Julia Watson

Botany Honours

2004

Supervisor: Prof. Timm Hoffman

Is the use of *Willdenowia incurvata* (RESTIONACEAE) for construction at Melkkraal in the Northern Cape sustainable?

Abstract

The aim of this study is to evaluate the use of *Willdenowia incurvata* for the construction of dwellings on a farm outside Nieuwoudtville in the Northern Cape. The research intends to determine how much of the resource (*Willdenowia incurvata*) is used, the method of utilisation and whether this is environmentally sustainable. An extensive survey of each house in the area was included as a vital part of the study. We did transects to asses the biomass of *Willdenowia incurvata* in the field; we mapped areas where harvesting takes place; and we performed experimental harvests to determine the typical size and amount of restio used per metre during house construction. On average, it was found that each round house used 2 626kg of restios (wet weight), and rectangular houses used 1 189kg of restios. We found that patch size varied (from 0.19ha to 9.91ha) and patch biomass varied (from 21 041hg/ha – 54 021kg/ha) in the harvested areas. Utilising the general growth rate of *Willdenowia incurvata* (from Pierce, 1984) and the results of the calculated biomass present in the field and on the houses, three important conclusions were drawn. Firstly, it was found that the amount of restios used as construction material found on the 77 houses in the area is one third less than the amount of restios available in the harvested patches (xkg restios in harvested patches, xkg on houses). Secondly, if harvesting for a few houses (i.e. 10) takes place every five years, it seems that the use of *Willdenowia incurvata* is sustainable. Therefore no changes to the harvesting method, frequency and intensity are apparently necessary. Thirdly, the harvested areas have a higher density of restios per hectare than the unharvested areas. The use of *Willdenowia incurvata* for dwelling

construction on the farm outside Nieuwoudtville appears to be environmentally sustainable from the findings of this study. It is important to note that this is a snapshot view of the situation, and that assessments of sustainable harvesting practices need to be long term, and continuously reviewed.

INTRODUCTION

Sustainable harvesting of indigenous resources

A vital question that is central to many economies and cultures, and to the future of our natural resources, is whether a resource can be sustainably harvested. From large fisheries, to forests and indigenous plant use, natural resources are critical to every nation in the world. It is important to study the sustainable use of natural resources, as very few of them are able to withstand heavy usage, and loss of resources can lead to ecosystem instability and loss of biodiversity (Cunningham 2001). According to Pearce and Turner (1990), sustainability can be defined as "...maximising the net benefits of economic development, subject to maintaining the services and quality of natural resources over time". (Pearce and Turner 1990 cited in Bell and Morse 1999.)

Most research on sustainable harvesting practices has focused on the harvesting of animal populations (e.g. Mchich et al 2000, Hailey 2000). General papers abound too (e.g. Robinson 1993, Ludwig 1995). Sustainable harvesting of plants is a well-researched topic (e.g. Cunningham 1994, Hilborn et al 1995), but only a few long-term studies are available (Pfab and Scholes 2004).

Harvesting theory

According to Cunningham (2001), it is important to ascertain what the focus of one's study is when looking at sustainable harvesting of a resource. The focus should be either on the local livelihoods of the people who depend on the resource, or on the conservation of the resource itself (Cunningham 2001). Overexploitation of a resource leads to loss of biodiversity and habitat (on the conservation side) and loss of self-sufficiency (for people who rely on this resource) (Cunningham 2001). Large, intense and frequent harvests are what contribute to an increased risk of population decline (Cunningham 2001).

Biology of *Willdenowia incurvata*

Willdenowia incurvata is evergreen, grows on oligotrophic soils (like most Restionaceae) and its growth takes place predominantly in summer (Linder 1991, Pierce 1984). *Willdenowia incurvata's* growth form is simple and characteristic of most of the restio family (Linder 1991). It has a subterranean rhizome that bears aerial stems (culms) and adventitious roots. The female inflorescence is a solitary spikelet with numerous bracts – only one of which is fertile (Linder 1991). The male inflorescence has numerous spikelets with large spathes. The fruit of *Willdenowia incurvata* is a large woody nut. (Linder 1991). This elaiosome is what attracts and rewards the ants that disperse the nut of *Willdenowia incurvata* (Linder 1991).

The use of indigenous plant products for construction purposes

Many studies have looked at the use of indigenous plant products for economical and subsistence reasons (Cunningham 1988). The aim of these studies is usually to determine whether using a resource in a particular manner is sustainable in terms of the environment and future utilisation of the plant (Cunningham 1988).

In certain parts of Africa, *Hyphaene* palm leaves are used for weaving material especially as they are fibrous and strong(Cunningham 1988). A study was performed to look at the leaf production of *Hyphaene* and to "provide the basis for management of leaf harvesting" (Cunningham 1988). This is a classical type of study focussing on sustainable harvesting where the needs of both the people and the environment are taken into account, and the best solution for the specific situation is decided upon (Cunningham 1988).

In the Transkei, roofs of round houses are thatched (Johnson 1982). The grass species used for thatching is predominantly *Cymbopogon validus*. The bunches of this grass are tied on to the roof with *Sporobolis spp.* or *Eragrostis spp* (Johnson 1982). These roofs can last for 25 years. Unfortunately, in some areas, the indigenous forests have been completely ruined because a large amount of wood (species such as *Buxus macowanii, B. natalensis, Cryptocarya woodii* and *Chaectame aristata*) is required to build these houses (Johnson 1982). Sustainable harvesting research seeks ways to curb overexploitation of natural resources, and to find ways to supplement and adapt harvesting methods (Johnson 1982).

According to Liengme, the Tsongas in Gazankulu in the Northern Province thatch their houses with *Themeda triandra*. They utilise *Acacia nigrescens, A. caffra* and *Afzelia quanzensis* as structural support and *Eucalyptus* spp. too if it is available (Liengme 1981). Their method of thatching is to make grass mats that are then tied onto the framework using *Sporobolus africanus*(Liengme 1981).. It has been reported that a "fair amount" of wood and grass is required for the Tsonga construction method (Liengme 1981). The thatch roofs need replacing every five years, and it is the women who collect the grass and the men who perform the thatching process (Liengme 1981). As a lot of grass is required, women often walk many kilometers to fetch enough for the thatching (Liengme 1981).

People in Maputaland use reeds, thatch and wood for low cost building materials (Cunningham 1985). They harvest *Phragmites australis* and sell it to people in neighbouring lands for hut building, using it on the walls and roof. In 1983, 260 $\pm$ 60 metric tons were sold removed and sold from a wetland of 296ha (Cunningham 1985). The resource is cut in winter after flowering, when the stems are mature. In undisturbed areas, *P. australis* is three to four metres tall (Cunningham 1985). In disturbed areas (where it is trampled, cut, burned or grazed) it is 0.3-0.45m tall (Cunningham 1985). If these resources were lost (e.g. to overexploitation), there would be a loss of income. Poor housing resulting from this or expensive industrial modifications required for building purposes (e.g. corrugated iron) would then be necessary. Utilisation of the reed as a resource is very labour-intensive and there are two barriers to overexploitation. Firstly, if *P. australis* is cut too early it is less strong and has no commercial value. Secondly, only tall reeds are required to build the huts and so only a certain portion of the population is utilized (Cunningham 1985). Therefore sustainable harvesting of this resource seems possible as natural barriers to overexploitation are in place, but no clearly defined guidelines are obvious in the communities (Cunningham 1985).

