Appendix 2.1

Project Report

Title: A Survey of Marula Fruit Yields in North-Central Namibia

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Produced by: CRIAA SA-DC, PO Box 23778, Windhoek, Namibia

Date: October 2002

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A SURVEY OF MARULA FRUIT YIELDS IN NORTH-CENTRAL NAMIBIA

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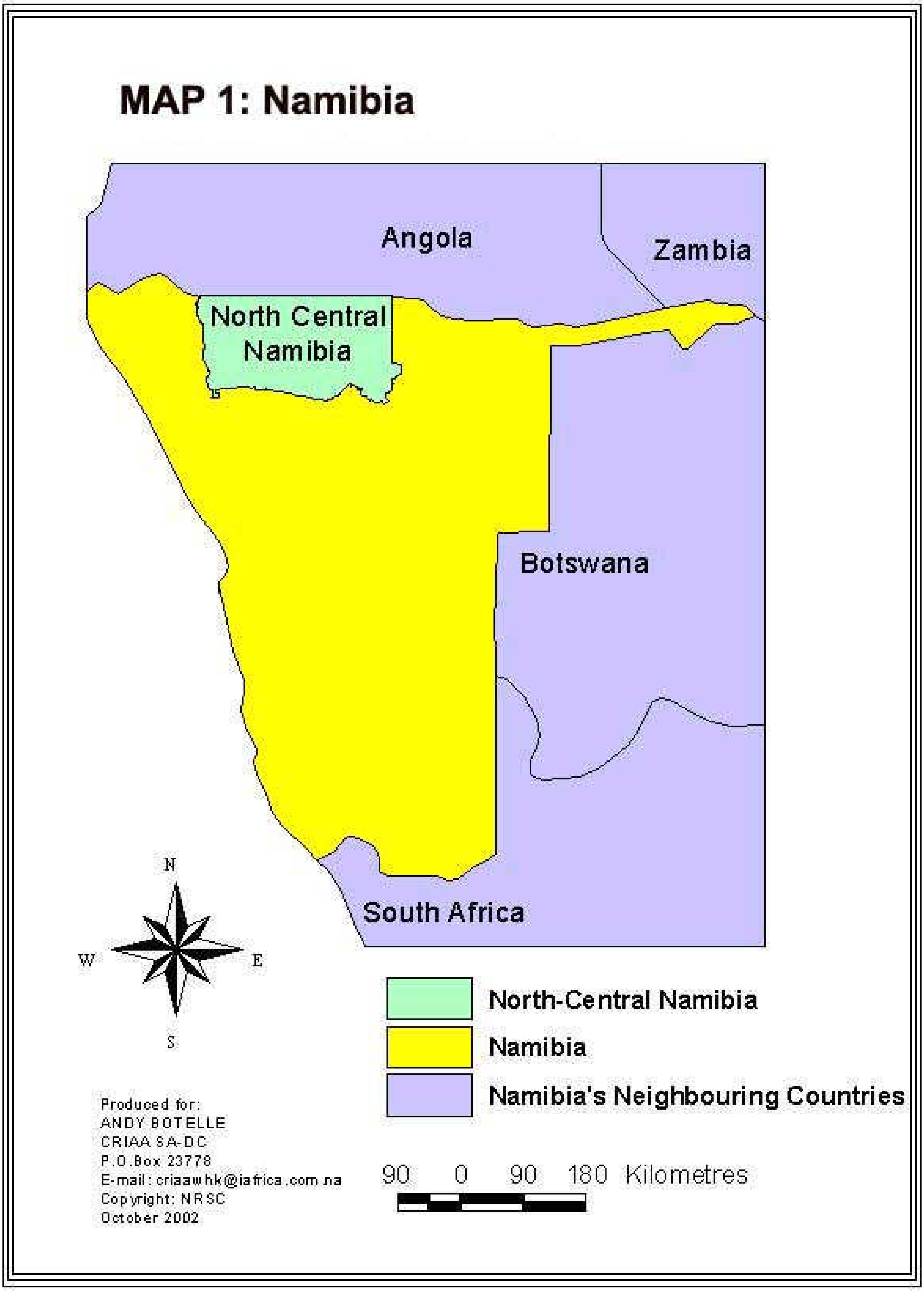
MAP 1: Namibia
Angola
Zambia
North Central
Namibia
Botswana
South Africa
N
W
E
S
North-Central Namibia
Namibia
Namibia's Neighbouring Countries
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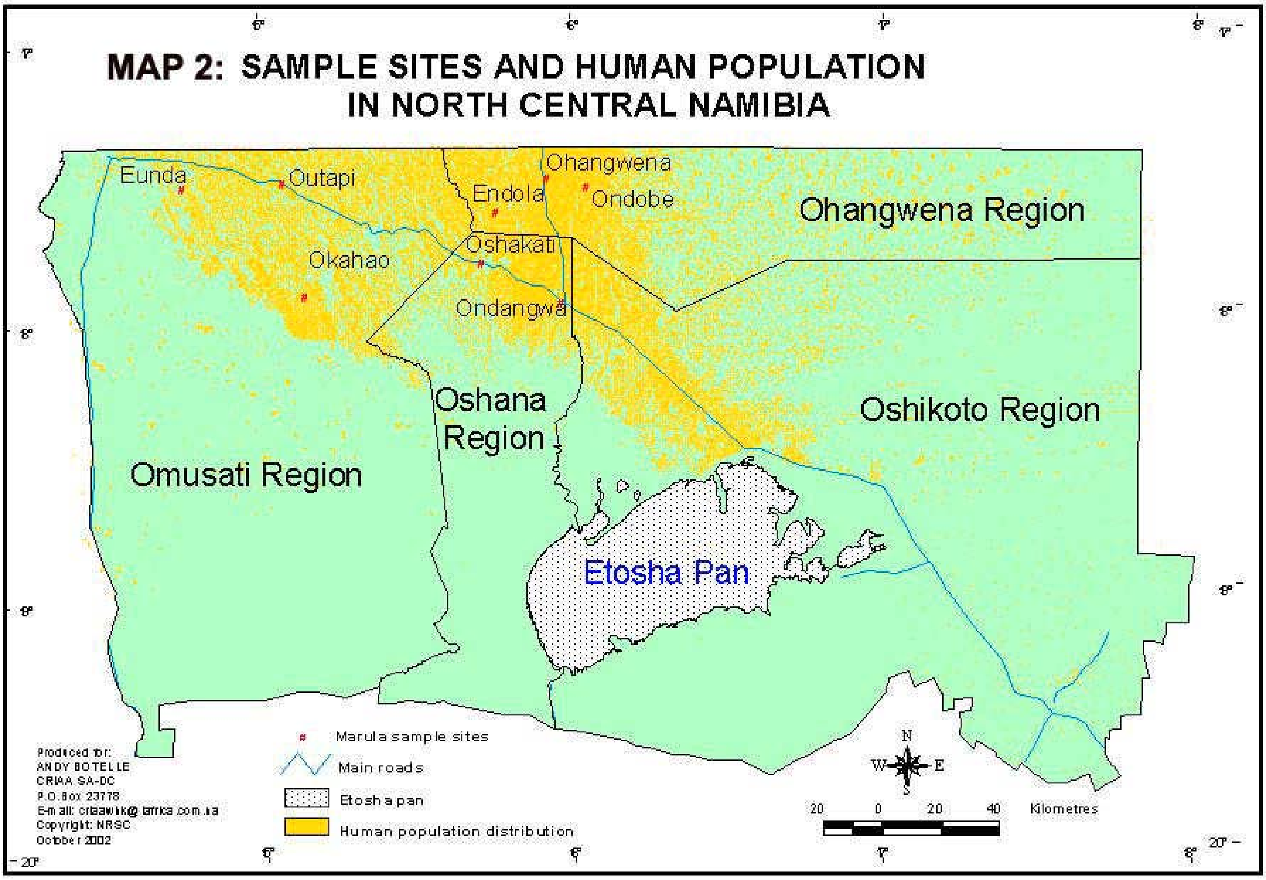
MAP 2: SAMPLE SITES AND HUMAN POPULATION
IN NORTH CENTRAL NAMIBIA
Eunda
Outapi
Ohangwena
Endola
Ondobe
Ohangwena Region
Oshakati
Okahao
Ondangwa
Oshana
Region
Oshikoto Region
Omusati Region
Etosha Pan
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Marula sample sites
Main roads
Etosha pan
Human population distribution
N
W
E
S
20
0
20
40
Kilometres
20°

INTRODUCTION

Study Criteria

The aim of this survey was to measure marula stem densities and marula fruit yields within different land use classifications in North-Central Namibia; "homesteads", "fields", "communal lands" and “protected areas".

