Wattle Eradication via the Working for Water Programme, Compared with Wattle Utilisation and Management for Makomereng, South Africa

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WATTLE ERADICATION VIA THE WORKING FOR WATER PROGRAMME, COMPARED WITH WATTLE UTILISATION AND MANAGEMENT FOR MAKOMERENG, SOUTH AFRICA

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On the cover is an image of wattle invasion down the investigated catchment with village of Makomereng in the distance.

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ABSTRACT

In the village of Makomereng, Eastern Cape Province, South Africa, an interdisciplinary investigation including social and environmental elements was conducted regarding the relative costs and benefits of invasion by alien black wattle *(Acacia mearnsii)* and silver wattle (*Acacia dealbata*) as well as the implementation of eradication efforts. Within this study, 31 open-ended interviews were carried out to assess social impacts of invasion, and attitudes towards eradication, key-informant interviews were conducted to assess implementation of eradication efforts, identification of invertebrates was used to assess herbicide leaching from eradication, and soil samples and species lists were utilised to determine environmental effects of invasion. From resultant data, wattle was found to offer significant social services and an uncertain, possibly positive, balance of environmental costs/services, eradication was critiqued according to principles of disturbance, and suggestions for further research were offered.

INTRODUCTION

The village of Makomereng, situated within the Madlangala District of South Africa's Eastern Cape, has been exposed to substantial invasion by *Acacia dealbata* and *Acacia mearnsii*, exotic trees species native to Australia. This village, situated in the Drakensberg region, on the border of South Africa and Lesotho, has experienced significant invasion by wattle primarily on unused land close to the community, over the past 15 years. Wattle comprises an important source of fuel, construction materials, fencing supplies, and income for the local community, but is highly invasive and provides cover for thieves. The current dominant strategy for dealing with the threats imposed by wattle invasion is complete eradication through the Working for Water programme. Yet, this approach may not yield a high level of services for the local community, when compared with exploiting opportunities for wattle utilisation through effective management.

Background

Black wattle history in South Africa

black wattle *(Acacia mearnsii)* and silver wattle (*Acacia* dealbata) are fast growing pioneer tree species, endemic to Australia, which have had important commercial functions in South Africa since the middle of the 19th century**.** wattle has subsequently spread to several rural areas in South Africa, as a result of the establishment of wattle plantations by farmers in the 1960s within the upper catchments of rivers, from which seeds were dispersed downstream (Care SA and EDA, 1999). The trees are currently primarily used to provide fuelwood, as well as timber for building and fencing. About 40% of the country's population live in rural areas where the primary household heat source is fuelwood. Furthermore, black wattle is an excellent hot-burning firewood, which has been traditionally favoured for bakers' ovens, and silver wattle is widely regarded as a superior fuelwood, as well. Accordingly, wattle has been observed to be a preferred local fuelwood species in the Maluti District (EDA, 2000). In addition, wattle can also be easily processed as an attractive timber, so it has excellent potential to provide quality construction material, as well (Kevin, 2000).

Physical characteristics of black wattle and silver wattle

Black wattle grows on a range of sites including a wide variety of soil types, from moist alluvial to skeletal eroded, and enjoys high versatility as a nitrogen fixer. Growth rates are high, at two to three meters annually, but the species is quite short lived, with a lifespan of only 15-20 years. Because of its nitrogen-fixing capability and short lifespan, this type of tree serves as an excellent nurse species for longer-lived crops, which can also benefit from improved levels of nitrogen in the soil (Kevin, 2000).

Silver wattle also maintains the ability to grow on a range of sites with varying levels of soil moisture, although it prefers sandy and loamy, well-drained soil types. Silver wattle maintains high rates of growth, at approximately two meters annually, but also has a short lifespan of approximately 30 years. Furthermore, this species, like black wattle, is a nitrogen fixer, which has the potential ability to improve certain soil properties (Plants for a Future, 2000; Southwest Slopes Revegetation Guide, NY).

Current management of wattle

However, wattle, as a pioneer species, with few South African competitors, is also very invasive and tends to encroach on arable land. Wattle also consumes a large amount of water, which in many regions of South Africa is a scarce resource. To help prevent water consumption by wattle, the Working for Water (WFW) programme has been established. Carried out by the Department of Water Affairs and Forestry, this is a national programme aimed at improving and securing water supplies, through the clearing of alien wattle trees and other invasive plant species, which reduce the flow of water in streams and rivers, and to manage cleared areas, so as to attempt to minimise soil erosion (Care SA and EDA, 1999). Over the longer term, the project has the goal of restoring alien-infested grazing land to "natural conditions," as well as provide employment. Wattle eradication is attempted by clearing the wattle forest using hand and mechanised tools, burning the remaining stumps and roots, and applying Garlon 4 or Timbrel to the cleared land (WFW, 1995). Local community members are temporarily employed in the programme to provide the labour for eradication, and the funding for this employment is provided by the national government (Care SA and EDA, 1999). However, once local eradication is complete, this period of employment ends, and consequent social benefits cease. In addition, because this strategy is reliant upon external capital budgets, even the continuation of temporary social benefits is subject to political whim and the constraints of government finances. Proponents of the programme admit that the clearing of the wattle often causes erosion, yet no study has substantially evaluated the environmental effects of such actions on soil erosion or water quality (Care SA and EDA, 1999). Since wattle often invades sloped riparian areas, and Triclopyr, the active ingredient of Garlon 4 and Timbrel, is a moderately persistent compound, there may also be significant risks of pesticide leaching into surface water (Dow AgroSciences, 2001).

Justification for research objective

Wattle, as an uncontrolled invasive species, can have deleterious effects on "pristine" ecosystems, and may negatively impact valuable resources, such as indigenous flora and water supplies. However, wattle eradication, as practised in the Working for Water programme may also degrade soil resources, and has the potential to pollute surface waters with eroded soil and herbicides. In addition, effective management may have the potential to transform wattle into a valuable and productive fuel and timber resource. As a result, the Environment and Development Agency Trust (EDA), a local organisation working in the region, has begun to implement community based wattle management as a means of effectively utilising this resource, while controlling the threat of unmitigated invasion (EDA, 2000). However, no rigorous assessment has been widely published regarding the potential services provided through wattle management, the effects of wattle on soil resources, or of the environmental effects of Working for Water eradication procedures. Consequently, this analysis will attempt to investigate whether wattle eradication, under the Working for Water programme, or a community based management approach would provide greater levels of environmental and social services for the residents of Makomereng.

RESEARCH OBJECTIVES

Main Objective – To investigate the relative deleterious and advantageous effects of potential Wattle eradication via the Working for Water programme, compared with Wattle utilisation and management, for the village of Makomereng.

Sub-objectives:

1. **To evaluate the ecosystem services and costs generated by the presence of wattle stands, with respect to water and soil quality.**

2. **To evaluate the environmental consequences of wattle eradication within the Working for Water programme, with respect to water and soil quality**

3. **To evaluate the current social services and costs resulting from the presence of wattle stands.**

4. **To evaluate the potential for expansion of social and environmental services provided by wattle stands, through the establishment of effective management and expansion of marketing opportunities.**

5. **To formulate recommendations for factors that should be included in plans for alternate means of wattle management, and delineate subjects requiring further research**.

METHODOLOGY

Household interviews

Within the village of Makomoreng, 31 household interviews were carried out. For the purpose of this investigation Casley and Lury's (1987; c. f. Casely, D.J and K. Kumar.1988) definition of a household "as comprising a person or group of persons generally bound by ties of kinship who live together under a single roof or within a single compound and who share a community of life in that they are answerable to the same head and share a common source of food" was utilised. Interviews began with a structured portion in which quantitative information was gathered regarding household composition, sources of income, and use of fuelwood. After the structured portion was completed, a "semi-structured" or "open-ended" interview component commenced, in which qualitative data concerning uses of wattle, opinions about the expanding wattle forests and the Working for Water project were obtained. An example of the interview outline is placed in appendix I and appendix II.

Different households were chosen via the convenience sampling method, as identified by Patton (1980). To get reliable information, diverse household locations within the village were interviewed, at different times of the day, in order to obtain a representative informant sample. For an overview of the geographic distribution of the interviewed households, see Figure 1.

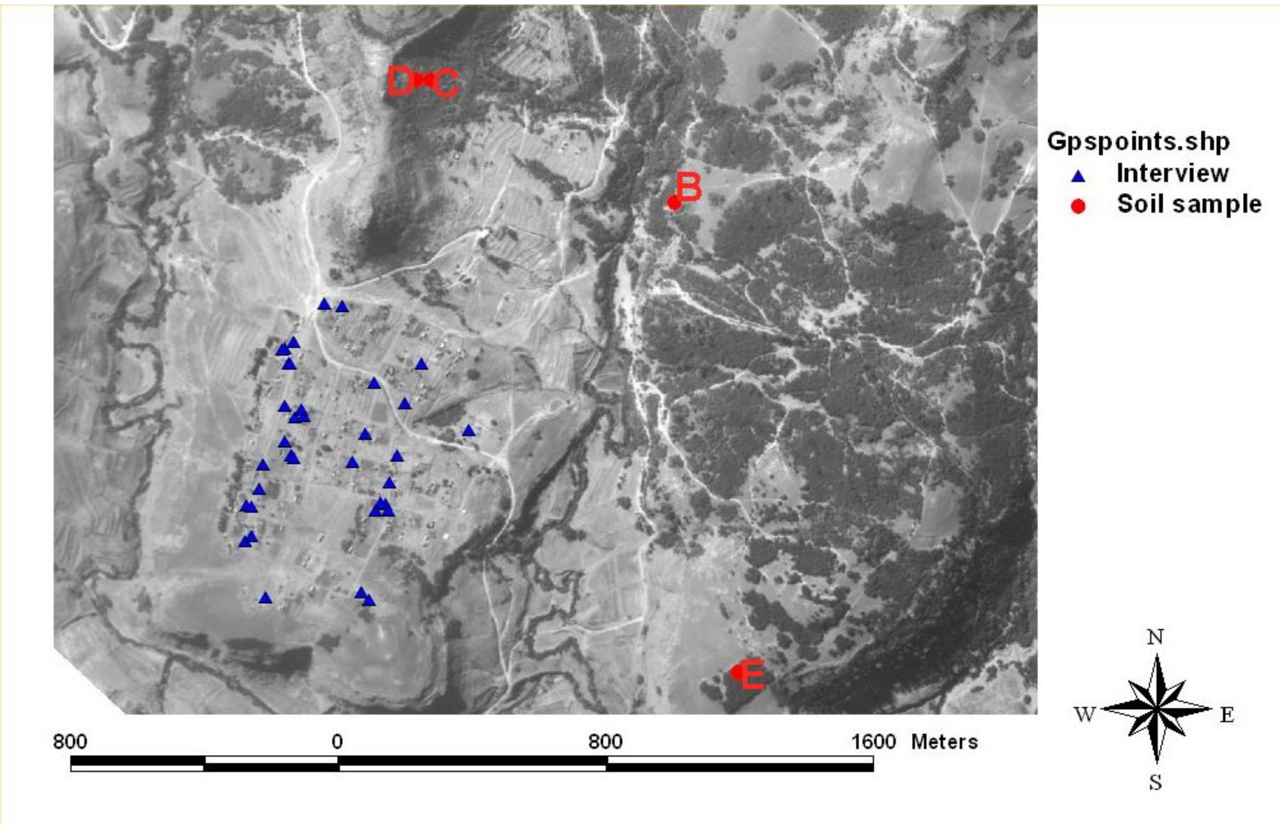

Figure 1. Aerial photo of areas in which open-ended interviews and soil samples were extracted near Makomereng. Blue triangles indicate households subjected to open-ended interviews. Red letters correspond to the following soil sampling areas: B. Open area of grassland vegetation (sample 3); C. Mixed black-silver wattle forest northeast of Makomereng (samples 4 and 5); D. Area with natural vegetation (sample 6); and E**.** Black wattle forest east of Makomereng (sample 7). It should be noted that the soil samples taken from Goxe are out of the range of this photograph.