The use of restios for thatching purposes

Restios have been used for thatching in the Cape from as early as 1652 when Van Riebeeck cut reeds for dwellings (Rourke 1974). *Thamnochortus insignis* was predominantly used for its hard, wiry characteristics and great abundance (Rourke 1974). *Willdenowia argentea* was also used but not in such large amounts as it was not as abundant (Rourke 1974). *Cannomois virgata* was popularly used for shepherd huts in the mountains (Rourke 1974).

Traditional use of indigenous resources is a well-covered topic too. According to the IUCN "Both consumptive and non-consumptive use of biological diversity are fundamental to the economies, cultures, and well-being of all nations and peoples." (http://www.iucn.org) Thatching has a rich history in the western Cape. Rourke (1974) noted that *Thamnochortus insignis* and *Chondropetalum tectorum* were used for thatching in the southern and western Cape for many years in the past. *Willdenowia argentea* and *Cannomois virgata* were used for shepherd huts and *Hypodiscus aristatus* was used in the Langeberg (Rourke 1974). At present, the greatest amount of thatching in the western Cape utilises *Thamnochortus insignis*. This species became popular for thatching after the First World War, and harvesting is now a robust economical trade. *T. insignis* is harvested and dried mainly in winter. A stand can be harvested once every five years. Use of restios to build houses (and for other purposes) is less economically important now for the people who build them than it was in the past. The use of restios for house building has declined in most areas with the replacement of walls and roofs with industrially produced materials such as metal. Only in some areas such as Melkkraal, some parts of the Cedarberg and the western Cape Sandveld are restios still used abundantly for house building.

Aim of study

This study has three main foci: firstly it aims to document the indigenous cultural building practices at Melkkraal in the Northern Cape; and secondly to assess the use of *Willdenowia incurvata* (Thunb. **ref**) and to ascertain whether the harvesting of *Willdenowia incurvata* is a sustainable practice at present. We focussed our questions on:

- types of houses in the area,
- the abundance of the resource,
- what the harvesting impacts on the resource are,
- and how much of the resource is used to thatch the houses in the study area.

Study area

Melkkraal was chosen as a study site for two reasons. Firstly and foremostly is a communal area where traditional use of plants has endured, and there is a fairly dense clustering of reed houses on the farm. This therefore makes it a place of interest, and facilitates collection of data from the reed houses. Secondly, the University of Cape Town has links with the area in the form of other projects, and this provides a useful aid when conducting research in an area especially where it involves personal interaction with people living there.

General location

The soils of the study area are derived from dolerite and are called Arcadia soils (reference 28). They contain clay minerals, which cause the soil to shrink and swell, producing cracks in the soil surface (reference 28). This causes a lot of the surface nutrients to be pushed lower into the soil profile (reference 28).

Social issues

The people living at Melkkraal are predominantly farmers; they cultivate crops such as maize and rooibos, and keep cattle (sheep, goats, donkeys). There are approximately x number of people living at Melkkraal.

If one does not base a harvesting model on assumptions that are generally valid, consequences such as overexploitation of the resource may occur

(Paysa 2004). One also needs to understand vital processes such as density dependence to be able to determine sustainable harvesting practices for a specific population (Paysa 2004). According to Hilborn et al 1995, habitat is the main factor controlling and limiting population size. This means that if seeds are continually deposited in the soil, the reproductive surplus does not increase linearly with the number of seeds, but factors such as competition for moisture, soil and other resources limit the seed surplus (Hilborn et al 1995). Therefore there is an ideal number of seeds per area of habitat. It is not only seed surplus that determines the optimal sustainable harvesting level of a population. (Hilborn et al 1995). It is important to also include factors such as possible decrease in soil productivity, changes in population structure and habitat loss as these are as influential on populations as reproductive output is (Hilborn et al 1995). In forestry and fisheries, the lesson has been learnt that initially, harvesting yields will be high due to old-growth present in the population (Hilborn et al 1995). If future harvesting principles are based on this initial level of harvest, overexploitation of the resource is a distinct possibility (Hilborn et al 1995). One must therefore review populations as harvesting continues. It was previously thought that a population behaves in a relatively uniform manner with little fluctuation in size. Subsequently, this has been shown to be incorrect (Hilborn et al 1995). Populations fluctuate greatly over time and therefore sustainable harvesting practices must take this into account.

METHODS

Resource abundance

To determine the abundance of harvestable restios within Melkkraal, I identified seven areas where restios are frequently harvested and took GPS readings at 5-18 points around the perimeter of each area. These data were imported into Arcview GIS version *** and the extent, in ha, of each harvested area determined.

Depending on the size of the harvested patch, between one and four transects were set up in each of the seven harvested areas. The basal diameter and height of every plant within a one metre strip of variable length was recorded until between 40 and 120 plants were measured in each harvested area. The transect lengths ranged from 35.4m to 102m (average of 67.4m ± 32.1m). The data from each transect within each patch were pooled to create one data set per patch. From these data the size class frequency distribution was calculated for each area and expressed on a per ha basis.

In the areas where harvesting never (or very infrequently) takes place (from now on called unharvested areas), a 50 m tape measure was laid out and the basal diameter and height of every plant within a one metre strip was measured. The transect was chosen to be 50 m because the unharvested areas were large in comparison to the harvested areas, and to measure 100 plants in each transect was not feasible in terms of the size of the area and number of restios present.

Biomass determinations

To determine the relationship between basal circumference and wet mass, 23 individuals from a range of basal circumference size classes were harvested in the field at ground level and immediately weighed using a five kg spring balance. The linear regression equation that was obtained between basal circumference and wet mass was used to calculate the biomass for each size class within each harvested (and unharvested) area. This was then expressed in terms of the total biomass for the area.

To ascertain the ratio of wet to dry mass, five replicate samples were weighed immediately upon harvesting and then oven-dried at 65 °C for five days before being re-weighed. The mean difference between wet and dry weight was used in subsequent calculations.

Harvest impacts

To determine the impact of different harvesting techniques on survival and regrowth, 24 plants of a similar size were experimentally harvested in four different ways with six replicates randomly assigned to each treatment. A hoe was used in all treatments that differed in the height of harvest and the amount of material harvested from each restio in the following way:

a. Whole plant harvested at the base (the presently-utilised method for harvesting restios at Melkkraal);

b. Whole plant harvested at approximately 10 cm above ground level;
c. Half the plant harvested at ground level;
d. Half the plant harvested at approximately 10 cm above ground level.

Harvested material was immediately weighed and the harvested plants left for six months. Survival was determined after six months at which time regrowth was harvested, weighed and expressed as a proportion of the weight of the material harvested six months earlier.

Survey of houses and other dwellings

To determine the amount of material used in the construction of dwellings in Melkkraal, each one of the 28 household clusters was visited in May 2004. Each construction, within each cluster was given a GPS co-ordinate and numbered (table 1).

A morning was spent with A. Fortuin, mapping where the restios were found, where water tanks and their associated pipes were found, where the telephone poles were, who owned livestock, what these livestock were and where on the study area they were found. Major roads and other farming practices (e.g. rooibos, oats, and mielies) were also recorded.