In North-Central Namibia (Map 1) there is a long history of intensive marula use. This is also the case with the other study areas in southern Africa. But there are fundamental differences between marula using cultures in the rest of southern Africa compared with the Oshiwambo-speaking population in North-Central Namibia. And these differences, it is believed, have a profound effect on yields (e.g. another study under this project found that Namibian fruits were “significantly larger than those from South Africa, due to their greater pulp mass, especially the flesh/juice component” (Leakey *et al* in press).

Marula trees in North-Central Namibia have been domesticated for centuries. Today, women own and manage marula trees which compliment the predominantly (wo)man-made landscape. This is a consequence of ecology, farming systems and settlement patterns. This marula fruit yield study was designed with other parts of southern Africa in mind, where there is a different human agent at work. As a consequence, many of the research outputs, such as stem densities within different land use classifications, are not applicable and therefore not included in much detail in this report. Instead, an attempt has been made to quantify (for the first time) Namibian marula yields, to investigate possible regional differences in yield, and to develop simple tools that can be used to predict yields for commercialisation purposes.

Factors Affecting Marula Fruit Yields

Ecologically, North-Central Namibia is a dry, sandy plain comprising mostly moisture- and nutrient-deficient soils. It is important to recognise that this part of Namibia is one of the flattest places on earth, with a typical gradient of 1:10,000 - that’s a drop of one metre for every 10 kilometres - with a general slope north-south. This area comprises an inland delta with raised areas of land between narrow waterways and lake systems that are dry for most of the year. This delta, the Cuvelai drainage system, is fed by summer rains falling locally and to the north on the Sierra Encoco mountains in Angola, slowly flowing with fish and nutrients through the meandering channels of North-Central Namibia and into the Etosha Pan. (See Map 2). Elevated strips of land between waterways have the best soils and it is in these areas where marula trees aggregate naturally. Small changes in elevation have a profound effect on settlement patterns and marula distribution (see Verlinden and Dayot 1999 and 2000). This is why the best land has a long history of settlement and marula use.

In most marula growing areas of southern and eastern Africa there exists a nucleated system of villages, each surrounded by fields, and beyond that, forest land and, perhaps, protected areas. In North-Central Namibia the system of land use is very different.

Firstly, there are no “wild” areas left where marula occurs ‘naturally’, except in the Tsumeb mountainlands and on the escarpment above Ruacana (which were not included in this study because the marula there is not utilised to any significant extent). Secondly, traditionally, and even today, extended families are isolated from one another. Individual homesteads dot the landscape, dispersed every 500 metres or so in a patchwork of farm plots. Until the 1960s there were no nuclear villages in North-Central Namibia and even today, it is the predominantly rural landscape where marula trees, and a marula industry, are concentrated.

Each homestead comprises huts surrounded by a palisade wall of dried tree trunks. This living area is a breeding ground for marula and other fruit trees. Families gather marula seeds and bring them into the homestead to decorticate, process and consume. In this way, new marula trees (and other fruiting tree species) propagate from discarded seeds by laying claim to corners, cracks and gaps within these palisade walls. Families benefit from the shade and the fruits of these large trees and encourage their growth. There is a direct and positive relationship between the siting of homesteads and the success of new marula trees, not least of which is the fact that the soils of homesites are fertilised by the occupants.

Moreover, when a homestead is abandoned (on the death of the owner or for other reasons) small marula groves, as well as isolated trees, are left behind, to become part of the broader agro-forestry farming system within fields (see Erkilla 2000). When a new homestead is constructed marula trees propagate once again within the safety of the homestead. This process has continued over centuries as the Owambo population has migrated and spread across the landscape. Today it is estimated that there are more than a million marula trees in North-Central Namibia, more than 95% of which occur within people's fields. And eight out of every ten of these trees are female, revealing a strong preference for fruit producing trees within fields.

Surrounding each homestead, individual family's fields (*epya*) and semi-wild vegetation (*ekove*) are cultivated and protected. Most homesteads today are fenced from one another to keep grazing animals out of arable fields. Between fenced farm plots, sections of open access grazing and forest areas do occur, although, as more and more land is fenced off each year with the growth of society, there is less and less "open access" land. In addition, herds of goats and cattle quickly graze any new marula trees (and other tree species) preventing marula from propagating on communal land. Livestock also graze cultivated fields after the harvest, which is why farmers have adopted the practice of protecting marula seedlings with thorn branches (often such trees are named after the person who found them). Even in cases where the seedlings are not actively protected they are only grazed while dormant and are often able to recover when the next rainy season comes. An interesting observed practice is to construct a pig sty under a young marula tree – this provides the pig with some shade, protects the tree from browsers, and fertilises the soil.

Around towns, and areas where soils are fertile, the density of homesteads increases with a concomitant decline in the size of farm plots. In the most fertile parts of North-Central Namibia population densities are quite high (for Namibia), between 100-300 people per square kilometre. In these locations virtually all land is owned, either by the local municipality or by traditional headmen who lease the land to individual farmers and their families.

Marula trees in fields are owned by those families and are managed by women, usually the farmer's wife or the female head of household. One requirement of this study, therefore, to calculate density of stems within different land use classes ("homesteads", "fields", "communal lands", and "protected areas"), is not applicable in the Namibian context as there are virtually no fruiting marula trees in communal areas and there are no protected areas in the densely populated part of North-Central Namibia where this study took place (refer to Map 2).

As we have stated, marula has been domesticated and integrated into the Owambo system of farming for centuries. Here farming comprises arable agriculture, agro-forestry and pastoralism. Marula trees prefer the deeper, more fertile soils found on higher ground, the same land traditionally inhabited by farmers for centuries, as it is the best land for farming and above floodwater levels. Indeed, marula trees are traditionally used as an indicator of soils suitable for crop farming. There are also a few situations where marula trees have clearly been introduced into areas where they do not occur naturally, but where the soils are suitable – in such situations the only marula trees are those that grow in homesteads. Only in the far north of the study area, around Ondobe for example, and in isolated pockets across the entire region, do extensive areas of deep soil occur. In these situations a few marula trees do exist outside of farm plots but most are owned and used by families. Most of these marula trees occur in homestead-sized groves, suggesting that they originally grew on farms, before the higher-lying land was expropriated for uses such as townships and roads

The neo-religious reverence for marula - tree naming, ceremonies, marula festivals, stories, rituals and songs - among the Owambo population reveals a long association with marula. The local population has a deep knowledge of marula for a myriad of different uses. And because of its many uses a symbiotic relationship has developed between (wo)man and marula. Some women actively transplant young marula trees and protect fruiting trees (see Photo 2). This survey revealed that 49 of the 104 trees recorded had been given names by the household. The names and their meaning in English are included in the data base at the end of this report (refer to Appendix 1). Tree names usually describe the qualities of the fruit, and the name of the person who owned the plot when the tree germinated or the name of the person who found and protected the seedling, again emphasising the relationship between owners and their marula trees.

The women responsible for gathering, processing and preparing marula have both indirect and direct impacts on the selection of fruit trees (e.g. Leakey *et al* found that fruits processed in South Africa represented the best 84% of the sample population – inferior fruits were discarded, or never harvested) and also a profound impact on the siting, sex, number and, therefore, yield of marula trees in family plots.

Typically, women have 3 to 10 marula trees dispersed within their fields. Some women have no marula at all and others have hundreds of trees. Usually a household will have at least one marula tree. The impact of women (and the local farming system) on marula is most evident by the sex ratio of male to female marula trees in North-Central Namibia. Based on current estimates, and on the results of this survey, eight out of every ten marula trees are female (compared to a ratio of 1:1 in 'natural forests' in the Caprivi and in the Kavango Regions where marula trees have not been domesticated) for the simple reason that families desire fruit-bearing trees whilst unproductive male trees are removed, as they can compete with arable crops for precious soil nutrients and moisture.