Before interviews proceeded with different households in the village, a pilot-interview with the local translator was conducted, to determine the suitability of interview questions. Consequently, questions regarding the precise age and educational level of informants were dropped, due to potential informant discomfort with such subjects

Key informant interviews

Several key informant interviews were conducted primarily to obtain factual data, with a secondary focus on perceptions, in contrast with the "open-ended" interviews, which had a primary focus on perceptual information (with the understanding that such "factual" data are still subject to bias). These interviews included the following: one interview with the contractor in the WFW project in Goxe, two interviews with different workers in the WFW project, three interviews with the contractor in Makomereng, one interview with the foreman, two interviews with different workers in the Woodlot-management project and finally an interview with an extension officer from Department of Water and Forestry Affairs.

Soil samples

Samples were taken with an auger at a depth of 20 cm at each location. These samples were put into plastic bags, which were labelled with a description of the tested location. Sampled soils were then taken out of the bags to dry five days after the date of extraction. After drying, these samples were stored within plastic bags for 25 days until testing could be conducted at The Royal Veterinary and Agricultural University (KVL) in Copenhagen, Denmark.
Soil samples were taken from following locations:

A. Silver wattle eradication area in Goxe (samples 1 and 2)
B. Open area of grassland vegetation (sample 3)
C. Mixed black-silver wattle forest northeast of Makomereng (samples 4 and 5)
D. Area with natural vegetation (sample 6)
E. Black wattle forest east of Makomereng (sample 7)

At the wattle eradication area in Goxe two soil samples (#1 and #2) were taken: one five meters from the riverbank and a second 20 meters further away from the riverbank. In an open grassland area adjacent to the mixed black-silver wattle forest (#3), where a fruit plantation is planned, a soil sample was taken, so as to have baseline data for uninvaded grassland. Two soil samples were taken in the mixed black-silver wattle forest (#4 and #5) in order to see if there were significant fluctuations in the soil composition of the mixed forest within the same area. The samples were taken within a distance of less than 15 meters from one another in areas of similar density. Another soil sample was taken in an area 40 meters upslope of sample #2, which has natural vegetation dominated by *Leucosidea sericea*,(#6) in order to have baseline data for the natural woody vegetation of the region. A soil sample from the black wattle forest was taken in the same altitude as in the mixed forest (#7).

The analysis of soil samples was conducted in Copenhagen at the Institute of Soil Science at KVL, so as to have greater precision than was possible at the field site. The samples were tested for pH, nitrate, phosphate, and organic matter. The guideline for the procedures for the soil tests can be found in Appendix III.

pH

Measurement was done by using a pH-meter and 10 grams of soil dissolved in ion exchanged water.

Nitrate

NO_3^- in the soil was determined by using sulfanilin acid as an extractant, and a spectrophotometer adjusted to 500 nanometer wavelength was used to estimate concentrations of extracted compounds.

Phosphate

PO_4^{3-} is also measured by using an Olsen sodium bicarbonate method, with 0.5 M sodium bicarbonate at pH 8.5 as an extractant, and a spectrophotometer adjusted to 890 nanometer wavelength was used to estimate concentrations of extracted compounds.

Organic matter

Organic matter was determined by burning the dry soil for 24 hours at 900^o C. All results were adjusted after the weight of the dry soil was determined. Such adjustment was done by drying soil samples in an oven for 24 hours at 100^o C to derive the percentage of dry matter in the samples, and multiplying observed concentrations by this proportion to compensate for soil moisture.

Water samples

Water samples were taken at and downstream of the location of wattle eradication efforts in Goxe, as well as above and below wattle eradication in Makomereng. The purpose of taking samples above and below the eradication point was to see if the use of Timbrel and Garlon 4 would cause significant leaching into the streamwater. Intended analysis for herbicide concentrations in the water samples was abandoned, due to resource constraints.

At the area of sampling in Goxe the quality of the water was tested by using a simple *Water Quality Slide*. The scale is divided into 5 categories and the indicator for the quality is the presence of invertebrate indicator species. Ten different invertebrates function as indicators of water quality, including: stonefly nymph (*Plecoptera*), mayfly nymphs (*Ephemeroptera*), dragonfly nymphs (*Odonata*), sludge worm (*Tubifex Tubifex*), caddisfly larva (*Trichoptera*), bloodworm(*Glycera dibranchiata*), water snail (*Planorbis*), whirligig beetle (*Gyrinidae*), flatworm (*Platyhelminthes*) and rat-tailed maggot (*Eristalis tenax*). The *Water Quality Slide* can be found in Appendix IV.

Species lists

Species lists were conducted at a silver wattle dominated forest, a mixed black-silver wattle forest, and a black wattle dominated forest all east of Makomereng, at the same areas from which soil samples were taken. To define areas for inventories, a 10 x 10 meter square plot of 0.01 ha was established in each location, within which all present trees, shrubs, and herb species were identified. Each individual species was not counted within the plot and it is therefore not possible to give an estimate for how frequent it is found within a plot. The species identified during the conduction of each list can be found in Appendix V.

Scientific species names were determined for all identified plants, although some plants were not identified at the plot, but later in the village. The local villagers identified the local names for species which were difficult to key, and scientific names were then identified by using different field guides to the wildflowers of KwaZulu-Natal and the Eastern Cape region.

Forest encroachment estimation

The current boundary between wattle dominated forests and open lands nearest to Makomoreng was estimated for the Makomoreng river catchment, which is located east and north of the village. This boundary was estimated via the use of a Garmin GPS III Plus global positioning system unit, by recording waypoints along the forest boundary at 75 meter intervals of boundary length, with a Liberia 1964 map datum. For the purpose of boundary estimations, areas with more than 25%

crown cover were considered as forest, and encroachment down dongas was ignored, due to difficulties in following such terrain. Resultant data were transferred to a laptop computer via the GPS 2 Win interface program, loaded into ArcView 3.2, converted to shapefile format, and shifted to an ARC 1950 Lesotho datum.

An aerial photo from 1995, taken at 1:16,000 scale, was used for comparison, in order to estimate encroachment over the past six years. This photo was scanned from a paper original as a TIFF format image, and imported into ArcGIS 8, where it was assigned the ARC 1950 Lesotho datum. Georeferencing was then conducted using four identifiable landmarks, which had been marked with GPS waypoints, as "control points," with coordinates from the shifted waypoint shapefile used for reference. Comparison was then made between the houses of interviewed households marked in the waypoint shapefile and the location of these houses in the aerial photo, in order to assure that accurate georeferencing had been achieved. Once the referencing was satisfactory, the photo was rectified in ArcGIS for enhanced contrast and clarity.

Boundary encroachment estimation was then conducted by measuring this distance between individual boundary waypoints and the closest portion of the forest border with the "measure tool" in ArcView 3.2, and denoting whether such distances were negative (forest recession) or positive (forest encroachment). The total group of measurements was then averaged, and subjected to the Wilcoxson Rank-Sign Test, as well as the t-test for paired data, in order to test for the significance of median and mean border encroachment values, respectively. These tests were then repeated with the data broken into two groups: encroachment onto eroded, sloped soil, and encroachment onto productive grassland, in order to compare the significance of encroachment.

RESULTS

Household interviews

During the fieldwork in Makomoreng, 31 household interviews were conducted in the village, of which 27 informants were women, while the remaining 4 were men. It appears that many men were working in urban areas, and, as a result, women are over-represented in this survey. The village consists approximately of 95 households, as counted from a hilltop near the village, so roughly one third of the households in the village have been included in the study. Basic data collected from the households can be found in appendix VI. The following data were obtained from these interviews:

- From the structured interviews it was determined that 90% (28 of 31) of the households interviewed use wattle as their primary heat-source, while the remaining three use it as a secondary source, with paraffin and gas as a primary heat-source. Since there is no electricity in the area, wattle is very important as fuel for cooking, as well as for heating during the winter. In addition to being an important fuelwood, respondents also indicated that wattle is very often used in construction of buildings, fences, kraals, and benches. All interviewed households use wattle for construction, except for one who indicated that she believes it is not strong enough for such use.

- Another result was the fact that 19% (6 of 31) of the households derive cash income from the wattle by collecting and selling it to other people in the village. The household owning the largest shop in the village is such an example, in which the sons go by tractor to collect wattle in the forest, and sell it to other people in the village who have the financial means to purchase it. In addition, one of the six households deriving cash income from wattle occasionally makes furniture for sale.

- Of the 31 households interviewed, 29% (9 of 31) recreate in wattle forest areas on a regular basis. These respondents stated that their children go to the forest for fun, or that they walk in the forest for the sole purpose of enjoyment.

- During the interviews it became clear that women play a major role in collecting fuelwood. The female informants consider it their responsibility to collect firewood, especially if the children are too young to go by themselves. Several of the women interviewed were heads of households, since their husbands have migrated to obtain work in urban areas. At about 10 to 12 years of age girls collect this resource as a daily task, while boys at the same age typically herd cattle back to the village from the pastures. Primarily when oxen or tractor are being used in collection of fuelwood boys and men apparently actively participate in the work.

- Several respondents mentioned different uses regarding the two dominant wattle species, black wattle and silver wattle. Black wattle was preferred as a fuelwood since it lasts longer, whereas silver wattle was preferred for construction since the stems are straighter and hence are more suitable to be used as poles in fencing and construction of roofs.

However, not all the answers regarding wattle were positive.

- More than half the informants responded that they feared criminals hiding in the wattle forests. Of the 31 interviewed, 52% (16 of 31) answered they were afraid of walking in the forest because of the potential risk of meeting cattle thieves or other criminals. Often, such respondents also indicated preference for eradication of forests that are located close to their homes, since such forests can function as hiding places for criminals, even though such eradication would also result in longer distances for fuelwood collection.

- According to the informants, there is not only a risk of having cattle lost via theft. Three informants stated that cattle can actually get lost in the dense forest due to poor visibility, when they are herded from the village to areas higher up in the mountains where the pastures are situated.

- None of the informants wants total eradication of the wattle forests, as most of them emphasised that they are dependent on wattle from these areas for fuelwood and for construction poles. The wattle is important and valuable as a resource, so therefore complete eradication is considered a waste of an important resource.