To determine the dry weight of restios used to construct each dwelling a number of variables were calculated. Firstly, the total surface area of rectangular constructions was calculated as the sum of the wall area and the roof area as follows:

Wall area = (l x h) + (b x h) * r * kg * w...(1)

Where: l = length of wall

b = breadth of wall

h = height of wall

r = number of layers of restios on wall

kg = average kg of restios per area of 1 m x 1.31 m (determined experimentally)

w = wet weight conversion ratio (1.57)

Roof area = (l * h) + (b * h * r) – (d *kg *w).....................................(2)

Where: l = length of roof

b = breadth of roof

h = roof height

r = number of layers of restios on roof

d = average door dimensions

The total surface area of round constructions was also calculated as the sum of the wall and roof area by the following:

Wall area = (h * c * r) – (kg * w)...(3)

Where: h = height of wall

c = circumference

r = number of restio layers

d = average door dimensions

The roof surface area of round constructions was divided into a top layer and then subsequent layers as follows:

Top layer = C * kg * w..(4)

C = surface area of a cone = pi * r * (r + (r2 + r2)$^{\wedge 1/2}$)

Where: r = radius

r2 = radius of layer above the previous layer in the equation

The radius was calculated from the right angle triangle formed by the top layer of the roof and the angle of the roof apex which was ascertained from a photo.

Subsequent layers = area of a frustum = F

F = Π * * (R1+R2) * sqrt[(R1-R2)^2 + H^2]...(5)

Where: Π = Pi (3.1415)

R1 = Top Radius

R2 = Bottom Radius

H = Height

Radius and height were calculated from a right angle triangle and the angle of the roof apex was ascertained from a photo. The area was then converted into kg wet weight, as per other conversions.

A mock building exercise was performed to simulate the construction process and to ascertain the amount of restios used during dwelling construction. A skilled builder constructed a wall one restio layer thick, one meter long and on average 1.31 m high as a simulation of the process involved in laying restios on the wall and roof during house construction. The dried restios used for this specific exercise were then weighed. This process was repeated four times, and the average weight used in subsequent calculations.

Statistical tests:

Where appropriate, Students t-tests for independent samples and correlation analyses were performed using Statistica v. 6.

RESULTS

Resource distribution and abundance

Willdenowia incurvata is patchily distributed at Melkkraal. There are no restios at the upper portion of the farm – only cattle and crops are found there. The restios are found mainly below the road that separates Melkkraal into the upper and lower parts (map 1). They are concentrated in patches, and many of these patches are found in areas that are more sandy than their surrounds. The patches vary in size.

There were significantly more plants per hectare in harvested areas than in unharvested areas (fig. 2, $t = 2.8$, $df = 9$, $p < 0.05$). There was more than three times the amount of kg of plants per hectare in the harvested areas than in the unharvested areas (fig. 2, $t = 4.2$, $df = 9$, $p < 0.05$).

Biomass determinations

There is a strong, positive relationship between basal circumference and kg per plant ($y = 3.8017x - 1.2048$, $R^2 = 0.8355$; $df = 19$, $p < 0.001$, fig. 3). To ascertain mean dry to wet weight measures, the five replicates of restio samples taken from patch number seven that T. Hoffman dried, at 65 degrees Celsius for five days showed that % dry weight is 7.32kg (stddev=1.14%). This means that 42.86% of the weight of the plant comprises water.

Harvest impacts

In the unharvested areas, the greatest number of individuals is found in the smallest weight class (class 0-3 kg, fig. 2). Several individuals are found in the subsequent weight class, although notably fewer, and very few in classes above 9kg (fig 2). In the unharvested areas, the greatest percentage of individuals is found in the first weight class (although less than are found in the harvested areas, fig. 2), with a gradual decline in numbers in each of the subsequent weight classes (fig. 2). The weights of the individuals were found to be significantly different when comparing the two areas (harvested mean is 2.03 kg $\pm$ 1.72 and unharvested mean is 4.58 kg $\pm$3.02, $df = 681$, $t = -7.16$, $p < 0.001$).

More than 70% of the harvested individuals were found in the smallest weight class, and less than 40% of the unharvested individuals were found in this same weight class (fig. 2). More than 10% of the unharvested individuals were found in weight classes above 9 kg, and less than 5% of the harvested individuals were found in weight classes above 9 kg (fig. 2).

Average basal circumference was greater in unharvested (mean basal circumference is 1.2 m2 $\pm$ 1.1) individuals than in harvested individuals (mean basal circumference of 0.5 m2 $\pm$ 0.4) as was average kg per plant ($t= -6.4$, $df=681$, $p < 0.001$). There was no significant difference ($t = 0.6$, $df = 681$, $p > 0.05$) in height between the two areas. Weight (average kg) per plant was more than twice as large in plants in unharvested areas (mean of 4.58 kg $\pm$3.0) than in plants in harvested areas (mean of 2.02 kg $\pm$1.72; $t = -7.2$, $df = 681$, $p < 0.001$.)

Survey of houses and other dwellings.

Table 1 includes all the species found on Melkkraal that are used for thatching and structural support of the constructions found here. Family names, common names and main construction use are included.

Seventy-seven constructions were measured that utilise restios as a portion of their construction material. This is the total number of constructions in the study area. The seventy-seven constructions were found grouped into 28 clusters (by owner). The constructions comprised living quarters, cooking shelters, storage areas, chicken coops and toilets. Appendix 1 contains all measurements taken at each construction. The approximate total area in which the constructions are found is x km2. Map 1 shows the distribution of the constructions in the area.

Rectangular constructions comprise 39 of the 77 constructions found on Melkkraal and round constructions comprise 38 of the seventy-seven. Not every one of the constructions used restios to entirely cover the walls and roofs, but all used restios on some part of the building (picture 1).

Table 3. The number of houses, mean basal area ($\pm$ std dev) and mean wet weight ($\pm$std dev) for each of the construction types is found in table 3. Most of the constructions at Melkkraal are used for sleeping and cooking shelters (65%). These two types of constructions utilise the greatest proportion of restios per wet weight. Rectangular living quarters have the highest average basal area (18. 2 $m^2 \pm$ 8.8), followed closely by round sleeping quarters (16.2 $m^2 \pm$ 6.5). Chicken coops have the smallest average basal area (1.9m2 $\pm$ 0.9).

Although round living quarters do not have the largest basal area, they use more restios than any other construction (1 841kg $\pm$ 1 143). Rectangular living quarters have the second highest mean wet weight (1 611kg $\pm$748). When comparing round and rectangular constructions, round constructions have a significantly higher wet weight than rectangular constructions ($df = 76$, $t = -4.75$, $p < 0.001$). Chicken coops have the lowest mean wet weight (115kg $\pm$ 30). Round constructions have a mean of 4.6 ($\pm$ 1.9) roof layers, and rectangular constructions have a mean of 3.3 ($\pm$ 2.2) roof layers.

The average basal area of a rectangular construction is $16.97m^2$, ($\pm$- std dev of $10.97m^2$). The average basal area of a round construction is $12.67m^2$ ($\pm$ $4.7m^2$ std dev). Table 2 shows the average measurements of basal area, number of wall layers, number of roof layers and kg of reeds used for each of the construction types found at Melkkraal.

Discussion

Resource abundance

It is hard to determine if the reason that the harvested areas contain more biomass in them than the unharvested areas is due to disturbance factors by the harvesters. A possibility may be that the harvested patches may have more biomass due to natural environmental factors (such as more suitable habitat, more available water) and the greater biomass available is the reason why the harvesters utilize these areas more than others do. Harvesting of the population may also create more space in the form of gaps for restio seedlings to emerge. The harvested areas seemed to be situated in lower-lying areas than the unharvested patches. Low-lying areas may collect more water as runoff after rain, and so provide a more suitable habitat for restios. This may be the reason why the restios are more abundant in these areas and are therefore utilized more heavily than other areas.