One plot had 117 trees (with 81 female, 13 male, and 23 trees too young to identify the sex). In addition there were 68 other fruit trees of various types in this owner's fields. For a single farm to have so many marula trees and other fruiting trees was unique in the drier, poorer soils around Okahao, in the far south of the study area and at the extreme edge of marula's distribution area in Namibia. In this particular case the farm was originally one plot, which two brothers divided between themselves when they inherited it from their father (a local headman). As they explained, "It was tatekulu (the old man) who started this 'marula project'. No one else in this area has this many marula trees". With a circumference of 1780 metres the plot was estimated to be 20 hectares, which calculates to an average of nearly 6 marula trees per hectare, of which 4 were female fruiting trees per hectare. In most plots though, this density will be much lower. And marula trees are concentrated on the best soils and absent in shallower soils.

In Ondobe, in the northern part of the study area, the highest density of human and marula populations can be found. Here, one woman had 112 mature trees within a 1660 metres circumference plot, estimated to be about 18 hectares, of which 91 were female and 21 male, with another 43 too young to identify as male or female. She also had 32 other female fruit trees of various species of which 15 were male. Here the density of marula stems in fields averages nearly 9 per hectare of which 5 are fruiting trees.

Secondary Objectives

The study has also been useful for estimating, for the first time in Namibia, the potential supply of marula by developing models using tree diameter (calculated from trunk circumference) and canopy size to predict future yield, based on the yield figures for 2002. Another indirect benefit of this survey has been the identification of cultivars as orchard trees for propagation trials. In addition, the study aimed to test and develop simple indicators (trunk circumference, canopy size, age, health, and alike for local women to be able to monitor fruit yields of their trees in future years. And with a suitable methodology for estimating fruit yields, this study aimed to develop improved prediction models based on the strongest and most reliable correlations identified in this study.

METHODOLOGY

Sampling

The marula trees chosen for this study were not randomly selected. The results of this study, therefore, are not statistically valid, but they do offer a better understanding of the relationship between tree size and fruit yields as well as the positive impact of farming and domestication of fruit trees on yield.

The choice of trees to measure was a subjective process for two reasons. Firstly, because of the protracted nature of the marula fruiting season, marula trees in North-Central Namibia abscise their fruit between December and May. Only after the first marula trees had dropped their fruit did this study begin. At this time (March), the marula fruiting season was in full swing and some of the early fruiting trees had even finished fruiting. Trees already fruiting could not be included in this survey for the obvious reason that yields would not include all fruit produced within a single season. Similarly, "winter trees" - trees which fruit late in the season (April/May/June) - were excluded from this study as data collection was scheduled to finish in April. The extremes therefore - at the beginning and end - of the season were not included in this research study and only trees that started fruiting in the peak season were included.

The second subjective selection of trees relates to the importance of designing a methodology for weighing fruit yields which mirrors the rhythm of the women's work. To ensure that data collection did not conflict too heavily with people's daily routines and to minimise the demands of this research on people's time, farmers and their wives chose their favourite trees. These were inevitably the trees with the best fruit (sweetest, largest, easiest to decorticate, most productive). These trees also tended to be located inside or close to people's homesteads. This subjective selection of trees, therefore, is not statistically sound because it will most likely cause an overestimate of average yield, a bias in favour of the best fruit and the highest yielding trees.

Data Collection: Weighing and Recording Marula Fruit Yields

Initially, women were asked to separate the usable fruit and unusable fruit and weigh them individually. In practice, most women did not differentiate between usable and unusable fruit on their recording sheets. Although some women did methodically separate and weigh the two types of fruit, to overcome any confusion, in the final analysis both categories of fruit were combined to give the total seasonal fruit yield. It is this total which is correlated with the different aspects of tree size in the final analysis.

Researchers worked with the women owners of trees. In most instances the matriarch devolved the actual weighing of fruits to younger women in the homestead, the primary marula harvesters and processors in actual practice. Because many older women are semiliterate and are "afraid of this technology" (the weighing scales) younger women and girls of school age were responsible for recording fruit yields on specially designed, simple data sheets. Periodically researchers went back to check if the weighing and recording was going well.

The original intention was to survey 120 individual marula trees spread across the four regions making up North-Central Namibia. In the final instance data was collected from 104 trees, from 20 farm plots in 8 sample sites spread across 3 regions (See Map 2). A total of 16 trees were omitted from the survey because recording forms were not returned. The largest omission was from the Eunda site where Ministry of Agriculture, Water and Rural Development extension officers responsible for conducting the tree survey were unable to carry out the work due to a lack of transport.

Measurements describing different aspects of the tree (fruit yield, trunk size, canopy area, age, height, and alike were collected from most of these trees sampled.

DATA ANALYSIS

A significant proportion of the 104 trees surveyed were removed from the final data analysis because the weighing-recording of fruit yields was not completed correctly. Numerous unforeseen circumstances occurred preventing women from completing the weighing process. Typical examples of why sample trees were not completed correctly and therefore excluded from the final analysis include:

* snakes moved into trees preventing weighing
* trees were chopped down after recording began (because they were unsafe)
* some trees were measured for a few days or weeks only, not the full fruiting season because those girls responsible had to go back to school
* yields were recorded incorrectly e.g. a unfeasibly high total yield of 5,000 kilograms was recorded in one instance, inferring this, and other extreme results, were suspect
* recording sheets were lost, incomplete or damaged
* goats ate the fruit meant for weighing
* trees were struck by lightning damaging the tree and the fruit

* the quality of fruit was so poor that women stopped harvesting (and therefore weighing) the tree
* some trees were too old and did not produce fruit this season

Data cleanup also forced the removal of other trees from the final analysis. Apart from incomplete yield figures for a number of trees, often one aspect of a tree was left out of the original tree survey (tree height, trunk size, canopy size, age and alike. In these instances as well, the relationship between that particular tree characteristic and its yield could not be analysed simply because the data was missing. Finally, 'outlier values', extreme values, in the data sets were scrutinised and in some instances removed (particularly if, after going back to the original recording sheets, they were considered errors) otherwise results would be skewed towards these extreme values. It must be noted that marula trees do naturally experience considerable variability in their size and appearance, as well as total fruit yields over a season. This natural variability was respected. Trees with extremely high or low yields, or extremely large or small physical characteristics (trunk, canopy, height, age, and alike were included in the final analysis because it is precisely this variability which we are trying to understand to predict fruit yields.

Factors Affecting Fruit Yield and Indicators Measured

Soil types and land forms combined with rainfall play a key role in marula fruit yields. Within the scope of this study it was not possible to conduct a temporal/spatial study of rainfall and its effect on fruit yields. Similarly, it was not possible to classify soil types and associated land forms to understand how soil fertility and drainage affects fruit yield. Soils do vary enormously within people's fields and farm plots as well as between regions. Soils often vary over space of a few metres. And individual trees tap different soil types by extending over a wide area. The researchers conducting this marula study were not trained in soil analysis in the field. This study recommends a deeper analysis to test the relationship between rainfall and various soil/land classifications which, it is believed, are primary factors effecting fruit yield. Working with local farmers and their wives to classify soil/land types would be a good starting point. It would be extremely useful to include an assessment of soil depth above the water table, and to correlate this to time of fruiting and fruit yield.

Another variable which farmers mentioned affected fruit yield is the occurrence and severity of a natural plant parasite of the mistletoe family, *Erianthemum dregei* (Loranthaceae). From the survey it appears that marula trees most affected by parasites occur in and around towns and in the southern part of the study areas (the Okahao and Ondangwa sites on the extreme natural range of marula in Namibia. See Map 2). Perhaps their prevalence is due to environmental stress, such as drought and poorer soils, making them weaker and more susceptible to disease, such as parasites. Birds, the host and transport agent for the parasite, congregate in towns in southern regions because there is more food and more fruit trees in these locations compared to the surrounding, open, bare land. Birds in the forested regions in the far north of the study area, on the other hand, have a richer choice of trees to feed from and roost in, making the incidence of parasites in people's fields much lower. Photos 4, 5 and 6, show young and old trees affected by this plant parasite.