- Yet, 58% (18 of 31) of the informants desired partial eradication. Most of these informants showed preference for the eradication of forests which are located close to their homes, since these forests function as hiding places for thieves and criminals. On the other hand, many informants indicated acceptance of WFW project eradication in areas far away from their homes, since these areas were not used for collecting wood. The remaining 42 % (13 of 31) of the informants want no eradication since they consider wattle too valuable to be eradicated.

- Regarding the local people's knowledge about the WFW project, 29% (nine of 31) of the informants were able to tell the exact purpose of the project, while 19% (6 of 31)of the informants indicated some knowledge of the project, but did not illustrate understanding of why it was taking place. The remaining 52 % (16 of 31) claimed they had no knowledge about the project.

- Of the16 informants with very little knowledge about the WFW project, 11 illustrated preference for no eradication at all, while only 2 informants with some or great knowledge want no eradication. In addition, 6 of the 16 informants with very little knowledge about the WFW project had a negative attitude towards the project. Most of these 6 informants have heard about employees who have been working in the project, and were then paid a substantially smaller amount than they were promised, despite good-quality work. On the other hand, of the nine informants with great knowledge about the project, seven of these have a positive attitude towards the project. One claimed to be neutral, while the last informant stated that she has also heard of project employees getting cheated of proper pay, and, as a result, did not approve of the project.

- The male responses did not differ significantly from the female responses with regard to opinions towards wattle and the Working for Water project, as 11 women out of 27 (41%) interviewed wanted partial eradication, whereas, 2 men out of 4 (50%) interviewed had the same sentiments, and the overall average of both male and female attitudes towards the WFW project was nearly neutral.

Key informant interviews

The following data were gathered through interviews with the contractor of the WFW project in Goxe, as well as the contractor and foreman of the Woodlot project in Makomereng, and are indicative of their subjective views on wattle and wattle eradication.

Interview with contractor of WFW project in Goxe

Through the interview with the contractor of the WFW project in Goxe it was explained that 30 years ago there were no wattle trees in the area, but with the establishment of a white farm further up in the catchment, wattle trees were introduced, and have spread invasively downstream. The method of eradication via the project is to work down the catchment in a 10 meter wide riparian swath, to minimize water consumption from the wattle, although wattle has already regenerated above the current area. Eradication is accomplished by poison-gridling wattle with Timbrel, and spraying potential regrowth with Garlon. Severe budget fluctuations and uncertainties have lead to ineffective wattle eradication, where there has not been financial support for a second follow up. The surrounding villages have socially benefited from the project because of the equal distribution of local employment and the money earned from selling fuelwood. The payment of the workers ranges from 30 to 45 Rand a day. A chainsaw-operator is paid 45 Rand, while unskilled manual labour is paid 30 Rand. The contractor emphasised that training of the workers is very important, since they are working with chemicals and machines and that thus far no accidents have occurred. In addition, the contractor stated that the community wants all the wattle eradicated, since the children are afraid of walking with the cattle through the dense forest, which harbours fierce animals and dangerous criminals.

Interview with contractor and foreman of Woodlot project in Makomereng

The approach in the Woodlot-project in Makomereng differs from that of the project in Goxe. The goal of this eradication is to clear for the creation of plantations, which will generate products for the community on a long-term basis. The following income generating activities are in the planning phase:

- Planting of non-invasive species of wattle for the purpose of timber production, pulp production, fuelwood, poles and bark for tanning.
- Planting of fruit trees in order to sell fruits at the market in Matatiele and perhaps later the establishment of a small plant where fruit is canned.

At this site the probable source of wattle invasion is an old white farm located further up the hillside, and there were no wattle trees in the area more than 15 years ago. Due to financial constraints only burning of the cleared areas and cutting have been used as control strategies. Project employees live all over the District, so that each village is represented proportionally. The payment here ranges from 30 to 45 Rand per day, according to the skills of the worker.

The decision-making structure of the community

The contractor also had great knowledge about the formal decision-making structure of the community, since she is the current Chairperson of this body, which is entitled the Development Committee. This exogenously designed structure is centered upon grant proposals and government assistance, rather than independent community management. The Development Committee structure was created in 1995, so as to meet government requirements for South African government grant eligibility, and is headed by a Steering Committee, under which are issue-based committees (Figure 2). Working for Water is the subject of one such committee, and forestry is only a sub-committee under this, which has been formed to deal with the potential planting of a plantation in Makomoreng. All of these committees come together to vote upon proposals. It should be noted that both the current (1999 – present) and previous (1995-1999) Chairpersons are Working for Water contractors, who are technically not entitled to profit from their involvement in the programme, under District regulations. However, these two contractors are permitted to take a salary for their involvement in the programme, while they simultaneously chair the Steering Committee.

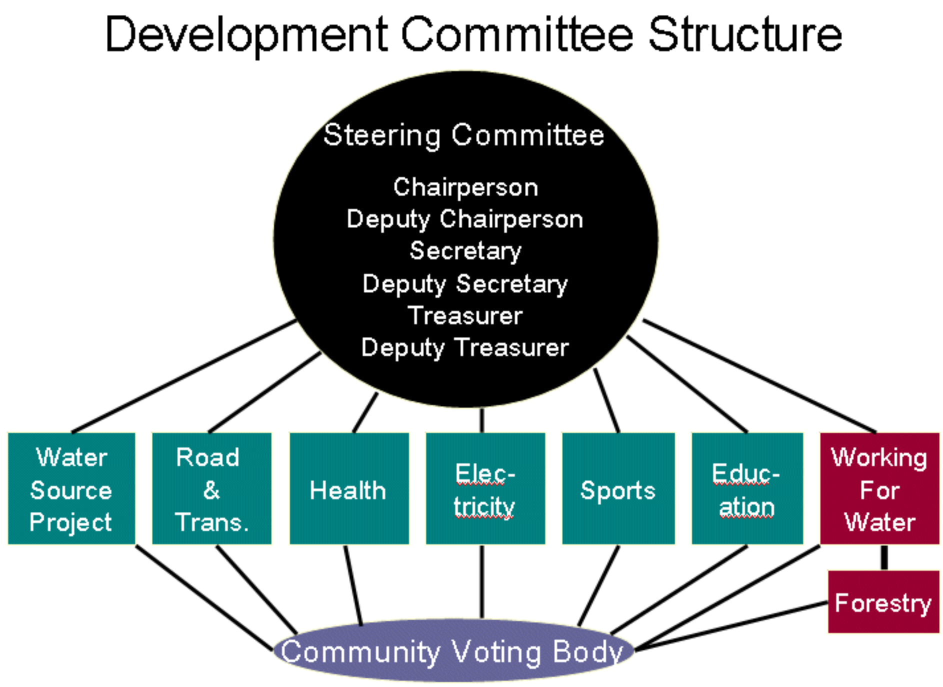

Figure 2. Structure of Development Committee, and included Steering Committee as well as issue-based committees, which decide upon development issues for Madlangala District.

Soil results

The results of the soil tests are presented in Table 1, after adjustment according to the percentage of dry matter. Due to errors in testing procedure it was not possible to accurately measure the amount of potassium, so no results are presented for this nutrient. All observed soil properties are herein compared to reference values provided by Herrera, 2000. Classification can be found in Appendix VII table 2-4.

Table 1 : Results of soil tests conducted under different types of land use in order to assess patterns of *Acacia mearnsii* and *Acacia dealbata* presence, compared with soil nutrient levels. The areas denoted are as follows: *A. dealbata* eradication area in Goxe (samples 1 and 2); Open area of grassland vegetation (sample 3); mixed *A. mearnsi –A. dealbata* forest northeast of Makomereng (samples 4 and 5); Area with natural vegetation dominated by ***Leucosidea sericea*** (sample 6); *A. mearnsii* forest east of Makomereng (sample 7).

Sample #	1	2	3	4	5	6	7
pH	5.3	5.4	5.6	5.4	5.5	6.1	5.7
Nitrate (ppm)	66.5	29.2	15.0	29.3	15.7	7.6	17.7
Available Phosphorous (ppm)	9.3	4.8	10.2	9.9	7.8	9.2	8.1
Dry matter (%)	84.2	92.6	93.2	95.6	95.8	92.7	96.2
Organic matter (%)	13.7	8.1	5.3	6.5	6.3	5.5	4.5

The lowest pH value is observed to be 5.3 and the highest is 6.1. All of the soils range from moderately acidic to strongly acidic, and since the average pH is 5.6, with a standard deviation of 0.3, these six samples stay within these two categories, within one standard deviation from the mean.

The observed concentration of nitrate varies from 7.6 to 66.5 parts per million (ppm), with an average observed level of 25.9, and a standard deviation of 19.6 ppm. The highest observed concentrations are found in the areas with wattle, especially in the vicinity of eradication near Goxe.

Levels of observed phosphate range from 4.8 to 10.2 ppm, and the average observation is 8.5 with a standard deviation of 1.8. The observed concentrations of phosphate range from low to very low, according to the reference classification system.

Organic matter is given in percentage of the total weight of the soil samples. Due to higher humidity, the observed levels of organic matter are highest in closest proximity to the river at Goxe, with the highest level of 13.7 % observed in the riparian zone. The remaining observations range from 4.5 % to 8.1 %.

Water results

Invertebrates observed in the river downstream of the WFW project in Goxe indicate very low levels of impacts on water quality. The following aquatic fauna, identified as indicative of high water quality on the *Water Quality Slide* were observed in the water: stonefly nymph (*Plecoptera sp.)*, mayfly nymph (*Ephemeroptera sp.*) and bloodworm (*Glycera dibranchiata*). Since mayfly nymphs are only found in clean water, the presence of this particular species denotes low levels of impact.

Species list results

The largest number of species was found in the mixed *A. mearnsii* and *A. dealbata* forest (10 species), followed by the *A. dealbata* dominated forest (7 species), and only *A. mearnsii* was present in the *A. mearnsii* dominated forest. Only *Euclea coriacea* and *Diospyros dichrophylla* were found in both the mixed and *A. dealbata* dominated forests (Appendix V.).

Forest encroachment results

The individual observed encroachment values are summarised in Appendix VIII. The overall median and mean encroachment values are 18.11 and 5.5 meters, respectively. Overall encroachment is estimated to be significant, both by the Wilcoxson Rank-Sign test, as well as by the t-test for paired values at α.levels below 0.01 (Fowler and Cohen, 1992). Thus, with a minimum of 99 percent certainty, the observed average and median encroachment levels indicate that the observed values are indicative of change in the forest boundary, and are not a product of chance. The exhibited mean encroachment level can be extrapolated to an average overall rate of encroachment of approximately 5 meters annually for the past six years (Figure 3).

