (*please respond on the space below in bold italics*)

Estimated financial costs of the decline

Other effects (*please respond on the space below in bold italics*)

8) How would a 100% decline in pods available for harvest affect you? (*please respond on the space below in bold italics*)

Estimated financial costs of the decline

Other effects (*please respond on the space below in bold italics*)

9) Do you consider prosopis a threat to the Northern Cape environment? (*please boldly highlight the correct answer*)

Yes No

10) Have participated in the control of prosopis? (*please boldly highlight the correct answer*)

Yes No

11) Do you believe enough is being done to control prosopis? (*please boldly highlight the correct answer*)

Yes No

12) Who should take a leading role in the control of prosopis? (*please boldly highlight the correct answer*)

The department of water and forestry

The local municipalities

Individual farmers

Direct prosopis product consumers

Other (specify) (*please respond on the space below in bold italics*)

13) Comments on increased biological control of prosopis are welcome(*please respond on the space below in bold italics*)

THANK YOU,