Harvest impacts

The fact that there are so few individuals in the largest weight class is probably due to harvesting practices. (The harvested areas have a large number of individuals in the smallest designated weight class.) If a patch gets harvested every 5-10 years, the restios in this patch do not have sufficient time to reach a large size, as in the unharvested areas where there were more individuals in the 9-12 kg weight class. The reason that there are some large individuals found in the harvested areas is related to the quality and age of restio that a harvester looks for. When a restio becomes old (and therefore big), a harvester will not select this individual even if other requirements (such as correct height) are met. This is because an old restio has a lot of dead and brittle stems that are not useful in building a construction of good and lasting quality. The few large individuals that are found in the harvested areas were probably there because they were overlooked in previous harvesting periods and had the chance to reach a large size and old age. Therefore, harvesters only look for a certain size and quality of restio, leaving unsuitable plants to remain.

The ability of *Willdenowia incurvata* to recover after disturbance

Willdenowia incurvata resprouts after fire (Linder 1991). This is observed by people living at Melkkraal who burn restio fields to make way for rooibos tea farms and have trouble controlling the regrowth of the restios, and by research (Linder 1991). Some studies have shown that the survival of the restio depends on the season of burn, and a burn soon after new shoots have been sent out can kill a restio (Linder 1991). If harvesting methods are to be sustainable, season of burn must be controlled. A harvested population that is healthy at present may suffer greatly if a fire occurred at a season that would cause the greatest fatalities. A factor in favor of future survival of *Willdenowia incurvata* even during fires in 'dangerous' seasons is that the restio retains its seeds on the plant for some time (similar to serotiny, Linder 1991). This may be a method to avoid fire and to ensure survival.

A reproductive strategy representative of some of the restionaceae (including Willdenowia incurvata) is that producing fewer seeds (or decreased fertility, Linder 1992) but larger seeds that are more drought resistant (Caddick and Linder 2002). Many studies have supported this hypothesis of larger seeds having a higher drought resistance, as well as larger seeds having a higher seedling survival rate than smaller seeds, especially in times of low rainfall (Westoby and Kidson 2000, Leichmann and Westoby 1994, Bond and Maze 1999.)

How the biology of *Willdenowia incurvata* is affected by harvesting:

Willdenowia incurvata is a reseeder as well as a vigorous resprouter. It does not produce many seeds (the seed is described as a large woody nut) per plant and these seeds are ant dispersed (Bond and Slingsby, 1983).

Willdenowia incurvata grows by increasing the number of stems per plant, and therefore expanding its basal circumference. As kilograms of wet weight per restio is strongly and significantly correlated with basal circumference, it is possible to deduce that there are many young restios in the harvested areas because there is a large number of individuals found in the smallest weight class. In the field, we observed that there were areas where there were many individuals per meter. That is, the restios were growing very densely. These individuals tended to be tall with a very small basal circumference. Possible competition for space may have forced young individuals to grow tall quickly rather than to expand their basal circumference in proportion to the increasing height. In some of the less dense areas, the restios were not as tall and had basal circumferences more in proportion to their height. They therefore had less reason to grow tall quickly and could focus energy into expanding the number of stems present, and therefore their basal diameter. Any processes that are influenced by the density of the population will change and adjust if the population is harvested (Paysa 2004). When a population is harvested at a rate that reduces its population size below a certain level, the population may respond by increasing its reproductive rate (Paysa 2004). The rate is therefore increased to a level higher than an unharvested population and is termed compensatory natality (Paysa 2004).

Survey of houses and other dwellings

Most of the constructions at Melkkraal are used for sleeping and cooking shelters (65%). These two types of constructions utilise the greatest proportion of restios, and are therefore the area of most interest regarding sustainable harvesting of the restios. This is because they would have the greatest impact on the population size after harvesting restios to construct them.

The reason that round living quarters have a higher mean wet weight than rectangular living quarters relates to the number of layers used for thatching the roofs. The normal method of building (whether for round or rectangular constructions) is to utilise only one layer of restios for the walls. For rectangular constructions, the roofs then have fewer average layers on each side compared to the round constructions. This contributes to an increased mass of restios used to build round constructions. One of the reasons that toilets and chicken coops have a very low average kilogram of restios used to build them is not only because of their small size, but also because they are usually rectangular in shape and therefore do not utilise many roof layers. More importantly though, the majority of these types of constructions have sink metal or chicken wire roofs rather than roofs made of restios.

The sustainability of restio harvesting at Melkkraal

From the data we gathered and analysed, it seems clear that the present harvesting level of *Willdenowia incurvata* at Melkkraal is sustainable. The method of harvesting appears to be one that is inherently environmentally aware and causes the least damage to the restio. *Willdenowia incurvata* is mainly harvested in summer, and so the restio is able to recover in winter which is the season that it sends out new shoots. If the season of harvest were to change to winter, this would have a serious impact on the ability of *Willdenowia incurvata* to recover after harvesting. The populations of *Willdenowia incurvata* in the harvested areas are healthy with a large number of juveniles present.

The use of *Willdenowia incurvata* for construction is evidently sustainable at the current rate of replacement and method of harvesting. Future use of *Willdenowia incurvata* for construction is a sustainable practice, as long as the current methods are retained. Rooibos harvesting in the area may be the only threat to restio populations, as the rooibos is planted in areas which are most suited to restio growth.

In conclusion, this study has provisionally shown that *Willdenowia incurvata* is sustainably harvested for construction at Melkkraal.

References:

1. Bell S and Morse S, (1999). *Sustainability Indicators*. Earthscan Publications Ltd, London, pp175.

2. Bond W.J. & Slingsby P, (1983). Seed dispersal by ants in shrublands of the Cape Province and its evolutionary implications. *South African Journal of Science* 79:231-233.

3. Bond WJ, Honig M & Maze KE, (1999). Seed size and seedling emergence: an allometric relationship and some ecological implications. Oecologia 120:132-136.

4. Caddick LR & Linder HP, (2002). Evolutionary strategies for reproduction and dispersal in African Restionaceae. *Australian Journal of Botany* 50:339-355.

5. Cunningham AB, (1985). *The Resource Value Of Indigenous Vegetation To Rural People In A Low Agricultural Area*. Unpublished PhD thesis. University of Cape Town.

6. Cunningham AB, (1988). Leaf production and utilisation of (finish) Hyphaene. *South African Journal of Botany* 54:189-195.

7. Cunningham AB, (1990). Income, sap yields (finish) palm wine. *South African Journal of Botany* 56:137-144.

8. Cunningham AB, (2001). *Applied Ethnobotany: People, wild plant use and conservation*. Earthscan Publications Ltd, London, pp300.

9. Dasmann RF, (1985). Achieving the sustainable use of species and ecosystems. *Landscape and Planning* 12,3:211-219.

10. Dungumaro EW and Madulu NF, (2003). Public participation in integrated water resources management: the case of Tanzania. *Physics and Chemistry of the earth* 28 (20-27): 1009-1014.

11. Hailey A, (2000). Implications of high intrinsic growth rate of a tortoise population for conservation. *Animal Conservation* 3: 185-189 Part 3.