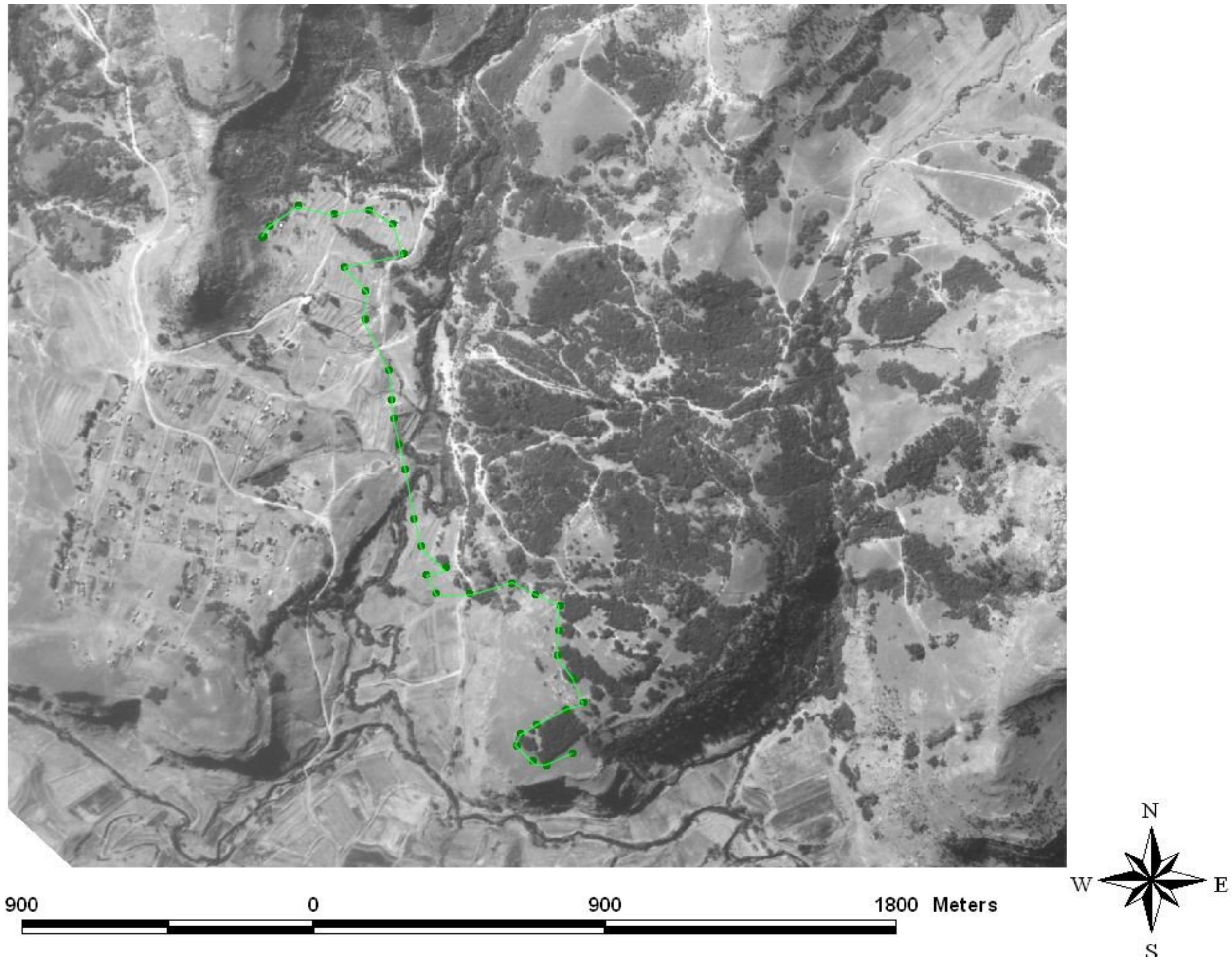

Figure 3. Delineation of current forest boundary, compared with aerial photo of forest produced in 1995. The lower levels of encroachment onto the more productive pasture land in the south end of the photograph, as compared to the more significant erosion onto the sloped soils in the northern portion, should be noted.

However, significant differences between the relative degree of encroachment in degraded/sloped lands, compared with well-maintained grasslands, are present. When observations from the boundary between pristine grassland and the wattle forest are analysed independently, the overall mean and median encroachment values are negative 0.5 and 0 meters, respectively. These encroachment levels are not significant enough to reject the null hypothesis of no significant difference in forest boundaries between 1996 and the present by either the Wilcoxson or the t-test at a α.level of 0.05. Consequently, no significant change in forest boundary over the past six years is exhibited.

Conversely, when the boundary between sloped/degraded grasslands and the wattle forest is considered in absence of observations from the good-quality grasslands, the level of encroachment is even more pronounced, with median and mean encroachment values of 23 and 28.7 meters, respectively. The significance of this change is substantiated by both the Wilcoxson test and the t-test at α.levels below 0.01. Hence, these results can be extrapolated to an annual mean encroachment level of approximately 5 meters over the past six years for sloped/degraded lands.

DISCUSSION

Limitations

Household and key-informant interviews

Prior to analysis and discussion of the gathered data, a number of limitations should be noted. Since the household interviews have been carried out by six different people, the data collected in each interview will differ, because each researcher has a different manner of interviewing people (Mikkelsen, 1995). Even though a universal structured interview preceded all semi-structured interviews, for which a common guideline was prepared, some interviewers tended to confine themselves to the written questions only, while others were very diligent in following up on promising leads.(Casley & Kumar, 1998). Thus, these limitations must be considered when attempting to compare between and among interviews.

Another limitation to the household interviews is the method by which the households were selected. Households were selected via the "convenience sampling" method (Mikkelsen, 1995), and this may have allowed for inherent bias in the selection of individual households. In order to assure representation of all geographic locations within the village, households were selected primarily on the basis of geographic location. The geographical distribution of the selected households is shown in Figure 2. Since quick, superficial assessments primarily based upon location are used to ensure representativity, selection may take place according to an unconscious selection factor. However, alternative methods that allow the potential for more accurate representation require time-intensive prerequisite data collection, so as to properly stratify informants, and, hence, divert time from interview conduction. As a result, fewer interviews would have been conducted via more time-intensive, representative sampling methods, and statistical significance would have been sacrificed for increased representativity.

In addition, the households selected were those in which somebody was home between 08:00 and 19:00. Consequently, informants who were home during these limited hours, in the month of October, may not be representative of the entire village. Bias imposed by the interview period may be exemplified by the gender composition of informants, as 27 out of 31 (87%) were women, and it is likely that this is due to the fact that men often work during the hours of interviews or have migrated to urban areas. However, the overrepresentation of women may not have significant deleterious impacts upon the utility of the results, as interviews indicated that women are the primary harvesters of forest products for household consumption. Thus, women represent the core subsistence users of forest resources, and are the most important target group for the focus of the present study. In addition, although statistically insignificant, the responses of the four interviewed men did not seem to differ appreciably from those of the women.

Since a local guide was available during a portion of the interview period, she played a major role in determining which households to interview. Thus, it is possible that the informants to whom she introduced the researchers were not representative of village views of wattle. After having conducted three to four interviews in a couple of hours, the local guide also seemed to become impatient and rush through some of the questions. The translation often became inaccurate, and she began to standardise her answers.

Finally, there were problems with quantification concerning the time spent on collecting fuelwood and quantity collected. It appeared difficult for the informants to estimate precisely how much time was spent per week on collecting fuelwood and the quantity collected, since heating needs vary during the year, and informants were not used to attributing standard units to such data.

Key-informant interviews are often subject to problems of bias, poor recall, and a poor or inaccurate articulation. As a result, it is important to triangulate, or corroborate data derived from this (and other) methods with information from other sources (Yin, 1994).

Soil samples

The utility of the soil sample results is rather limited, since the number of samples taken at each location varies between only 1 and 2, and a higher number is required in order to overcome the fluctuations that may occur within each location. One mixture, consisting of at least 20 randomly extracted samples, which total at least two kilograms, can be representative for up to one hectare of land, provided that there are no marked changes in soil type or in management in the test area (Voelcker science, 2001). Ground near gateways, hedges, paths, waterlogged areas should also be ignored, in order to get a representative sample. Consequently, the sample taken near the eradication area in Goxe may be especially unrepresentative of soil under wattle in general.

In addition, sometimes the auger was not available for use during sampling, so a hole was dug to the required depth with a spoon, and a sample was taken. Consequently, during this procedure topsoil might have mixed with the darker surface layer, artificially increasing organic matter estimates. Finally, the storage of the samples in plastic bags for 25 days before analysis might have altered chemical properties (Voelcker science, 2001), although the equal storage period for all samples may equalise such effects.

Water samples

If Timbrel and Galon 4 do not affect the aquatic organisms listed on the *Water Quality Slide,* it is not possible to detect whether the application of these herbicides is impacting water quality. However, according to the Material Safety Data Sheet for these two herbicides, Garlon 4 and Timbrel possess a moderate level of acute toxicity for aquatic invertebrates (1-10 milligrams/liter LC_{50}) (Dow Agrosciences, 2001). Consequently, significant leaching of these two herbicides is likely to have apparent impacts on sensitive microfauna, and the *Water Quality Slide* should be able to diagnose such effects. However, the *Water Quality Slide* comprises a relatively limited, non-specific invertebrate inventory, so results from such are of limited significance. In addition, longer term cumulative impacts of these herbicides cannot be assessed via this method.

Species lists

The data collected via the species lists of the three selected plots is of limited scope, and conclusive analysis cannot be extrapolated solely from this information, for a number of reasons. Perhaps the most important limitation is the small total area covered by the plots. These three 100 square meter plots fall well short of the recommend 5% of the study area recommended for a forest below 50 ha (GISCF, 2000). In addition, with a greater number of plots it would be possible to effectively randomise plot location within each of the vegetation categories, rather than purposefully select plots, as was conducted in the present study. The absence of many plots also makes it very difficult to assess β-diversity, or the change in species composition from place to place, within the different types of forest cover, as the small geographic scale of each plot prevented comparisons of different environmental conditions. Compounding this limitation is the absence of data on relative species frequencies within the plots, which makes it nearly impossible to have any conclusive analysis regarding overall diversity. Finally, this sampling method did not take into account the annual temporal or seasonal variability in vegetation abundance, so observations may not relevant for other times of year.

Forest encroachment values

Several methodological limitations inhibit making conclusive interpretations of the encroachment estimates. Perhaps most significantly, estimations of where the wattle forest boundary currently exists were highly subjective, due to a number of factors. It was difficult to determine a precise threshold level of crown cover for observed forests, to compare with that at which the forest classification is utilised. In addition, the forest boundary was highly irregular, as it currently follows dongas down slopes, and these interjections were ignored where present. Furthermore, there are patches dominated by grassland, with small patches or strips of dense wattle forest interspersed, and these could easily confuse boundary interpretation. The utilised Global Positioning System may have had non-random inaccuracy, as well, since sources of interference may have constantly skewed estimates in a non-random way during the course of boundary estimation. Finally, relative encroachment estimates may have been biased by the determination of the boundary measurement interval. This interval of 75 meters was determined as straight line distance from one waypoint denoting the forest border to the next, along the forest boundary. Consequently, the relative degree of jaggedness or spatial heterogeneity exhibited by the forest boundary may have affected sampling density, and, consequently, the degree of representation in calculations. If there is any correlation between this degree of boundary smoothness and levels of boundary change, overall encroachment estimations may have been distorted

To compound measurement errors, there may have been errors with the baseline estimates for comparison, as well. First, the baseline aerial photo did not undergo orthomographic rectification, to compensate for displacement error in the image, created by the angle of photography, due to lack of a detailed digital elevation model for the area. Consequently, the baseline photo offered a skewed projection of the project area. Secondly, there may have been errors in the implicit assumptions made during georeferencing. One of the four utilised control points was a corner of the forest boundary, which appeared in exactly the same pattern in both the aerial photo and the boundary demarcation. The assumption that this point is static may have been erroneous. The other four control points, based on household interviews may have been slightly inaccurate as well, if personal recollections were inaccurate as to the sides of the homesteads at which the GPS markings were taken.