In fruiting trees the size of the canopy (width x height in this survey) and the diameter of the trunk (at 50 cm above ground level in this survey) are traditionally good indicators of the productive capacity of a given tree. These relationships were measured in the field and statistically tested using a simple correlation between canopy size and total fruit yield of trees as well as trunk size and fruit yield.

The significance of this correlation (between canopy size, as well as trunk size, and fruit yield) was tested using simple regression analysis. It should be noted that the physiognomy of marula trees varies enormously from tree to tree. Typically, marula trees have between one and three stems (main trunks). In the final analysis these trunks were combined in order to give a total trunk size. In the same way canopy size and its condition varies considerably from tree to tree, most notably with age and health (old and sick trees have a relatively thin canopy which "look like an old man's hair" according to one farmer). Trees affected by parasites also have a thinner canopy cover.

Women were asked the age of each tree in order to test the relationship between age and yield. This seemed an appropriate idea because locally this concept would be easily understood. If age did correlate closely with fruit yield it might be a simple and cheap means of monitoring and predicting fruit yields in the future. Unfortunately, respondents in too many instances were unsure of the age of trees, particularly the largest trees, many of which were thought to be more than 100 years old because they were known to be older than any living person in the area. The age of these oldest trees were estimated based on known events and people of the past and are probably within 10-20 years of their true age. Even so, according to this survey, age was not a reliable indicator of fruit yield.

As we have mentioned, a number of factors affected the reliability of fruit yield values used in this study. Below are some more factors which caused specific fruit yield results to be excluded from analysis:

* The quantity of usable and unusable fruit is unknown. Bad and damaged fruits were almost certainly included in the final analysis whilst in other instances bad fruit was ignored by harvesters.
* Unmeasured fruit almost certainly fell onto piles of fruit already measured meaning the actual number of fruits was higher than recorded
* Fruit fly adds dramatically to the quantity of fruit which perished. Towards the end of the season these unusable fruit are often ignored by harvesters and excluded from the survey yields figures.

Within this survey, although it was attempted, there is no reliable record of the proportion of useable and unusable fruit within the total fruit values. Women did mention that towards the end of some fruiting seasons there can often be a glut of fruit; women cannot process all that is available. Perished fruit is ignored and left to rot. It is believed, therefore, that the quantity of unusable fruit is quite high in some instances and yields should not be seen as the exact amount of fruit produced by trees.

The size and quality of fruits varies considerably from tree to tree. Some trees produce exceptionally large fruit (averaging 60 grams plus) whilst others produce tiny fruits (less than 10 grams). Exceptional fruit trees are well known locally. And some male trees produce a small number of fruit each year (see Photo 10) while some female trees produce fruit intermittently and not every year. One tree included in this survey suddenly started fruiting for the first time when it was more than 40 years old. The owner explained that she thought it was a male until it unexpectedly started fruiting and, in 2002, produced more than 1,000 kilograms of fruit. This broad temporal variability - the occasional fruiter, the infertile and the exceptionally fertile - was not captured within this study.

As we have mentioned, rainfall is a primary determinant of yield. And Namibia is prone to extreme variations in rainfall; year to year and place to place. A typical example of this is a comparison of rainfall patterns this year (2002) compared with last year and its suspected effect on the two fruiting seasons. Rainfall was good initially this year (2002) but quickly died off. As a result, most marula trees fruited early and most had finished by the beginning of May, 2002. Last year (2001), on the other hand, the rains came late and fell heavily at the end of the season, continuing even after May. Similarly, the fruiting season was late. How rainfall effects yield cannot be tested in a single year in a survey such as this. The results of this year, therefore, are not indicative of other seasons. In a few cases the trees and their fruit characteristics were known to the researchers from work done in the 2001 season and – especially in the case of late fruiters – these trees were observed to have smaller and less juicy fruits than in 2001. The overall effects of the early cessation of the 2002 rains on yields can not be quantified accurately, except to state that late trees had fewer and drier fruits in 2002 than in 2001.

RESULTS

Analysis of the Sample Population: Averages

Below is a description of the 'average tree' based on the results of this survey (See Appendix 2). Sample sizes are given:

Table 1: Averages: Marula Fruit Yield and Tree Characteristics

Tree characteristic measured	Sample size	Tree average
Total fruit yield (2002)	56	596 kilograms (std. dev. 465kg)
Average fruit mass	49	30 grams
Canopy size (w x h)	56	45 square metres
Trunk diameter	90	67 centimetres
Tree height	100	10,2 metres
Tree age	65	53 years

The total fruit yield of individual trees for the 2002 season varied from a few kilograms (from a tree which was fruiting for the first time), to a high of 2,860 kilograms, (from one very impressive, 17 and a half metre high, 80 year old tree called "Nangubu", meaning, "in the thorn brush fence"). Of the 11 fruiting trees in this woman's fields, this exceptionally large tree was the owner's favourite because of its large shade area, its prodigious yield and the exceptional size of its juicy, sweet fruit. Among the discarded data were records of trees bearing up to 5 000 kg of fruit, which – although discarded – is not impossible, as there are records from Botswana of some trees bearing up to 6 tons of fruit in a single season. Other extremes include very old trees (more than 100 years old), and very young trees (producing fruit for the first or second time). The results of the survey indicate that very young and old trees often net less than 100 kilograms in a season. Of the 56 trees measured for yield the average was 596 kilograms, and includes both useable and unusable fruit. The high standard deviation – 465 kilograms - reveals wide variability in fruit yields between trees. The median yield is 482 kilograms and the mode was 100 kilograms.

Calculating the average mass of individual fruits was done by the women by weighing 150 fruits and dividing the net weight by 150. Of the 49 trees measured the average fruit size was 30 grams. Although the scales used were not sufficiently accurate to make these results reliable, what the results do show is the wide variability in fruit mass between individual trees. The trees in Photos 7 and 8 produced fruit of around 50g in mass. Unfortunately, these particular fruit perished before they were weighed properly. Leakey *et al* (in press) recorded a mean fruit mass of 26.68g for Namibian marula, excluding the highly exceptional "Namibian Wonder", which had a mean fruit mass of 69.9 g. Photo 10 shows small and unusable fruit produced by (some) male trees.

Trees as young as 5 years old are producing fruit, although this is an exceptional example. (The next youngest tree bearing fruit in this survey was 10 years old – grafted trees have, however, been reported to fruit after three years). Six trees were estimated by their owners to be more than 100 years old, and recorded as such. As mentioned earlier, most of these very old and very young trees produced only a few fruit but were included in the analysis because of this natural skew. The average age for trees in this survey was 53 years. There was a weak statistical relationship between the ages of trees and their yield (with a correlation coefficient of 0.22 for the sample population of 46 trees).

The height of fruiting trees was calculated using an abney level and a simple formula based on distance and angle to the bottom and top of each tree, respectively. Trees varied from 3.99 to 21.43 metres high with an average of 10.2 metres for the 100 trees measured.

Analysis of the Sample Population: Correlation Coefficients

Throughout the analysis a simple correlation formula (R) was used to test the relationship between any two given parameters: in this instance, tree height and fruit yield. This same formula was used throughout this analysis to test the relationship between other variables, such as tree age and fruit yield, tree girth and fruit yield, tree canopy size and fruit yield, etc, to give a correlation coefficient between 0 and 1.

As a rule of thumb a simple correlation (R) of 0.5 [1] reveals a statistical relationship but not a very strong one; it explains half the relationship between the two variables; 1.0 shows a perfect correlation and 0 indicates no relationship at all. For example, the simple correlation coefficient (R value) for tree height and fruit yield was 0.56 (n=100) and shows a relationship between the two variables; tree height being a determinant affecting tree yield.

The relative importance of the R value depends on the sample size. The larger the sample size, the lower the value of R that can be accepted as indicating a significant relationship. R is the index of the variability accounted for around the mean relationship between two measures (e.g. fruit yield and stem circumference). The real interpretation of the R value depends upon its associated P value. P value indicates the statistical significance, i.e. the statistical probability of obtaining the relationship measured by R by mere chance. The greater the sample size the lower the theoretical probability of this happening, and hence a lower R value.

International convention in biological science is that P must be 0.05 or less to be acceptable , indicating that only 5% of the time will we have said there was a significant relationship when it was actually not so. (In medical sciences it is 0.01 or less).