12. Hilborn R, Walter CJ & Ludwig D, (1995). Sustainable exploitation of renewable resources. *Annual Review of Ecology and Systematics.* 26:45-67

13. Johnson CT, (1982). The living art of hut building. *Veld and Flora* 68:109-110.

14. Kidson R & Westoby M, (2000). Seed mass and seedling dimensions in relation to seedling establishment. *Oecologia* 125,1:11-17.

15. Leishmann MR & Westoby M, (1994). The role of seed size in seedling establishment in dry soil conditions – experimental evidence from semi-arid species. *The Journal of Ecology* 82,2:249-258.

16. Liengme CA, (1981). Plants used by the Tonga people of Gazankulu. *Bothalia* 13: 501-518.

17. Linder HP & Ellis RP, (1990). Vegetative morphology and interfire survival strategies in the Cape Fynbos grasses. *Bothalia* 20,1:91-103.

18. Linder HP, (1991). A review of the southern African Restionaceae. *Contributions from the Bolus Herbarium* 13.

19. Linder HP, (1992). The structure and evolution of the female flower of the African Restionaceae. *Botanical journal of the Linnean Society* 109: 401-425.

20. Ludwig D, (1995). A theory of sustainable harvesting. *Siam journal on applied Mathematics* 55 (2): 564-575.

21. Manning, J and Goldblatt P (1997). *A Guide to the Wild Flowers of Nieuwoudtville-Calvinia-Botterkloof*. pp. 204, paperbound, Claremont, 1997.

22. Mchich R, Auger P, Raissi N Acta, (2000). The dynamics of a fish stock exploited in two fishing zones *Biotheoretica* 48 (3-4): 207-218.

23. Paysa H, (2004). Ecological Basis of Sustainable Harvesting: Is the Prevailing Paradigm of Compensatory Mortality Still Valid? *Oikos* 104,3: 612-615.

24. Robinson JG, (1993). The limits to caring: Sustainable living and the loss of biodiversity. *Conservation Biology* 7,1:20-28.

25. Rourke J, (1974) On restios and roofs. *Veld and Flora* 4:57-59

26. Pfab MF & Scholes MA, (2004). Is the collection of *Aloe peglerae* from the wild sustainable? An evaluation using stochastic population modelling. *Biological Conservation* 118, 5: 695-702.

27. Pierce S. (1984). A synthesis of plant phenology in the Fynbos Biome. *South African National Scientific Programmes Report number* 88: 1-55.

28. http://www.iucn.org/themes/sustainableuse/policy/polstateng.html date used: 28/06/04

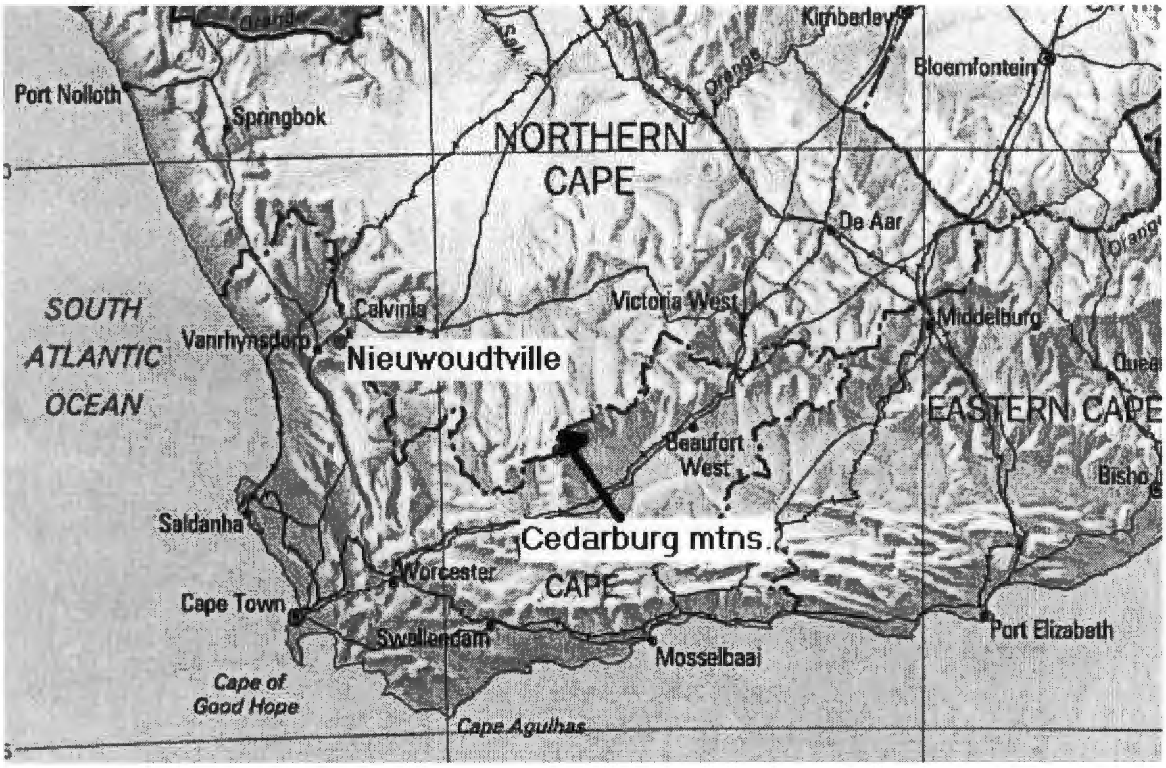


Fig. 1. Map of South Africa, indicating the position of Nieuwoudtville (which is 11km away from Melkkraal) and the Cedarburg mountains.