Interpretation of Results by Method

Discussion of results obtained from the open-ended interviews

From the household interviews conducted in Makomereng, it is apparent that the wattle forests have great importance for the villagers, since 90% of the interviewed households use wattle as their primary heat source. There is no electricity in the area, which may explain why wattle is very important as fuel for cooking, as well as for heating during the winter months. This scenario is common for many rural areas in South Africa, where it is estimated that in certain regions up to 80% of rural households use wood for energy (DWAF, 1996).

Compared to other villages in South Africa, there is plenty of wood for construction and fuel available in close proximity to the village, since wattle has spread down the river catchments during the last 15 to 20 years, according to several key informant interviews. A major positive effect of having such a resource is the possibility of using wattle for the construction of buildings (particularly, traditional cone-shaped roofs), fences and kraals. The vast majority of informants — 97% (30 of 31) use wattle for other purposes than fuelwood, and this prevalence exemplifies the significant role of wattle, since it is prohibited to cut indigenous species.

Another advantage of having wattle forests in the vicinity is the possibility of deriving cash income by selling collected wood to other people in the village. Currently, 19% of the households interviewed derive cash income this way from internal markets. However, it also seems likely that there may be an even larger potential for employment if external local markets are served, as well.

The results obtained from the interviews showed that a great number of women were head of household, since the men had migrated to urban areas for work. This is typical for many households in rural areas, where women between the age of 16 and 65 often outnumber men by 30% to 40%. (DWAF, 1996). Therefore, it is important to focus on women in the development of rural areas, and this goal is encompassed in the design of the WFW programme, in which one of the goals is to allocate 60% of the jobs to women (Binns et al., 2001).

From the interviews, it appears that there are different use preferences concerning black wattle and silver wattle. Several informants stated preference for black wattle as fuelwood, because of its higher energy content, even though it is more difficult to cut and more heavy to carry. On the other hand, silver wattle was used more frequently for fuelwood and construction, since it is easier to cut and the stems are straighter, which makes them more suitable for construction, even though black wattle is stronger. Consequently, it appears that there is a high level of local knowledge regarding potential uses for the species, and this knowledge represents a valuable resource, which should not be ignored in management efforts.

During the interviews, it was illustrated that the wattle forests are of high recreational and aesthetic value. Since 29% of the interviewed households utilise the forests for enjoyment, it is obvious that the forest not only provides fuelwood, but also has value in diversification of the landscape. Several informants stated that they appreciated the beauty and aroma of wattle flowers, which flower collectively from July to December. The presence of the forests may make the landscape feel more heterogeneous, which appears to increase aesthetic values for the villagers, and may provide increased aesthetic values for ecotourists.

Prior to commencing the interviews, it was expected that the encroachment of wattle into grazing land was considered a major deleterious impact, but it turned out that none of the informants mentioned this as a problem. Perhaps this can be explained by the fact that only one of the interviewed households possessed large numbers of cattle, although theft, not land availability appeared to be the primary constraint for cattle production. Informants did not appear to perceive infringement on grazing land as a significant problem, although the concealment of criminals and cattle thieves from Lesotho in the forest was considered a serious threat, which made several informants fear walking in the forest alone. The degree of this threat is difficult to assess, although declining cattle numbers in the Madlangala District does appear to be coincident with invasion by wattle. However, this correlation does not imply causation, as there are many mitigating factors affecting the ability of criminals to traffic across the border. Additional research is required to assess whether wattle provides significantly better concealment for thieves than do indigenous woody species. The assertion of thieves coming from Lesotho could also be an illustration of the numerous historical conflicts between the two countries which still pervade transboundary attitudes. Another problem identified by the informants as a detrimental consequence of wattle invasion is the risk of cattle loss, due to poor visibility in the dense forest. Nevertheless, this problem was only mentioned by three households, and therefore seems of minor significance, compared with concealment of thieves.

Since the wattle is such an important resource to the community, it follows that no informants want total eradication despite the problems associated with the presence of wattle. Although total eradication will devastate a vital resource, 18 informants still were positive towards partial eradication, so as to reduce concealment of thieves close to their homes and cattle loss in the dense forest.

Discussion of results from soil analysis

Soil tests indicate that the soil is moderately acidic in all areas where samples were taken. However, the observed pH values do not significantly limit agricultural options, since most crops only grow satisfactorily on soil with a pH ranging from 5.5 to 8.3, and the only soils to exceed this range were in forested areas (Ahn, 1993). Thus, wattle may either be invading acidic soils, or the presence of wattle may increase soil acidity. However, as wattle prefers somewhat acidic soils (Bean, 1981), it is likely that wattle is more invasive in areas with greater acidity, and is not significantly reducing pH. Consequently, if such is indeed the case, wattle invasion may be the most substantial in areas of limited production potential, due to acidity.

The following site preferences have been noted for silver wattle, which is the most prolific wattle in the study area (Bean, 1981):

- Sandy and loamy soils are preferred
- Good soil drainage is required
- Moderate acidity is preferred
- The species is shade-intolerant
- Wattle is moderately tolerant of drought.

From visual observations, it appears that such conditions are met in the gullies, as such soils vary between sandy and medium loamy, and this relatively sandy texture allows for good drainage (Herrera, 2000). All nutrient levels are relatively low, apart from the highest nitrogen values, all observed under wattle forests, which may be explained by the physical characteristics of wattle as a nitrogen fixer. This assumption is supported by observations that the presence of *A. dealbata* weeds in *Eucalyptus nitens* plantations in Tasmania increased soil nitrogen levels by as much as 100 percent (Hunt et al., 1999) and that soil nitrogen has been increased by as much 28 percent in pine stands with heavy *A. dealbata* growth (Turvey et al., 1984). In the Working for Water eradiation area close to Goxe observe nitrogen levels are especially high, probably as a result of elevated organic matter levels in riparian zones, which increase nitrogen levels through increased rates of mineralization (Herrera, 2000).

Under forests with high levels of *A. mearnsii,* the soil organic matter does not appear to benefit from increased litter production, although forests with significant numbers of *A. dealbata* did have the highest levels of observed organic matter content, which may be a product of litter additions. However, it is apparent from soil testing in the present investigation, as well as the observations of Hunt in Tasmania and Kessel et al. (1988) in the Western Cape that this invasion by alien Acacias is not likely to significantly improve other soil properties.

In addition, allelopathic effects of wattle presence may undermine any increased productivity conferred by heightened soil nitrogen levels. Carballeira and Reigosa (1999) observed that germination of *Lactuca sativa* was inhibited 30% by throughfall, 60% by stemflow, and 75% by soil percolates from rainfall during the blossoming of silver wattle. Furthermore, radicle growth of *L. sativa* was inhibited 23%, 33%, 48% by the same flows, respectively. The decomposition of fallen wattle flowers on the ground was attributed for the observed effects by Carballeira and Reigosa. If such allelopathic interactions between wattle and indigenous vegetation occur in the study area, the growth of indigenous vegetation could be suppressed, rather than aided by wattle induced augmentations of soil chemical properties. The long blossoming period of silver wattle, which lasts more than three months, also allows for significant flower leachate accumulation, which may render such effects substantial. However, in the mixed wattle forest with the lowest frequency of human induced disturbance, a significant number of indigenous species were identified. Consequently, allelopathic effects are not so severe as to thoroughly prevent the germination of indigenous species, although the presence and degree of such effects cannot be estimated more comprehensively through the present study.

Wattle invasion does appear to have significant potential for reducing soil erosion. In the study area, it appears from the encroachment estimation that wattle invasion is most severe on eroded or exposed soils. Such invasion is consistent with the ecological role of wattle as an early-successional colonial species. The leaf litter present under *A. dealbata* also visually appeared to better cover the forest floor than did the litter of indigenous *Leucosidea sericea,* which left bare soil exposed on the ground, and this observation is substantiated by higher observed organic matter contents in the soils of the adjacent wattle forest than in the *L. sericea* dominated shrubland. In addition, the extensive root system of this species has been noted to help prevent soil erosion, and has been widely employed in slope stabilisation projects in Southern Europe (Bean, 1981). Consequently, it appears that the litter layer of this species may help to reduce sheet erosion, while the root system may assist in anchoring the sloping land on which invasion has chiefly occurred. However, the observed effects of *A. mearnsii* were not so beneficial. Visual observations indicated that the soil litter layer was shallower under this species, and these observations are substantiated by the fact that *A. mearnsii* had the lowest observed levels of organic matter. Conversely, black wattle is commonly cited in literature as a favoured species for soil nutrient enhancement, green manure, and erosion prevention (Duke, 1983), so it is likely that such observations are not representative of soil under black wattle forests in general.

Discussion of results from aquatic impact assessment

Results indicate that there are no significant impacts on water quality, as a result of herbicide application, since an invertebrate inventory according to the *Water Quality Slide* classifies the water as uncontaminated. Initial and subsequent eradication efforts involve heavy herbicide application only to trunk tissues, through a poison-gridling method, and involve no general applications to the soil. As a result, the potential for leaching of herbicides into adjacent surface waters appears to be effectively minimised. In addition, the relatively short half-lives of these herbicides allows for effective degradation of the active ingredient of both (Triclopyr) in less than one day to parent acids, and further breakdown of the parent acid in 6-52 days (Dow AgroSciences, 2001). Consequently, long-term effects of the herbicide application may be minimal, as well.

Figure 3. Example of poison-griddling with Timbrel, as applied to invasive A*cacia dealbata* in Goxe, under the Working for Water Programme.

Species list

High frequencies of high-intensity disturbance result in oscillations between non-equilibrium conditions and early successional states (Savage et al., 2000). In the present study area, human clearing of wattle trees for subsistence timber needs has artificially increased the frequency and intensity of disturbance regimes for forests in close proximity to the village. Since wattle is an early successional species, human cutting is clearly a disturbance that will create optimal conditions for wattle proliferation. As a result, higher density of wattle in the forest was observed in the plots closer to the village, since the wattle regenerates with several shoots when the stem is cut, and similar observations have been made in South Africa's Western Cape by Macdonald and Richardson (1986, c.f. Huntley, 1999).

Forest encroachment estimation

Encroachment does appear significant on eroded or degraded soils, while such encroachment is insignificant on the "higher quality" pastures. This observation suggests that the invasiveness of wattle may be controlled through effective grassland management or reclamation, and that wattle invades areas with the lowest production potential. Consequently, productivity losses from wattle invasion may be of low significance, and increasing production intensivity through more active grassland management may be a primary means by which such invasion can be prevented.