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[1] A simple correlation R-value of 0.7 can also be expressed, and corresponds to, a multiple R^2 value of 0.5.

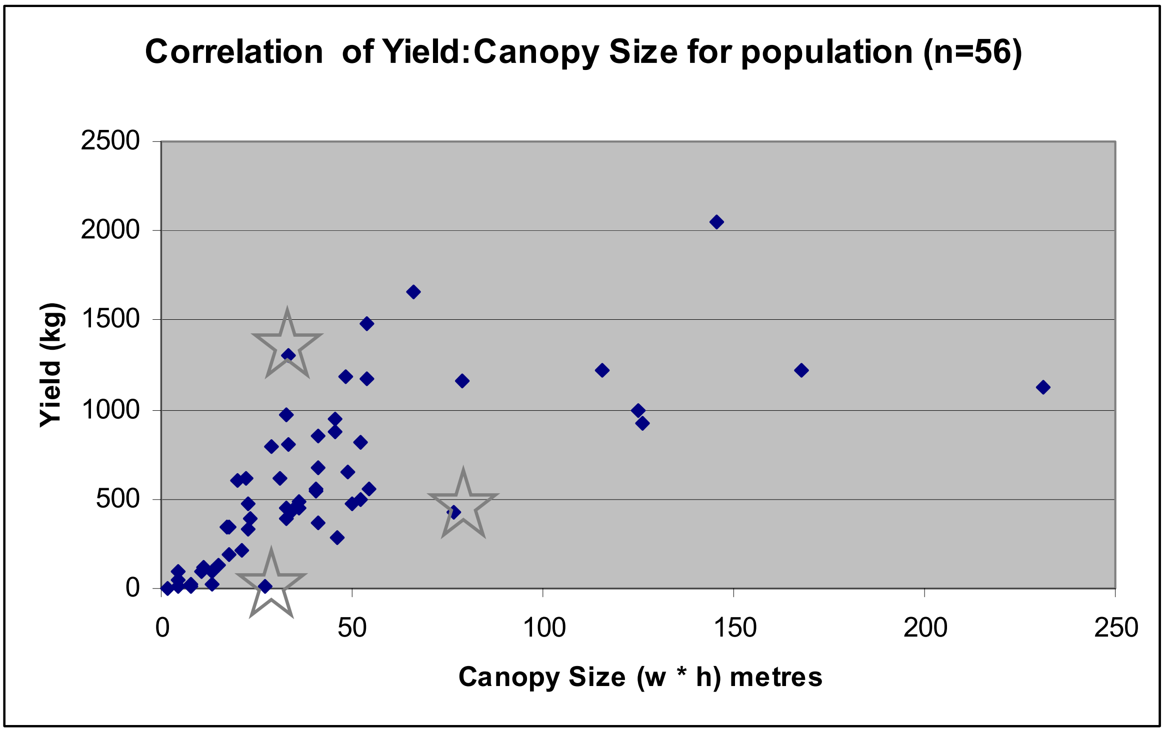
It should be noted that no detailed analysis of standard error or the residual were done in this study although figures are included in the statistical tables included in Appendices 5 and 6 for reference.

When studying natural phenomena, a simple correlation (R value) of 0.6 to 0.7 reveals a satisfactory correlation (although this is dependent on the sample size and associated P value). As we have explained, one of the goals of this study is to try and develop prediction models based on the most reliable variables measured. With a satisfactory correlation we can perform simple regression to make predictions. Only variables known to have the strongest relationship with each other can be employed to generate prediction models. For example, estimating fruit yield from the age of a tree will not produce a reliable prediction model. Later we will see that tree girth and canopy size have the strongest and most reliable relationship with fruit yield and it is these parameters that are used to develop a prediction model (refer to Appendices 5 and 6).

Logically, canopy size (width x height x depth of an ellipse to nearest half metre) is a good indicator of fruit yields, where a thick, healthy, expansive leaf crown produces more fruit than a small, sparse, unhealthy canopy. In forestry inventories, trunk diameter is traditionally a relatively simple parameter to measure. This study measured only width x height to give a two-dimensional, cross-sectional area for canopy size. This is why canopy size in this report is measured in square metres, not cubic metres. Based on the entire sample population, canopy size and trunk diameter were analysed to see if they had a convincing statistical relationship with fruit yields.

Canopy size (height x width) varied considerably, from 3 to 231 metres^2. Even within this large spread, the results of this survey highlight a good correlation between canopy size and fruit yield (See Figure 1 below). Out of the 56 trees measured there was a correlation coefficient of 0.67 with an acceptable P value of < 0.05. This indicates a significant relationship between the size of a marula tree's canopy and its fruit yield, even with extreme values included. The scatter graph below shows this relationship; a generally linear relationship with extreme values as outliers located on the edges of the graph. Examples of outliers are highlighted with grey star icons on the graph. (The data set for this graph is included in Appendix 3).

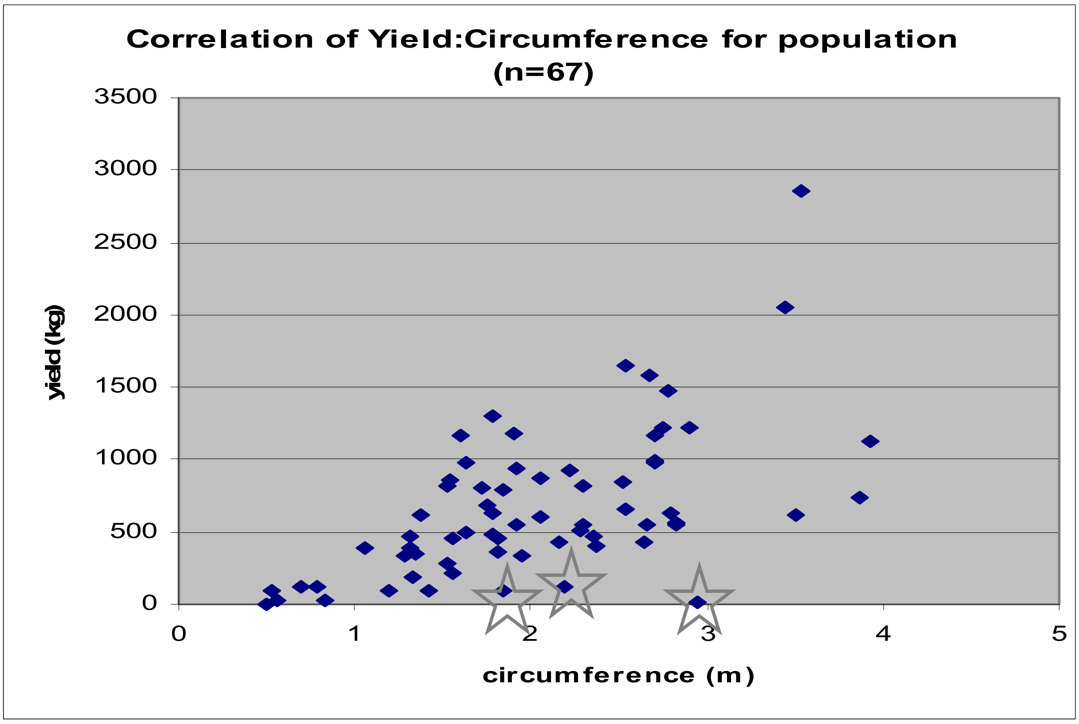
Figure 1: Correlation of Yield and Canopy Size for all Regions



Simple Correlation Coefficient = **0.67** P value = < **0.05**

The girth of trees was measured and analysed to see if there was direct relationship between the size of a tree trunk and fruit yield. The correlation coefficient for the sample population of 67 trees measured was 0.59 which (P = < 0.05) indicates a significant relationship. It should be noted that even with extreme values included in these calculations, of which there were 11 (16% of all trees measured), there was still a strong relationship recorded between the size of a tree's trunk and its fruit yield. For example, some trees with large trunks had low fruit yields mainly because they were very old and virtually infertile. And some small trees, mostly those fruiting for the first or second time, also produced very low quantities of fruit. Even with this variability included within calculations there does appear to be a strong relationship between the size of a tree's trunk and its fruit yield. The scatter graph below shows this relationship; a generally linear distribution with extreme high and low values appearing as outliers, depicted on the graph as grey star icons (the data set for this graph is included in Appendix 4).