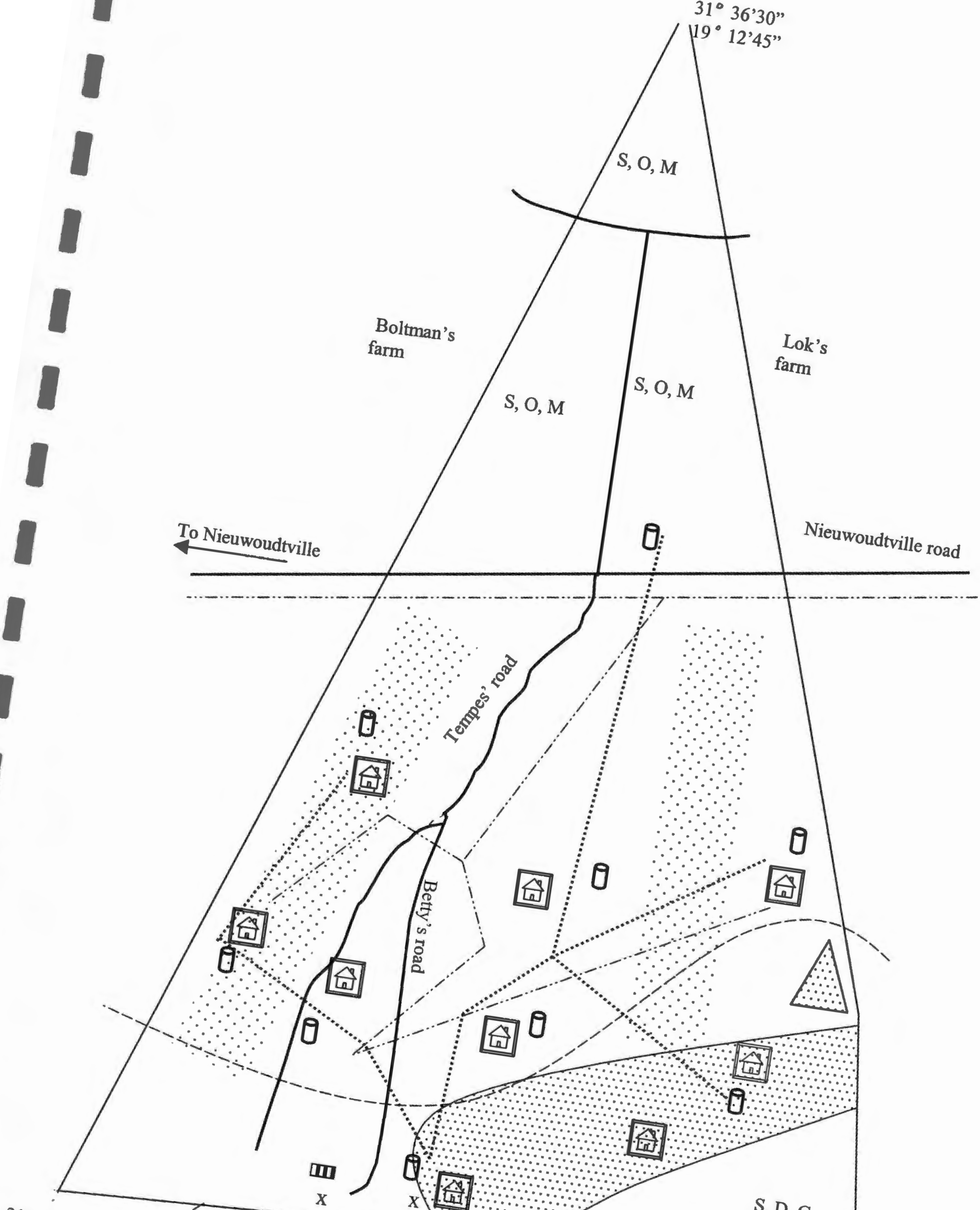


Fig. 2. Detailed diagrammatic map of Melkkraal. Co-ordinates are accurate to within 15 degrees.

Key to fig. 2

Cluster of houses 

Solar panel 

Water tank 

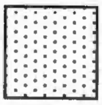
Telephone line

Water pipe

S, O, M – sheep, oats, maize

S, D, C – sheep, donkeys, cows

D, C, H – donkeys, cows, horses

Rooibos 

Restios 

Road

Karoo river 

Windmill x

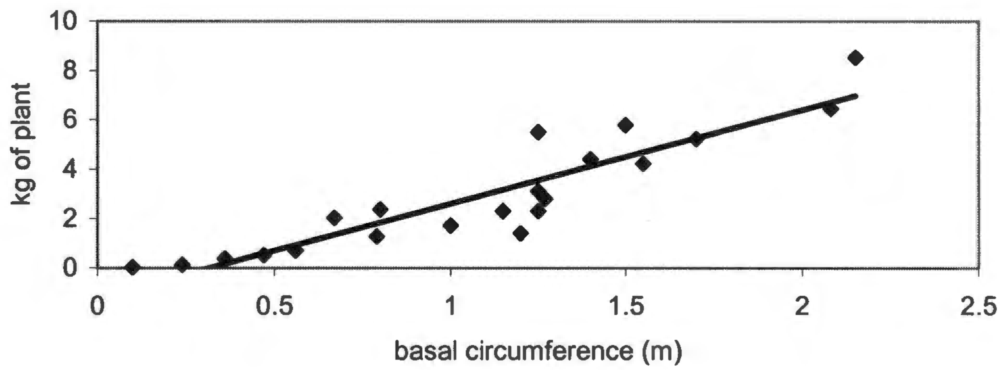


Fig 3. Relationship of basal circumference to kg of each of the 21 plants measured at Melkkraal (y = 3.8017x - 1.2048, R2 = 0.8355.)

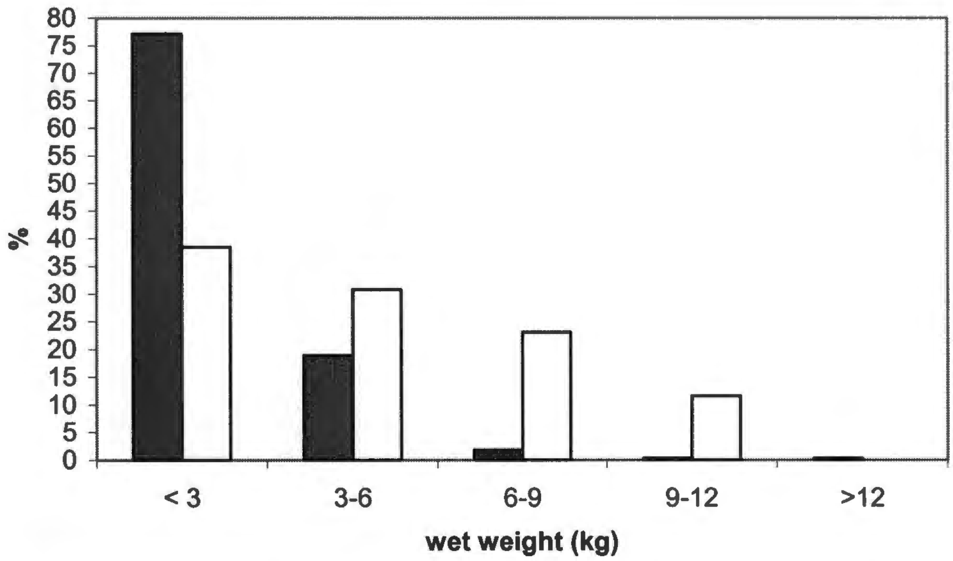


Fig. 4. The percentage frequency of plants found in each weight class in the harvested and unharvested areas of Melkkraal. Black bars represent harvested areas, n = 657; open bars represent unharvested areas, n=26.

Table 1. List of species used for thatching and structural support at Melkkraal. Included are scientific and colloquial names for the materials used. Species are arranged in the sub-categories by order of importance.

Plant type	**Family**	**Common name**	**Main construction use**
Spp used for thatching			
Willdenowia incurvata	RESTIONACEAE	Sonquas riet	walls and roof
Cannamois saundersii	RESTIONACEAE	Katstert	walls
Ischyrolepis sp	RESTIONACEAE	Fors riet	apex
Typha capensis	TYPHACEAE		walls
Spp used for structural support			
Poplar sp	SALICACEAE	Popler	walls and roof
Pinus sp	PINACEAE	Pine	walls and roof, door frame
Eucalyptus sp	MYRTACEAE	Bloekkom boom	walls and roof
Rhus undulata	ANACARDIACEAE	Taaibos	walls and roof
Dodonea sp	SAPINDACEAE	Sand olienhout	walls and roof
Olea europaea	OLEACEAE	Kierrie olienhout	walls and roof

Table. 2. Number of hectares, plants, kg per hectare and kg present for each of the harvested patches

Patch no.	Area (ha)	Density (plants/ha)	Biomass (kg/ha)	Total biomass (kg)
1	0.19	9 901	31 681	6 019
2	0.15	7 800	24 017	3 603
3	1.24	28 249	54 021	66 986
4	0.34	21 097	31 041	10 554
5	0.96	15 381	26 628	25 563
6	2.80	44 395	43 589	12 2049
7	9.91	9 488	21 041	20 8516
Total	15.58			44 3290
Mean	2.23	19 473	33 145	63 327
Std dev	3.51	13198	11 717	77 032

Table 3 Constructions at Melkkraal separated into categories based on type of construction. Number of constructions excludes any measured constructions that were built from reeds other than the *Willdenowia incurvata*. Average basal area is in m^2 and average wet weight is in kg.