Synthesis

Environmental effects of wattle

The balance of environmental impacts of black and silver wattle invasion is difficult to delineate, due to the diverse nature of such effects, and contradictory analysis of impacts in the literature. Wattle invasion has both positive and negative effects for indigenous flora and fauna. Positive effects for flora may include increased soil nitrogen levels, reduced erosion, increased shelter from wind, and reduced temperature extremes. Negative floral effects may include displacement of indigenous species, allelopathy, reduced incipient radiation, and interspecific competition for nutrients and water. Fauna may benefit from increased levels of edge habitat and niche differentiation resulting from more heterogenous land cover imposed by patchy invasion, or may be negatively impacted by displacement of native forage species. Comprehensive analysis of the effects of invasion on indigenous species requires detailed study of the interaction of each these factors, and hence is beyond the extent of the present study.

The effects of wattle on streamflow are not within the scope of village level analysis of the consequences of invasion, as water for the local community is drawn from a source in the catchment located above the invaded areas, and water downstream appears to be relatively unutilised within the village. However, if conclusions from the present investigation are to be extrapolated to a broader geographic scale, water use effects of invasion must be considered. Black and silver wattle do have significant water consumption. Beyers (1998; c.f. Binns et al., 1991) observed that a significant reduction of streamflow, particularly during the driest and hottest months of the year, was caused by black wattle in the riparian zone of the Sand River in the Eastern Cape. Furthermore, Maitre et al. (2000) found that black wattle was the most significant invasive water consumer in South Africa. Silver wattle is slightly less consumptive, and is rated by Maitre et al. as the fourth largest water consumer. However, in comparison to certain plantation Eucalyptus species, silver wattle has very low levels of water use. For example, Hunt and Beadle (1998) found that the presence of silver wattle weeds in *Eucalyptus nitens* plantations in Tasmania reduced plot water use by more than 50%. Since silver wattle comprises the bulk of invasive wattle forests in the study area, water use may be significant, but it is probably much lower than many commercial plantation alternatives. In addition, the presence of invasive riparian woody species, such as wattle, may help to stabilise streambanks, and prevent negative effects imposed by channel migration for the local community.

In summation, wattle invasion in the study area appears to increase soil nitrogen levels on the land with the lowest productive potential, stabilise channels, and reduce erosion, although these benefits are offset by potentially allelopathic interactions, and moderately increased water consumption, which does not present a significant constraint for the local community. When the observation of significant encroachment primarily in areas on sloped/eroded and acidic soils is compounded with the fact that *Acacia* species are well-known for their nitrogen-enhancing properties, it is likely that wattle invasion may be providing environmental services, in the form of some degree of soil improvement. Effects on indigenous biodiversity require additional study, but the balance of the information collected thus far appears to indicate that the overall environmental effects of invasion are positive for the village of Makomereng.

Social effects of wattle invasion

Household interviews indicated that wattle was a valuable and prised resource for the local community. For the vast majority of informants, it is the primary source of energy, and it also provides materials for construction and fencing for many residents of the village. Since the harvesting of indigenous woody species from natural forests is prohibited by law in South Africa (Republic of South Africa, 1993), wattle represents the only viable local source of timber for community members. Without wattle, local residents would probably have to rely upon their current dominant secondary energy source – paraffin for all heating needs, and this would present a significant financial burden. Construction and fencing materials would have to be imported into the community, further increasing living expenses for the villagers. Wattle not only provides services by reducing living expenses – it actually provides informal sector employment for a significant number of residents. Wattle also offers aesthetic values and recreational opportunities for many inhabitants of the area. The only significant social costs associated with wattle invasion that were identified by informants related to wattle density, and secondary effects of this density upon criminality and cattle loss. Consequently, on balance, the overall social consequences of wattle eradication appear to be overwhelmingly positive, as evidenced by the fact that none of the respondents wanted the wattle totally eradicated.

Evaluation of Working for Water project implementation

Representation of community preferences in WFW eradication efforts

Despite the significance of social services provided by wattle, the Working for Water Programme is currently pursuing a long-term goal of complete wattle eradication in the area. This goal clearly contradicts the preferences of the community residents for at most partial eradication, as elucidated during open-ended interviews. The source of this misrepresentation may lie in the structure of the Development Committee. As noted previously, the two Chairpersons who have sequentially chaired the committee since its inception in 1995 have both been contractors for the Working for Water programme, while simultaneously holding chairmanship. Thus, they have been able to direct community actions towards eradication via the programme, while also receiving substantial income as a result of such actions. Consequently, there has been a strong incentive for these Chairpersons to use their positions to bring eradication programmes into the area, even if such action is undesired by the community. Furthermore, the structure of the committee itself is biased towards considering this programme as the only potential management option for wattle forests, since the Forestry subcommittee only exists as a subset of the Working for Water committee.

Community desires are slightly more accurately represented in the implementation of the Woodlot Project in Makomereng. The implementation of this project recognises that the community will desperately an alternative source of timber, if effective complete eradication were to occur. However, the exact details of this project remain largely unresolved, and it is unclear how responsibility for regeneration and access rights will be allocated within the community, since access to this limited resource will be restricted. With the relatively unmitigated potential for village leadership to dominate management decisions, so as to maximise private gain, already illustrated by the chairmanship of the Development Committee, it is unclear that management of a restricted access system will accurately represent the preferences of community members.

Effectiveness of eradication efforts

The overall disturbance-based eradication strategy pursued via the Working for Water programme appears inappropriate to the ecological role of wattle, as an early-successional r-strategist species. Wattle flourishes in the wake of disturbance, as evidenced by observations in Australia that it may regenerate prolifically in the wake of severe fires or regeneration burns. As an r-strategist it grows quickly, matures early, and releases prolific seeds of very long dormancy (up to 200 years) at an age of only 4-5 years (Hunt et al., 1999). Consequently, increasing disturbance frequency and intensity through cutting and burning will not eradicate wattle, and will only make conditions more ideal for its flourishment. The use of chemical herbicides, as is intended to be employed in the Programme, may be effective at killing individual wattle trees, but will also foster early-successional conditions ideal for wattle regeneration from the profuse seed bank in the soil. Such conclusions are substantiated by observations in the field of extensive wattle regeneration in nearly every area in which eradication was pursued.

Any effective eradication effort must foster conditions that are unsuitable for wattle regeneration and growth. As an early successional species, wattle requires disturbed conditions, and cannot survive when conditions become more late-successional, in the absence of frequent, high-intensity disturbance events. For example, since wattle is moderately shade-intolerant, canopy closure is one means by which wattle can be suppressed (Hunt et al., 1999). Consequently, the introduction of a late successional, shade-tolerant, resource-conserving, K-selected species into the understory may be one means by which wattle can eventually lose dominance in the forest. When wattle ages, it will quickly lose competitive ability, as plant resources are allocated towards high rates of growth, rather than tissue protection and longevity. As a result, once the canopy is closed, K-selected species have competitive advantage in the understory conditions, and can more effectively compete for canopy gaps when they arise from low-intensity disturbance, such as is generated by the collapse of dead tree trunks (Barbour, 1987). Such a suppression means is supported by observations of Hunt et al. (1999) that the competitive ability of *A. dealbata* waned after approximately seven years of age in Tasmania, and that this species would be eventually eliminated from the investigated plantation by inferiority in interspecific competition with *Eucalyptus nitrens* for light.

Another means by which wattle may be effectively controlled through the promotion of late successional conditions is the establishment of the climax community for the area, native grasslands, in the perimeter of wattle infested areas. The forest encroachment estimation illustrated that wattle encroachment is insignificant in highly productive grasslands, whereas sites with bare, disturbed soil had significant encroachment. Consequently, if highly productive grasslands, characterised by low-intensity, high-frequency burning-based disturbance regimes are established, in areas of potential encroachment, wattle site colonisation may be effectively mitigated.

Environmental impacts of eradication efforts

Although the impacts of potential herbicide leaching appeared to be negligible in the present study, other significant adverse environmental impacts may be more substantial. The current eradication strategy of burning eliminates much of the soil nitrogen improvement fostered by the presence of wattle, because such reserves will be volatilised into nitrous oxide by heat. In addition, sulphur, which is often a soil limiting factor, may be volitalised by burning, further reducing soil productive potential (Ahn, 1993). The clearing and burning of wattle also allows for increased sheet erosion, due to the removal of soil vegetative cover, and this sheet erosion may further impact water quality through increased siltation. Indigenous flora and fauna which grow in association with wattle are likely to be detrimentally impacted by wattle removal, as well.

Potential for expansion of social and environmental services provided by wattle

There exists substantial potential for extension of social services generated by wattle. Presently, a significant amount of employment is generated through wattle harvesting and transport to internal markets. However, if these markets were supplemented with additional local external markets, such as adjacent communities lacking forest resources, significantly greater employment could be potentially provided, while simultaneously reducing energy costs for the supplied communities. According to a forestry extension officer working with the village, such potential markets exist within 10 kilometres of the study site. Accordingly, the Working for Water contractor in Goxe asserted that if he were provided transport machinery, rather than funds for eradication, he could provide more employment and pay higher wages than is possible under the current eradication project. The existing impediments to exploitation of these potential local markets require further study, as it is unclear why the apparent opportunity to earn substantial income through local timber trade has not already been exploited.

Within the village there exists substantial indigenous knowledge regarding potential uses for wattle and wattle processing. This knowledge represents an under-utilised resource, which has significant potential for the development of a small-scale value-added wattle processing sector within the village. For example, there is one informant who used to produce wattle furniture for sale, but has now ceased to do so, because of old age. Skills such as hers should be transferred to others within the community before they are lost, and increased marketing opportunities for the products of such skills should be identified and developed.

The deleterious social consequences of wattle invasion could also be minimised through effective management. If fuelwood collection were organised according to collective consensus, so as to minimise disturbance levels induced by harvesting closest to the village, the nearest forest would become less characterised by dense, sprawling growth, which can effectively hide thieves, over time, as competition for light would result in fewer stems. Effective management of human-induced disturbance regimes offers the potential for forest development more according to community preferences.

Research Recommendations

Much additional research is required to effectively assess potential management options for the wattle forest in Makomereng. Additional data regarding eventual forest successional patterns in the absence of disturbance, over long periods of time, should be gathered, so as to understand potential future forest changes, and the temporal scale of invasion-induced effects. Effects of wattle invasion upon indigenous flora and fauna, as well as interactions of these effects with disturbance frequency and intensity require further study, so as to understand the potential implications of forest management options for biodiversity levels. The relative potential of introduced K-selected late successional forest species for eventual wattle suppression should be analysed. If such an artificially increased rate of succession is indeed an effective suppression strategy, then the feasibility of the suppressive species introduction, as well as social and environmental benefits and costs resulting from the introduction, should be assessed. Potentials for wattle containment through the establishment of highly productive grassland, as well as the feasibility of implementing such a strategy should be considered. The economic feasibility of and necessary investments for expanded harvesting and processing of wattle timber for local markets should be investigated, to evaluate the degree to which additional social benefits can be yielded. To effectively extrapolate village-level results to broader geographic scales, the relative social and environmental benefits yielded by the wattle must be balanced with water use costs, in addition to local social and environmental costs.