Figure 2: Correlation of Yield and Trunk Circumference for All Regions



Simple Correlation Coefficient = **0.59** P value = < **0.05**

Analysis of each Region

To provide a more detailed picture of the sample population, an analysis of the relationship between canopy size and fruit yields, and trunk size and fruit yields, was conducted for each of the three administrative regions within the study area (see Map 2).

An Analysis of the Relationship between Fruit Yield and Canopy Size by Region

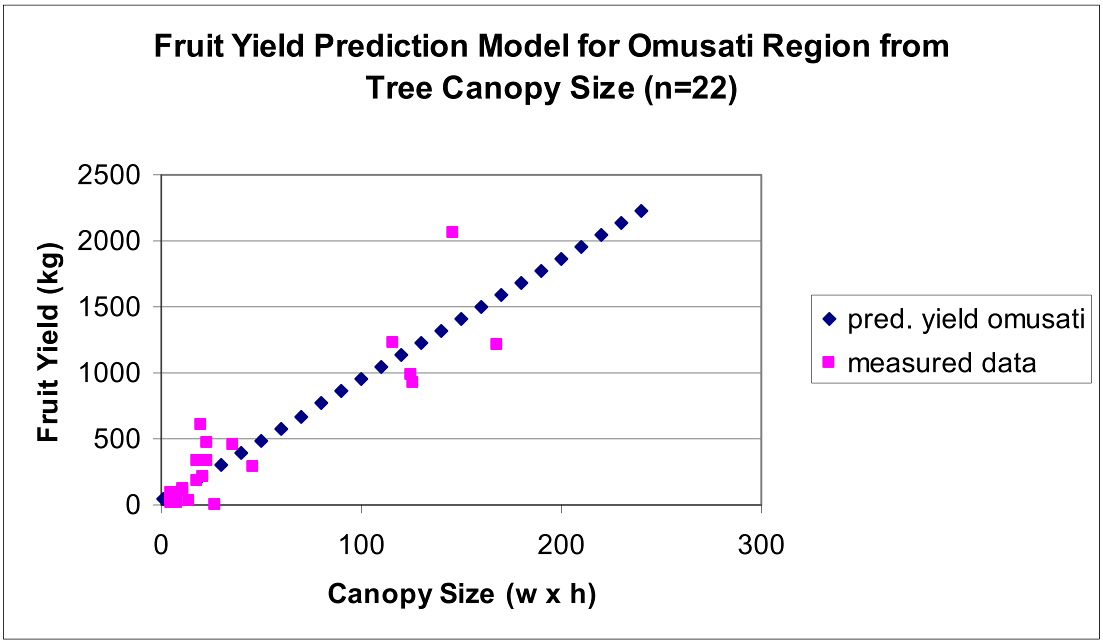
The figures below indicate that the Omusati Region has a very strong correlation between canopy size and fruit yield; 0.9 is a very strong relationship for natural a phenomenon such as this. Ohangwena has a weaker (but still significant) relationship of 0.4 and Oshana has a good relationship of 0.59. Within the population average of 0.67 then, there is considerable variability between each of the regions.

Table 2: Correlation Coefficients for Fruit Yield and Canopy Size by Region

Region	Sample Size	Correlation Coefficient
Omusati	22	0.90
Ohangwena	12	0.40
Oshana	22	0.59

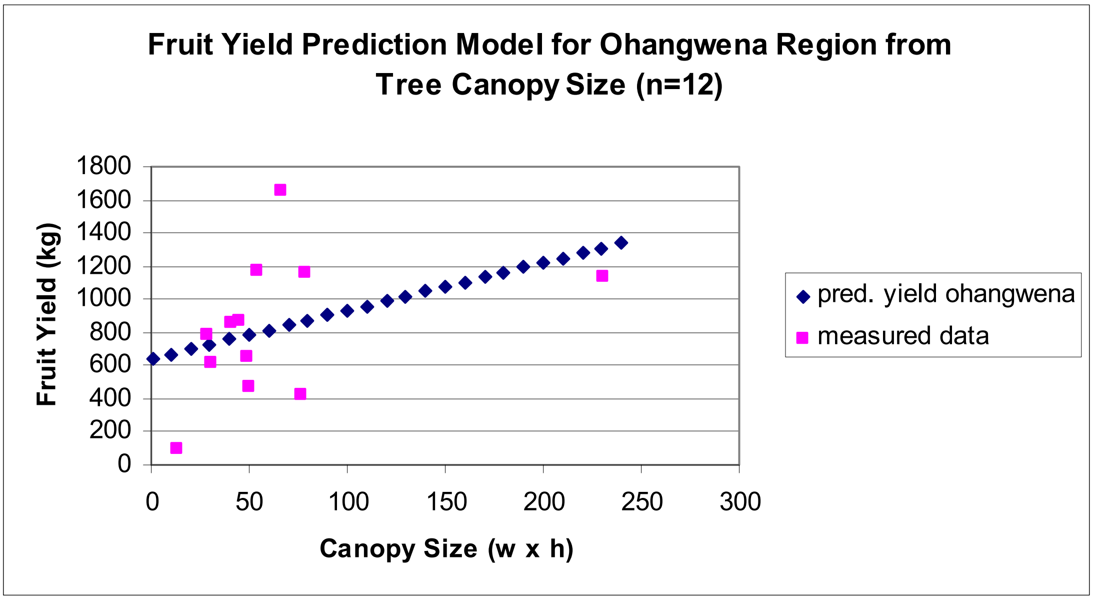
The graph below and data set (included in Appendix 3) show that the Omusati Region is dominated by a few large trees and many small trees. Within this variability though is a strong, linear correlation. Based on the Omusati sample of 22 trees the Region has a few large, old trees producing a lot of fruit, (the largest with a canopy of 145 metres and a fruit yield of 2055 kg), but the region is characterised by relatively small trees producing average yields. Typically, trees have a canopy of 5-35 metres, producing between 25-400 kilograms of fruit. The exceptionally high correlation of 0.9 shows that there is little variability in yield when trees are the same size. One exception was a tree with a canopy size of 27 metres^2 producing just 7 kilograms of fruit during the entire season. This tree is typical of the natural variability within the marula population throughout the study area in the sense that it is a very old tree and, although large to look at, has a sparse canopy and numerous broken branches, some of which are hollow. Its old age makes marula yield difficult to predict; according to farmers, older trees fruit well in some years and poorly in others, such as this year, 2002.