Type of house	No. of houses	Ave. basal area (+-stddev)	Ave. Wet wt (+-stddev)
Chicken coop	2	1.87 (± 0.94)	115.67 (± 30.29)
Cooking shelter	20	13.84 (± 3.01)	3 187.92 (± 1 466.59)
Round storage	9	7.37 (± 2.91)	1 596.43 (± 1 435.56)
Rectangular storage	5	7.42 (± 3.93)	825.02 (± 465.16)
Round sleeping quarter	4	16.24 (± 6.50)	1 841.26 (± 1 143.51)
Rectangular sleeping quarter	24	18.18 (± 8.87)	1 611.16 (± 748.84)
Toilet	2	3.09 (±1.72)	385.05 (± 376.11)

Appendix 1

House and Cluster No.	Co-ordinates South	East	Owner	Construction Type	Date Constructed	Shape	Reeds Replaced	Basal Area	No. of Doors
1.1	313636.6	190953.5	August Africa	Living quarters	2003	rectangular	no	17.16	1
2.1	313608.9	190946.3	Tempes skeepes	Wash House	2002	rectangular	no	8.17	1
2.2	313608.7	190946.0	Tempes Skeepes	guesthouse	2004	round	no	17.65	1
2.3	313608.8	190946.7	Tempes Skeepes	Cooking shelter	2000	round	no	13.93	1
2.4	313609.0	190946.4	Tempes skeepes	Meeting House	2000	rectangular	no	23.39	1
2.5	313608.2	190946.4	Tempes skeepes	Toilet	2002	rectangular *	no	1.78	1
2.6	313608.6	190948.1	George Gouws	Living quarters	2003	Square	no	5.67	1
3.1	313610.8	190946.3	Dina Lot	Cooking shelter	2001	round	no	17.46	1
3.2	313611.4	190945.6	Dina Lot	Living quarters	2000	round	no	15.18	1
4.1	313612.4	190939.9	Jan Syster	Cooking shelter	2001	round	no	17.82	1
4.2	313612.5	190939.8	Jan Syster	Living quarters	2002	round *	no	9.46	1
4.3	313612.0	190940.8	Jan Syster	Chicken Coop	2003	Square	no	1.21	1
5.1	313609.3	190933.6	Sanna Kotze	Cooking shelter	1990	round	no	13.04	1
6.1	313612.3	190929.4	Danie Gouws	Living quarters	1995	rectangular	no	5.28	1
8.1	313611.0	190928.0	Sanna Kotze	Cooking shelter	2000	round	no	13.00	1
8.2	313611.0	190926.9	Sanna Kotze	Toilet	2001	Wiuare	no	31.36	1
9.1	313659.1	190913.4	Gert Witbooi	Cooking shelter	1998	round	yes	1.20	1
9.2	313559.2	190913.2	Gert Witbooi	Living quarters	2003	rectangular	no	14.88	1
9.21	313559.4	190913.1	Gert Witbooi	Wall	2000	Linear	no	na	na
10.1	313609.3	190920.3	Maria Kotze	Storage	1999	round*	no	3.12	1
10.2	313609.4	190920.1	Maria Kotze	Cooking shelter	1985	round*	yes	12.44	1
10.3	313609.5	190919.9	Maria Kotze	Storage	?	round	no	7.19	1
10.31	313609.4	190919.7	Maria Kotze	Chicken Coop	?	rectangular	no	2.24	1
10.4	313609.8	190920.0	Maria Kotze	Living quarters	1985	rectangular	yes	25.67	1
10.5	313610.1	190921.2	Maria Kotze	Living quarters	?	rectangular	no	10.99	1
11.1	313613.7	190923.7	Maria Syster	Cooking shelter	2003	round	no	16.19	1
11.2	313613.6	190923.5	Maria Syster	Living quarters	2002	rectangular	no	12.69	1
14.1	313630.6	190924.9	Willem Beukes	Living quarters	1997	round	yes	16.85	1
14.2	313634.3	190925.1	Willem Beukes	Storage	2003	round	no	5.67	1
14.3	313634.5	190925.0	Willem Beukes	Cooking shelter	1997	round	yes	9.37	1
15.1	313628.80	190923.90	Abraham Fortuin	Cooking shelter	1995	round	yes	12.43	1
16.1	313626.2	190920.7	Anna Lot	Living quarters	1995	rectangular	yes	9.62	1
16.2	313625.8	190921.2	Anna Lot	Cooking shelter	1995	round	yes	9.67	1
16.21	313625.8	190920.8	Anna Lot	Storage	1998	rectangular	no	4.64	1

No. of Windows	No. of Wall Layers	No. of Roof Layers	Sp used for Thatching	Sp. Used for Structural Support	Source of Thatching Material	photo no.
0	2	4	Wi	Pi, Po	3, 7	
0	2	9	Wi	Pi,Ru, O	3,7	
0	1	9	Wi	Pi, Eu g, Ru , O	1-4	
0	1	5	Wi	Eu g, Pi, Ru, O	1-4	
1	2	na	Wi	Eu g, Pi, O	1-7	
0	2	na	Wi, Cs	P, O Ru, Po	1-7	
0	2	na	Wi	Po, Pi, Kers	1-7	
0	3	4	Wi	Eu g, Ru, O, Kers	1-7	
0	2	3	Wi, Cs	Po,Pi, Ru, O	?	
0	1	3	Wi, Cs	Po,Pi,Kers, O, Ru	1-7	
0	3	2	Wi	Po, Ru, Kers	1-7	
0	1	0	Wi	Po	1-7	
0	na	6	na	Pi, Po	1-7	
0	1	3.5	Wi	Ru Po, Kers, O	1-4	
1	na	7	Wi	Pi, Po, O	1-7	
0	2	na	Wi	Pi, Po, O	1-7	
1	1	2	Wi	Pi, Ru, Po, O, Vlee	5	
0	na	3	na	Po, Pi, Ru	5	
na	2	na	Wi	Vlee	5	
0	1	2	Wi	Eu g,o	5	
1	na	4	Wi	Po, Pi, O	5	
0	1	3	Wi	Pr, Eu g, Po, O, Ru	5	
0	1	na	Wi	Pi,RuPr,Eu g	5	
1	na	3.75	na	Po,Pi	5	
0	1	2.5	Wi, Cs	Po, Eu g, Pi	5	
0	na	5	na	Po,Eu g	5	
0	1	3	Wi	Pi, Po, Ru, Eu g	5, 1-3	
0	1	3	Wi	Pi,Po, O, Ru	1-3	
0	1	3	Wi	Eu g,O	1-3	
0	1	4	Wi	O	1-3	
0	1	6	Wi	Eu g,Po, Ru	1-3	
0	1	3	Wi	Pi.Eu g,Po	6	
0	na	4	Wi	Po,O,Ru	6	
0	1	1 with perdriet on apex	Wi	Po, K	6	