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Appendix I

Start time:________

Date: ____
Name : ______________________________________
Location:_____________________________________

Sex

Female	
Male	

Age of informant

Age	0-5	6-10	11-15	16-20	21-30	31-40	41-50	51-60	61-70	70+

Number of people in household:_____________

Sources of income

Category	**Specific Details**	
Household farming		
Pensions, welfare, remittances		
Agricultural laborer		
General laborer		
Crafts		
Traditional role		
Urban employment		
Services		
Professional (specialised education)		

Education

Grade 1-4	Grade 5-7	Grade 8-10	Grade 11-12	University studies

Age composition of household

Age	0-5	6-10	11-15	16-20	21-30	31-40	41-50	51-60	61-70	70+
Number										

Tribe

Xhosa	Zulu	Sotho	Venda	Other (Specify)

Area of land managed

None	0.01-0.5 ha	0.5-1.5 ha	1.5-5 ha	5 + ha

Appendix I

Grazing livestock owned

Cows	Sheep	Goats	Other

Time in area

Years	0-1	2-4	5-10	11-20	21+

Heat Source

Type	Wattle wood	Other wood	Paraffin	Coal	Gas	Other (specify)
Percentage						

Time Spent on Fuelwood Collection per Week

Hours	None	0-1	1-3	3-7	7-10	10-13	13-17	17+

Mass of Fuelwood Burned Daily

Kilograms	None	0-1	1-3	3-6	6-9	9-12	12-15	15+

Mass of Wattle Burned Daily

Kilograms	None	0-1	1-3	3-6	6-9	9-12	12-15

Use of Wattle

Use	Fuelwood	Construction	Crafts	Other (specify)
Rank (blank if unused)				

Notes on Social Role of Informant:____

____

End Time:________

Appendix VI

Basic data collected from the households interviews.

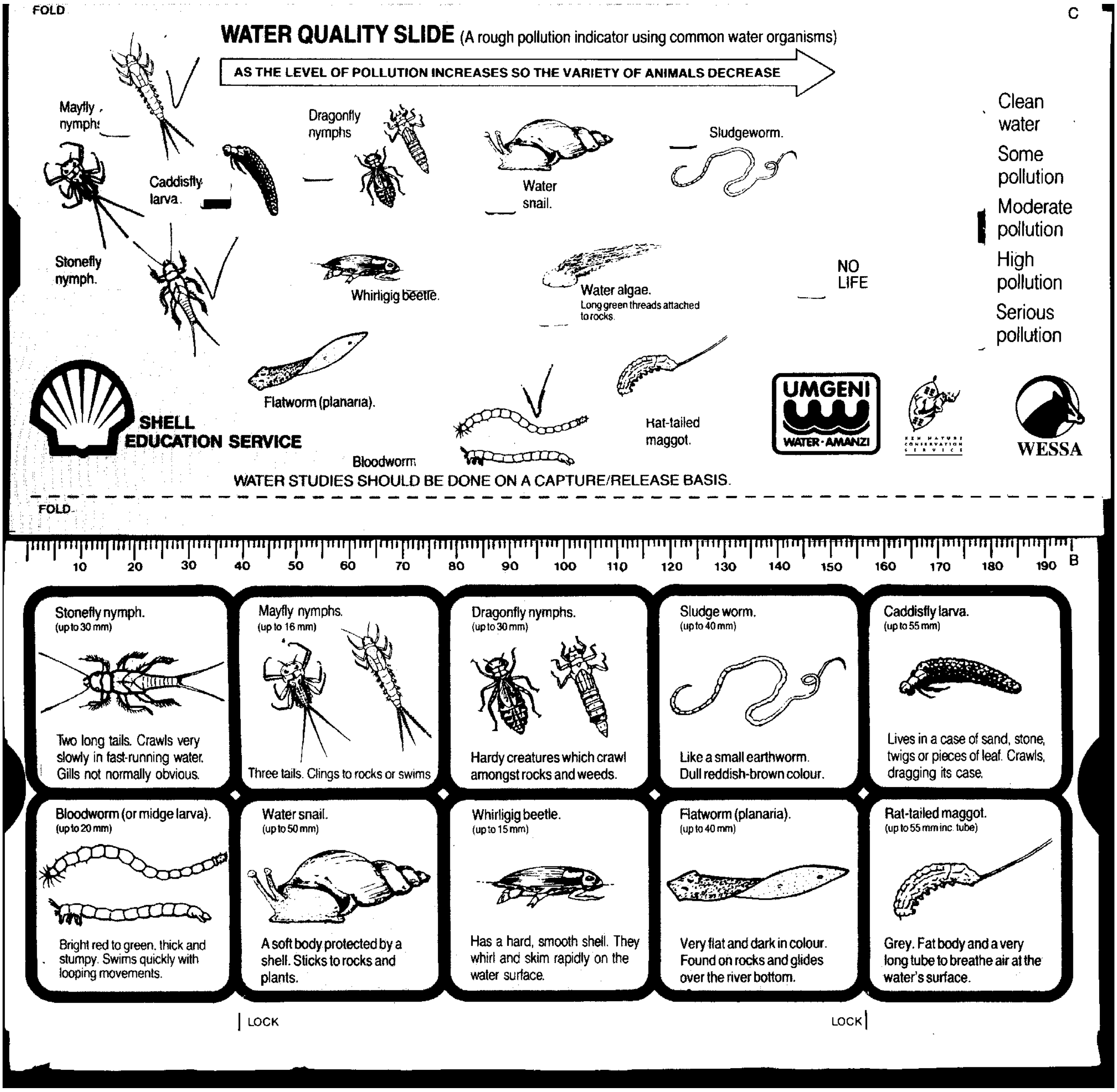
Household #	Sex	# of People in HH.	Adults	Child.	Source of Income	1.Heatsource	2. Heatsource	*Hours collect.	Use Fuelw.	Constr.	Crafts	Area of collect.	Partial/None	Know.WFW	Opin. WFW	Met.of coll.
1	F	6	4	2	Parents work at EDA	Wattle	Paraffin	2	Y	Y			P	3	1	c
2	F	5	1	4	Maid	Wattle	Paraffin	3	Y	Y	Y		N	2	0	d
3	F	5	2	3	Pensions	Wattle	Paraffin	5	Y	Y		R	P	3	1	c
4	F	8	4	4	Pensions, brew beer, veg	Wattle	Paraffin	5	Y				P	1	0	c
5	F	7	3	4	Urban emp.	Wattle	Paraffin	2	Y	Y	Y	R	N	1	0	c
6	F	9	3	6	Pensions, sell wood	Wattle		3	Y	Y		R	P	3	1	o
7	M	6	2	4	WFW, Brewing beer	Wattle	Paraffin	5	Y	Y		R	P	3	1	c
8	F	6			Unemployed	Wattle	Paraffin	5	Y	Y		R	N	1	-1	c
9	F	8	2	6	Transport	Wattle	Paraffin	2	Y	Y		R	N	1	-1	b
10	F	7	2	5	Brew beer, sell veg.	Wattle	Paraffin	5	Y	Y		L	N	3	-1	c
11	F	6	2	4	Urban emp.	Wattle		Buys fr. tract.	Y	Y			P	2	1	o
12	F	8			Shop owner	Paraffin	Wattle	Buys fr. tract.	Y	Y			P	3	1	t
13	F	7	2	5	Pension, Urban emp.	Wattle		3	Y	Y		L	N			o
14	F	4	1	3	Urban emp.	Wattle	Paraffin	5	Y	Y			P	2	1	o
15	F	5	1	4	Tourism	Wattle		5	Y	Y			P	3	1	b
16	F	1	1	0	Housekeeper, sell veg+fru	Wattle		1	Y	Y		R	N	1	-1	d
17	M	7	2	5	Sell chicken + wattle	Wattle	Paraff./Gas	5	Y	Y			N	1	-1	
18	F	3	1	2	Sister works in office	Wattle	Paraffin	2	Y	Y			N	1	-1	c
19	F	3	2	1	Sell beer + snacks	Wattle	Paraffin	2	Y	Y			P	2	1	b
20	F	4	3	1	Husband in WFW Project	Wattle	Paraffin	#	Y	Y		R	P	3	0	t
21	F	4	2	2	Husband in WFW Project	Wattle	Paraffin	5	Y	Y		R	P	3	1	c
22	M	6	3	3	Shop + teacher	Gas	Wattle	3	Y	Y		R	N	1	0	
23	F	1	1	0	Sell veg.	Wattle	Paraffin	1	Y	Y			N			
24	M	1	1	0	Daughter works	Paraffin	Wattle	1	Y	Y			P			o
25	F	8	2	6	Pension + WFW	Wattle	Paraffin	5	Y	Y			N			o
26	F	4	3	1	Sell fruits + veg.	Wattle	Paraffin	2					P	1	0	b
27	F	7	1	6	Urban emp.+ sell fruits	Wattle	Paraffin	#	Y	Y		R	P	2	1	d
28	F	8	1	7	Pensions	Wattle	Paraffin	#	Y	Y		R	P	1	0	o
29	F	5	3	2	Husband's pension	Wattle	Paraffin	1	Y	Y		R	P			c
30	F	6	1	5	Husband in urban emp.	Wattle	Paraffin	6	Y	Y		R	N			c
31	F	8	6	2	Husbands looks after catt.	Wattle	Paraffin	5					P			
								*In Summer								
													1=No knowl		Neg. =-1	
													2=Some kn		Neutral0=0	
													3=Particp		Positive=1	

Appendix V

Species identified during three inventories conducted within 10 by 10 meter plots. These plots were conducted on three different categories of forest lands: forest dominated by *Acacia dealbata*, with high levels of wood extraction; forest dominated by a mixure of *A. dealbata* and *A. mearnsii*, with a moderate rate of wood extraction; and *A. mearnsii* dominated forest with a moderate rate of wood extraction.

Scientific name	English name	Family	Tree/Scrub
***A. dealbata* dominated forest**			
Acacia dealbata	Silver wattle	Fabaceae	Tree
Acacia mearnsii	Black wattle	Fabaceae	Tree
Diospyros dichrophylla	Poison peach	Ebenaceae	tree
Euclea coriacea		Ebenaceae	scrub
Leucosidea sericea	Oldwood	Rosaceae	tree
Myrsine pillansii		Myrsinace	
Rhus dentate	Nana Berry		tree
Mixed *A. dealbata* and *A. mearnsii* forest			
Acacia dealbata	Silver wattle	Fabaceae	Tree
Acacia mearnsii	Black wattle	Fabaceae	Tree
Asparagens ssp.		Aspargagens	
Carissa dispinosa			
Diospyros dichrophylla	Poison peach	Ebenaceae	tree
Eckhone hirta			
Euclea coricea		Ebenaceae	
Gerbera ambigua		Asteraceae	
Maytenus heterophylla	Common spike-thorn	Malus	Scrub
Ptrocelastrus echinatus			
***A. mearnsii* dominated forest**			
Acacia mearnsii	Black wattle	Fabaceae	Tree

Water Quality Slide to determine level of water pollution.