Figure 3: Fruit Yield Prediction Model based on Canopy Size for Omusati Region



Simple Correlation Coefficient = **0.90**

Figure 4: Fruit Yield Prediction Model based on Trunk Size for Ohangwena Region

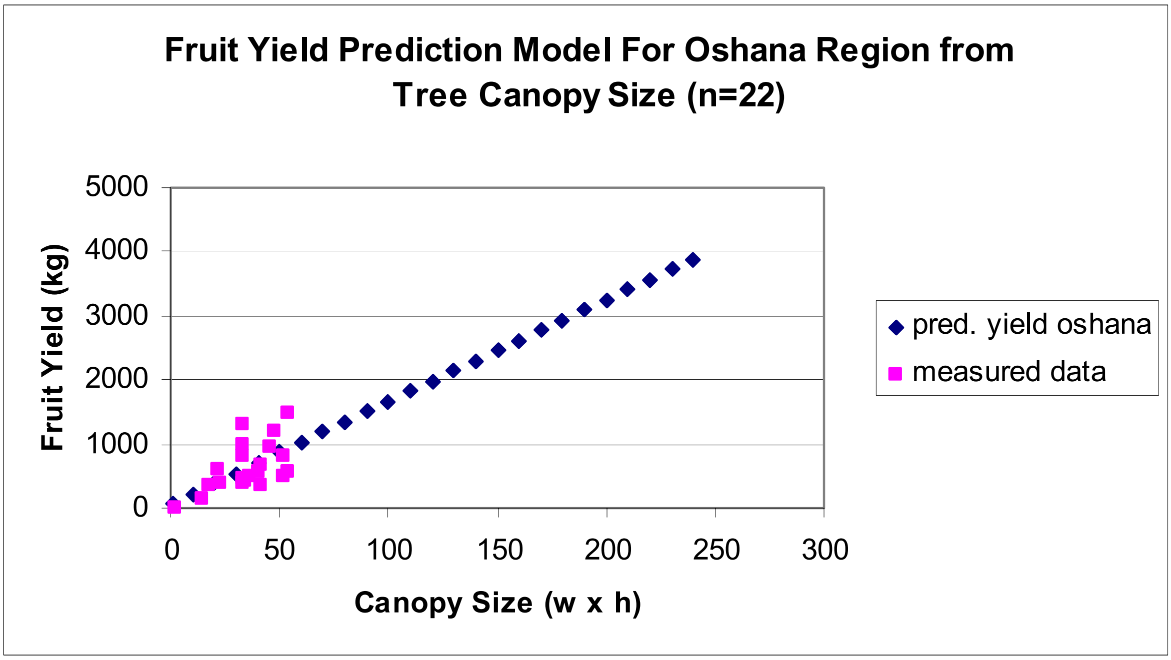


Simple Correlation Coefficient = **0.40**

The distribution of points on the graph for Ohangwena above shows the (almost) random relationship between yield and canopy size in this Region. (The data set for Ohangwena is included in Appendix 3). The high variability in fruit yields between trees of the same size is revealed by the low correlation coefficient of 0.40. This region sampled mostly medium and large trees with a high variability in fruit yield within these classes. For example one large tree with a canopy size of 66 metres² produced 1650 kg fruit whilst a slightly larger tree with a 77 metre canopy produced just 424 kilograms, that's about 25% the yield of a tree the same size. One medium-sized tree with a 54 metre canopy produced 1170 kilograms. And the tree with the largest canopy of the entire sample population, 231 metres in size, produced fewer fruit, just 1130 kilograms in all. This variability is compounded by the relatively small sample size in Ohangwena (n=12), where extreme values have a strong influence on the overall trend.

The Oshana Region had a good correlation of 0.59 calculated from 22 trees sampled. All of the trees measured were small or medium with a canopy size less than 55 metres. Large variations in fruit yields did occur though. For example, five trees had a canopy size of 33 metres but their fruit yields varied from 395 to 1310 kilograms (the data set for this graph is included in Appendix 3).

Figure 5: Fruit Yield Prediction Model based on Trunk Size for Oshana Region



Simple Correlation Coefficient = **0.59**

Comparing the three regions, Oshana has the most productive trees for their size, followed by Omusati and then Ohangwena. More importantly, small trees in Ohangwena produce quite reasonable yields. But the rate of yield increase is low where even a big increase in canopy size relates to a small increase in yield. This is shown by the relatively flat prediction line in Ohangwena compared with Omusati and Oshana. These two regions experience small trees with small yields but, as the tree size increases, so yields improve dramatically. This is particularly the case in the Oshana Region where a small increase in tree size corresponds to a significant improvement in fruit yield. Based on subjective field observations, the inverse seems more likely. Personal observations and discussions with local marula producers indicate that the biggest marula trees and the highest fruit yields are experienced in Ohangwena. This is related to the soils and rainfall which tend to be better in Ohangwena. It would be expected, therefore, that tree size and fruit yields would also be better in Ohangwena, which is not the case according to these data sets.

An Analysis of the Relationship between Fruit Yield and Trunk Size by Region

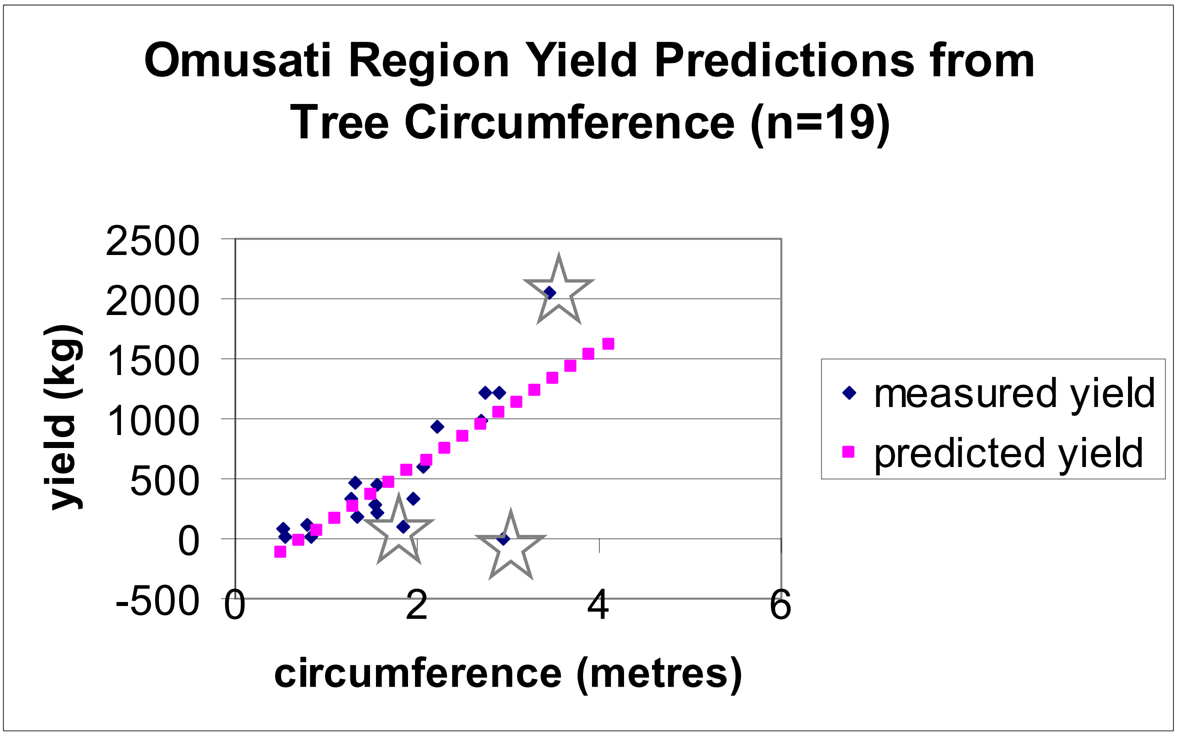
Based on the correlation coefficient of 0.59 for the entire population (where n=67) there appears to be a good relationship between the size of a tree's trunk and its fruit yield. Further analysis by region allowed comparison of this relationship in more detail (data sets are included in Appendix 4)

Table 3: Correlation Coefficients for Fruit Yield and Trunk Size by Region

Region	Sample Size	Correlation Coefficient
Omusati	19	0.76
Ohangwena	16	0.24
Oshana	32	0.56

If we compare each of the three regions on the graphs below it is clear that there is a well defined relationship between trunk size and fruit yields of trees in the Omusati and Oshana Regions. The Ohangwena Region, once again, has a weak relationship of 0.24

Figure 6: Fruit Yield Prediction Model From Trunk Circumference in Omusati Region