17.1	313620.6	190918.4	Jakob Koopman	Storage	1998	round	yes	14.51	1

House and Cluster No.	Co-ordinates South	East	Owner	Construction Type	Date Constructed	Shape	Reeds Replaced	Basal Area	No. of Doors
17.2	313620.3	190917.9	Jakob Koopman	Cooking shelter	1998	round	no	14.40	1
17.3	313620.5	190917.2	Jakob Koopman	Living quarters	1994	rectangular	yes	38.45	1
17.4	313620.7	190916.9	Jakob Koopman	Living quarters	1994	rectangular	yes	13.44	1
18.1	313619.8	190912.8	Lena Verrooi	Wi	1997	round	yes	11.22	1
18.2	313619.9	190912.1	Lena Verrooi	Living quarters	1910	rectangular	yes	30.82	1
19.1	313624.1	190910.5	Syster	Cooking shelter	1998	round	no	11.66	1
19.2	313623.6	190909.2	Syster	Storage	2003	round	no	7.19	1
19.3	313624.0	190909.1	Syster	Living quarters	2000	rectangular	no	12.69	1
19.4	313624.3	190909.1	Syster	Storage	2000	round	no	6.11	1
20.1	313623.6	190916.5	Lena Verrooi	Storage	1987	round	no	5.99	1
20.2	313623.6	190916.9	Lena Verrooi	Storage	1987	round	no	7.80	1
21.13	313627.3	190918.6	Ragel Kotze	Living quarters	1987	rectangular	no	14.14	1
22.1	313627.3	190913.0	Johanna Fortuin	Cooking shelter	2003	round	no	15.87	1
22.12	313628.0	190913.6	Johanna Fortuin	Living quarters	2002	rectangular	no	25.64	1
23.1	313630.9	190908.9	Andries Fortuin	Cooking shelter	1995	round	yes	21.65	1
23.2	313631.1	190908.8	Andries Fortuin	Living quarters	1997	rectangular	yes	9.14	1
23.3	313631.1	190908.5	Andries Fortuin	Living quarters	1999	rectangular	yes	17.96	1
23.4	313631.0	190908.0	Andries Fortuin	Living quarters	1995	rectangular	yes	18.84	1
23.5	313630.1	190909.3	Andries Fortuin	Storage	2000	round	no	9.80	1
24.1	313641.0	190949.4	Drieka Kotze	Cooking shelter	2003	round	no	12.50	1
24.2	313640.4	190949.6	Drieka Kotze	Storage	2003	rectangular	no	5.59	1
25.1	313649.9	190858.1	Sofie Kotze	Cooking shelter	2003	round	no	15.47	1
25.2	313650.1	190858.8	Sofie Kotze	Living quarters	2003	rectangular	no	29.19	1
26.1	313651.0	190850.3	Bettie Kotze	Living quarters	2003	rectangular	no	30.53	1
26.2	313656.0	190947.4	Betty Kotze	Cookibg shelter	1990	round	yes	21.67	1
26.3	313655.8	190847.40	Bettie Kotze	Living quarters	1975**	rectangular	yes	24.19	1
26.4	313655.2	190847.6	Bettie Kotze	Toilet	2000	rectangular	no	1.36	1
26.5	313655.8	190846.6	Bettie Kotze	Living quarters	1997	rectangular	yes	13.40	1
26.6	313655.9	190846.4	Betty Kotze	Storage	1996**	round	yes	13.45	1
26.7	313656.0	190846.4	Bettie Kotze	Living quarters	1985	rectangular	yes	35.25	1
27.1	313657.3	190849.7	Bet Sass	Living quarters	1999	rectangular	no	19.55	1
27.2	313657.5	190850.1	Bet Sass	Cooking shelter	1997	round	no	17.95	1
27.3	313657.9	190850.4	Bet Sass	Toilet	2004	rectangular	no	1.87	1
28.1	313702.2	190847.4	Martinus Kotze	Cooking shelter	1997	round	no	14.18	1

0	2	4	Vl	Eu g, Vlee	6
No. of Windows	**No. of Wall Layers**	**No. of Roof Layers**	**Sp used for Thatching**	**Sp. Used for Structural Support**	**Source of Thatching Material**
0	na	6	Wi	Pi,Po	6
1		5	Wi, Perd	Pi, Po	6
0	1	5	Wi	Pi, Po, V, O	6
0	na	3	Wi	Po,O,Ru	5, 6
2	na	9	Vl, Perd	Pi, Po	?
0	1	3	Wi	Eu g, O	5, 6
0	1	2	Wi	Eu g, O, Vlee	5, 6
0	1	2.5	Wi	Eu g, O, Vlee, Po	5, 6
0	1	2	Wi	Pr, O, Eu g	5, 6
0	1	3	Wi	Pi, O, Ru, Kers, Eu g	6
0	1	3	Wi	Eu g,Pi, Po, Vlee	6
0	1	5.5	Wi, Perd	Po, Eu g	6
0	1	3	Wi	Po, Eu g, O	1-4
0	1	4	Wi, Perd	Eu g, Pi, Po	1-4
0	1	7	Wi	Po	7
0	1	3.5	Wi, Perd	Pi, Po	7
0	1	5	Wi	Pi, Po, Eu g	7
0	1	5	Wi, Perd	Pi,Po	7
0	1	5	Wi	Eu g, Pi, Po, O	7
2	na	5	Wi	Pi	6
0	1	2	Cs	O, Po	6
0	1	2	Cs	Pr, Kers, O, Po	6
0	1	4	Wi	Pi,Po	6
2	2	na	Wi, Cs	Pi, Eu g	6
0	1	7	Cs	Pi,Po	6
0	1.5	na	Wi, Vl	Eu g, Pi, Po	6
0	1	na	Wi	Eu g , Pi, Po	6
0	2	na	Wi, Cs	Eu g , Pi, Po	6
0	7	8	Wi	Po,Pi	6
0	1	3.5	Vl	Pi,Po,Eu g,o	na
0	1	4	Cs	Pi,Po,Eu g	6
0	na	7	Wi	Pi	6
0	2	na	Wi	Pi,Eu g	6
0	2	7	Wi, Cs	Pi,Po	6

28.2	313702.5	190846.8	Martinus Kotze	Living quarters	1997	rectangular	no	10.34	1
House and Cluster No.	**Co-ordinates South**	**East**	**Owner**	**Construction Type**	**Date Constructed**	**Shape**	**Reeds Replaced**	**Basal Area**	**No. of Doors**
29.1	313707.2	190848.3	Hugo Kotze	Cooking shelter	2003	round	no	11.40	1
29.2	313707.3	190848.2	Hugo Kotze	Living quarters	1996	rectangular	yes	21.88	1
30.1	313712.5	190852.4	Maria Kotze	Cooking shelter	1993	round	no	14.50	1
30.2	313712.4	190852.4	Maria Kotze	Living quarters	1999	rectangular	no	22.41	1
30.3	313712.7	190852.1	Maria Kotze	Living quarters	1999	rectangular	yes	15.95	1
30.4	313712.7	190851.8	Maria Kotze	Living quarters	1991	rectangular	yes	31.98	1
30.5	313712.8	190851.4	Maria Kotze	Storage	1993	rectangular	no	10.20	1

0	1	3	Cs	Pi,Po,Eu g	6
No. of Windows	**No. of Wall Layers**	**No. of Roof Layers**	**Sp used for Thatching**	**Sp. Used for Structural Support**	**Source of Thatching Material**
0	1	7	Cs	Pi,Po	6
0	1	4.5	Wi	Pi, Po, Eu g	6
0	2	6	Wi, Cs	Pi, Po	6
0	1	4.5	Wi	Eu g,Po,O, Pi	6
0	1	4.5	Wi	Eu g,Po, Pi	6
0	na	7	Wi, Perd	Pi, Po	6
0	1	4	Wi	Po	6