4.2.2 Bestemmelse af pH-værdi

Orientering: En jords pH-værdi (reaktionstal, Rt) er et mål for den fri koncentration af brintioner i jordvæsken. pH-værdien i danske jorde ligger normalt i intervallet 4.5 - 8.5.

Apparatur:
pH-meter
Vægt
Vejeske
Prøvebæger med skruelåg
25 ml målekolbe
Bufferopløsning

Reagenser:
Ionbyttet vand

Procedure:
1. Afvej 10 g tør jord i et prøvebæger tilsæt 25 ml ionbyttet vand
2. Sæt låget på og ryst kraftigt, henstil 1 time.
3. Kalibrer pH-meteret ved medfølgende skruetrækker om nødvendigt. (Skruen sidder bag på pH-metret, hvor der er et lille hul.
4. Efter fornyet rystning måles suspensionens pH.

4.2.4 Bestemmelse af nitrat i jord

HACH # 8152 p. 299.

Analytisk princip: Cd reducerer NO_3^- til NO_2^- ,der i surt medium reagerer med sulfanilinsyre under dannelse af et diazonium salt. Dette salt reagerer med gentisinsyre og danner en lyserød forbindelse, der kan bestemmes spektrofotometrisk ved 500 nm.

Orientering: "Nitrate Extraction Reagent" benyttes i denne analyse til fældning af jorden.

Advarsel: De anvendte HACH-puder indeholder Cd og alle reagenser og emballage skal derfor bortskaffes som klassificeret kemikalieaffald. Brug handsker.

Apparatur:
Hach DR/2000 spektrofotometer
Mini digitalvægt
Koniske kolber 300 ml
Tragte 10 cm ø
Filtre 18.5 cm ø
Glas spatel
Måleglas 100 ml
Målepipette
Gummibold
Quartskuvetter (koster 800,- pr. stk - pas på !)
Sprøjteflaske med ionbyttet vand
Gummihandsker
Saks
Gummipropper til kuvetter

Reagenser:
Ionbyttet vand
NitraVer 5 puder (HACH®) (opbervares ved 5 °C)
NO_3^- standard (50 ppm NO_3^- -N) (opbevares ved 5 °C)

Ekstraktion af nitrat fra jord:

1. Afvej 4.5g sigtet tør jord i en rysteflaske (Sovirel®).
2. Fyld ionbyttet vand til 25 ml mærket.
3. Tilsæt Nitrate extraction Powder tryk ca. 5 gange på dispenserknappen (indeholder Cd brug derfor handsker !)
4. Skru låget på rysteflasken og ryst 30 s. Jorden koagulerer og der fremkommer et klar ekstrakt. (Hvis ekstraktet er uklart tilsættes mere pulver).

Måling med HACH spektrofotometer:

Måleområde: (0-55ppm NO_3-N eller 0-125 kg/ha). Danske jorde indeholder normalt mellem 10-60 ppm NO_3^- -N.

1. ENTER programmet for nitrate nitrogen (N). 366 READ/ENTER => 'ppm nitrate', Display viser nm 500.
2. Indstil bølgelængden på 500nm.
3. Tryk: READ/ENTER, benævnelsen på målingen fremkommer. (Se pkt. 1).
4. Udtag 1 ml klar jordekstrakt og fortynd til 25 ml med ionbyttet vand. Undgå organisk svæv.
5. Tilsæt en pude NitraVer 6.
6. Tryk: SHIFT og TIMER.Reaktionstid på 3 min. begynder, der rystes kontinuerligt.
7. Når timeren 'beep'er', tryk: SHIFT TIMER. Prøven henstår i 2min, Cd bundfældes.
8. Ved beep, dekanteres kvantitativt over i en kuvette, tilsæt en pude NitriVer 3, ryst 30 sek. Reaktionen stoppes. Tryk SHIFT, TIMER og en reaktionstid på 10 min. begynder.
9. Fyld en kuvette med ionbyttet vand, denne er blind-prøve.
10. Når timer beep'er placeres blindkuvetten i målecellen og låget lukkes, tryk på ZERO. Derefter måles prøven, tryk READ/ENTER. Resultatet fremkommer på displayet. Prøven er holdbar i mindst 10 min.
11. Præcisionen kontrolleres ved at fremstille en 10 ppm NO_3^- -N standard. Gentag trin 4-10 idet jordekstraktet erstattes af 10 ppm standard. Ved analyse på spektrofotometret skal denne standrad resultere i værdien 55 ppm ± 10. Er dette ikke tilfældet re-kalibreres (jvf. appendiks 1).
12. Udfyld Tabel 3

4.2.5 Bestemmelse af fosfat i jord

HACH-metode 8182 p. 485

Analytisk princip: Fosfat (PO_4^{3-}) ekstraheres fra jorden med bicarbonat og danner et kompleks ved reaktion med natriummolybdat. Dette kompleks reduceres med ascorbinsyre hvorved en intensiv blå farve opstår. Intensiteten af denne farve er proportional med koncentrationen af PO_4^{3-} og kan måles spektrofotometrisk ved 890 nm.

Orientering: Fosfortallet (Pt), angiver den mængde uorganiske fosfater, som frigives ved at ekstrahere jorden med 0.5 M bikarbonat (pH 2). En Pt-enhed er lig med 10 ppm P i jorden, svarende til ca. 25 kg P pr. ha i pløjelaget på mineralske jorde. Variationsbredden af Pt-værdierne er 1 til 15 i danske landbrugsjorde.

Apparatur:
Mini digitalvægt
Hach DR/2000 spektrofotometer
Kvartskuvetter
Gummipropper til kuvetter
Målepipette
Sprøjteflaske

Reagenser:
Ionbyttet vand
HACH® Soil Extractant 3
HACH® Nitrate extraction powder
HACH® PhosVer 4 pude
Standardopløsning 50 ppm PO_4^{3-} (16.3 ppm PO_4^{3-}–P).

Ekstraktion af PO_4^{3-} fra jorden

1. Afvej 1.0g sigtet jord og overfør den til en rysteflaske.
2. Fyld op til 25 ml mærket med ionbyttet vand.
3. Tilsæt en pude Soil extractant 3.

4. Ryst i 30 sek.
5. Vent 30 min.
6. Tilsæt ca. 3 doser Nitrate extraction pulver.
7. Ryst 30 sek.

Måling af fosfat i jord med HACH spektrofotometer:

Måleområde: Fosfat i jord (0-80ppm P eller 0-180 kg/ha)

1. Press 531 READ/ENTER til bestemmelse af ppm P.
2. Display viser: Dial nm 890.
3. Indstil bølgelængden press READ/ENTER
4. Afmål 5 ml af bicarbonat ekstrakten og overfør dette til et prøveglas, fyld op til 25 ml med ionbyttet vand
5. Tilsæt (langsomt) en PhosVer 4 pude ryst. Pas på der dannes overtryk af CO_2.
6. Tryk SHIFT timer og farvereaktionen forløber i 3 min.
7. Placer blindprøven (indeholder kun fortyndet prøve uden PhosVer 4) i kuvetteholderen og tryk ZERO. Inden 7 min skal prøven måles.
8. Tryk READ/ENTER og resultatet ses på displayet. Om nødvendigt fortyndes med ionbyttet vand indtil PO_4^{3-} koncentrationen ligger indenfor måleområdet.
9. Check nøjagtigheden ved gentage trin 4-8 med 50 ppm PO_4^{3-} standard. Der anvendes 0.5 ml standard i stedet for 5 ml bicarbonat ekstrakt (jvf, trin 4). Spektrofotometret skal vise 32.6 ppm ± 10 % PO_4^{3-}-P. Er dette ikke tilfældet re-kalibreres som beskrevet i Appendiks 1.
10. Udfyld tabel 4.

Tabel 4. Analyseresultater for PO_4^{3-}-P i jord.

Behandling	**Fosfat indhold (ppm PO_4^{3-}-P)**	
Kontrol		
P-mangel		
Fosfat standard	**Teoretisk** **32.6**	**Analytisk**

Appendix II

INTERVIEW GUIDELINES

1. **Wattle extraction**

    a. When?
    b. Where?
    c. Why?
    d. Who?
    e. How much?
    f. How important?
    g. Marketing?

2. **Ownership/tenure of wattle areas**

    a. Who controls access?
    b. Who owns Wattle areas?

3. **Family dynamics**

    a. Who in family collects firewood? Why?
    b. How much time is spent on collection?
    c. Who decides about forest management (with special attention to gender)?

4. **Attitude towards Wattle**

    a. Positive values?
    b. Negative values?
    c. Is eradication desired (with special attention to gender)?

5. **Attitude towards Working for Water programme (with special attention to gender)?**

    a. Knowledge of WFW?
    b. Past participation in WFW?
    c. Impression from previous knowledge?
    d. Impression after description (if necessary)?
    e. Suggestions for improvement?

6. **Attitude towards alternative management (with special attention to gender)?**

    a. Interest in generating income via Wattle, assuming such is possible?
    b. Interest in learning more about Wattle?
    c. Interest in participating in management decisions?

Appendix VII

Table 2. Classification of soil pH values (Herrera, E. 2000).

pH	Classification
> 8.5	strongly alkaline
7.9-8.5	moderately alkaline
7.3-7.9	slightly alkaline
6.7-7.3	Neutral
6.2-6.7	slightly acid
5.6-6.2	moderately acid
3.0-5.6	strongly acid

Table 3. Classification of nitrate content (Herrera, E. 2000).

Parts per million	Classification
< 10	Low
10-30	Moderate
> 30	High

Table 4. Classification of phosphate (Herrera, E. 2000).

Parts per million	Classification
< 7	very low
8-14	Low
15-22	Moderate
23-30	High
>31	very high

Appendix VIII

Table 6. Observations of overall changes in boundary location of Silver and Black Wattle dominated forest in the Makomereng river catchment adjacent to Makomoreng, South Africa, and the Wilcoxson T statistic and t-test t statistic derived from such data. [1] Wilcoxson T statistic = sum of the smaller of the ranks of either the positive or negative differences between data sets. [2] t-test t statistic = Σ differences in observations/ √((number of differences * Σ (differences in observations^2) – (Σ differences in observations)^2)/(number of differences – 1)).

GPS point	Change (m)	Change^2	Rank
51	0	0	5
55	0	0	5
56	0	0	5
59	0	0	5
41	0	0	5
85	0	0	5
74	0	0	5
79	0	0	5
80	0	0	5
43	2	4	10
54	-3	9	11
47	4	16	12
45	5	25	13
44	-6	36	14.5
57	6	36	14.5
66	10	100	16
53	-11	121	17
78	12	144	18
46	15	225	19.5
50	-15	225	19.5
64	20	400	21
65	21	441	22
48	22	484	23
86	25	625	24
76	27	729	25
58	-28	784	26
82	35	1225	27
63	38	1444	28
60	55	3025	29
77	57	3249	30
67	64	4096	31
84	65	4225	32
75	70	4900	33
62	72	5184	34.5
83	72	5184	34.5
Σ:	634	36936	
Average:	18.11428571		
Wilcoxson T statistic[1]:			88
Matched-pair t-test t statistic[2]:		3.916856287	