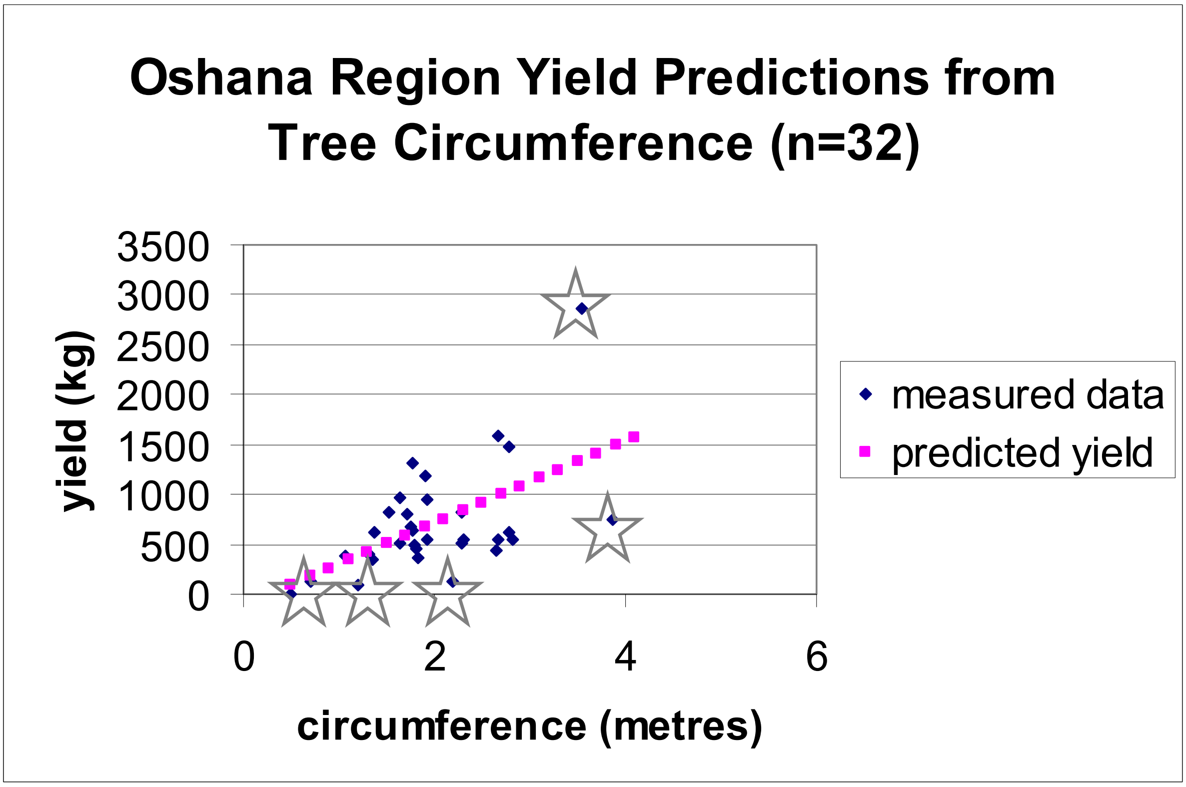
Simple Correlation Coefficient = **0.76**

The Omusati Region experiences a generally linear relationship with two extreme values: 2.95 metre trunk producing 7kg and 3.45 metre trunk producing 2055.5kg (grey star icons on the graph). (The data set for this graph is included in Appendix 4).

With a low correlation coefficient of 0.24 there is little point in plotting a graph or developing a prediction model for the Ohangwena Region. The error is just too high. For example, one tree with a trunk circumference of 2.45 metres produced a yield of 400 kilograms whilst a tree of similar size - a circumference of 2.54 metres - produced 1,650 kilograms, more than four times as many fruit. To compound the variability experienced in Ohangwena is its small sample size, just 16 trees, which further increases any differences between trees. This compares with a much lower variability in Omusati (where n=19) and Oshana (where n=32) with correlation coefficients of 0.76 and 0.56, respectively. (The data set for this graph is included in Appendix 4).

The Oshana Region does have some extreme variability within the general trend. The two largest trees (grey star icons on the graph) are virtually the same size (3.54 m and 3.86 m) but produced very different yields (2,862kg and 739kg, respectively). As well, the graph also shows quite high variations in fruit yield from small and medium sized trees. (The data set for this graph is included in Appendix 4).

Figure 7: Fruit Yield Prediction Model Based on Trunk Circumference in Oshana Region



Simple Correlation Coefficient = **0.56**

Comparing the two regions, Omusati and Oshana, they experience a similar (almost identical) relationship between fruit yield and trunk size. A small increase in trunk size produces similar improvements in yield.

Prediction Models

Description and Explanation of Results

The data sets on canopy size and trunk size were considered reliable enough to develop yield prediction models from the survey data. Each of the graphs describing regional data sets above includes a line showing the predicted fruit yields for each region. The only exception is the exclusion of a prediction model based on trunk circumference data in the Ohangwena Region. Here the data was considered to be so random and the correlation so poor, 0.24, that any prediction would have been little more than guesswork. (For reference purposes this data set and a scatter graph for Ohangwena is included in Appendix 4).

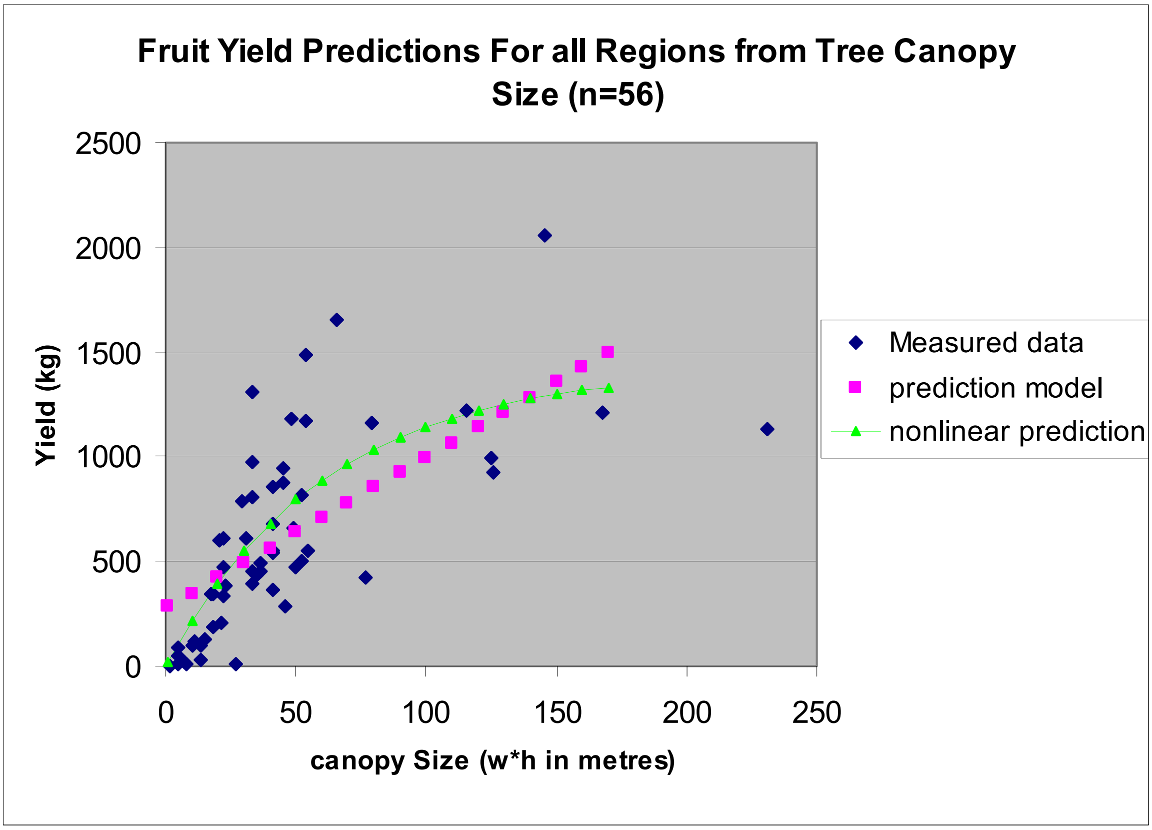
To minimize potential errors the prediction models below are derived from the total sample population. Data sets, regression outputs and scatter graphs for yield predictions using canopy size are included in Appendix 5. Data sets, regression outputs and scatter graphs for yield predictions based on trunk size are included in Appendix 6.

Using a simple linear regression function, two separate models were developed. These models are based on x and y axis coefficients (refer to Appendix 6 for details) calculated from, firstly, canopy size and yield data (with a correlation of 0.67), and secondly, from trunk size and yield data (with a correlation of 0.59). To make predictions of natural phenomenon it is, as a rule of thumb, considered wise to have a good correlation coefficient of at least 0.6.

Fruit Yield Prediction Model Using Canopy Size

The graph below shows the predicted marula fruit yield using measured yields and associated tree canopy sizes.

Figure 8: Fruit Yield Prediction Model Based on Canopy Size For All Regions



Simple (linear) correlation coefficient = 0.67
Nonlinear (curve) correlation coefficient = 0.79

Evidence from marula harvesters, as well as personal observation, suggests that the relationship between canopy size and fruit yield is not linear: smaller and medium sized fruiting trees produce relatively more fruit than very large trees. There is no doubt that examples of trees with large canopies can produce high yields of more than 2,500 kilograms but it appears, both from anecdotal evidence and from the results of this survey that yields do not increase in a linear fashion. Rather, as trees grow in size, yield tapers off.

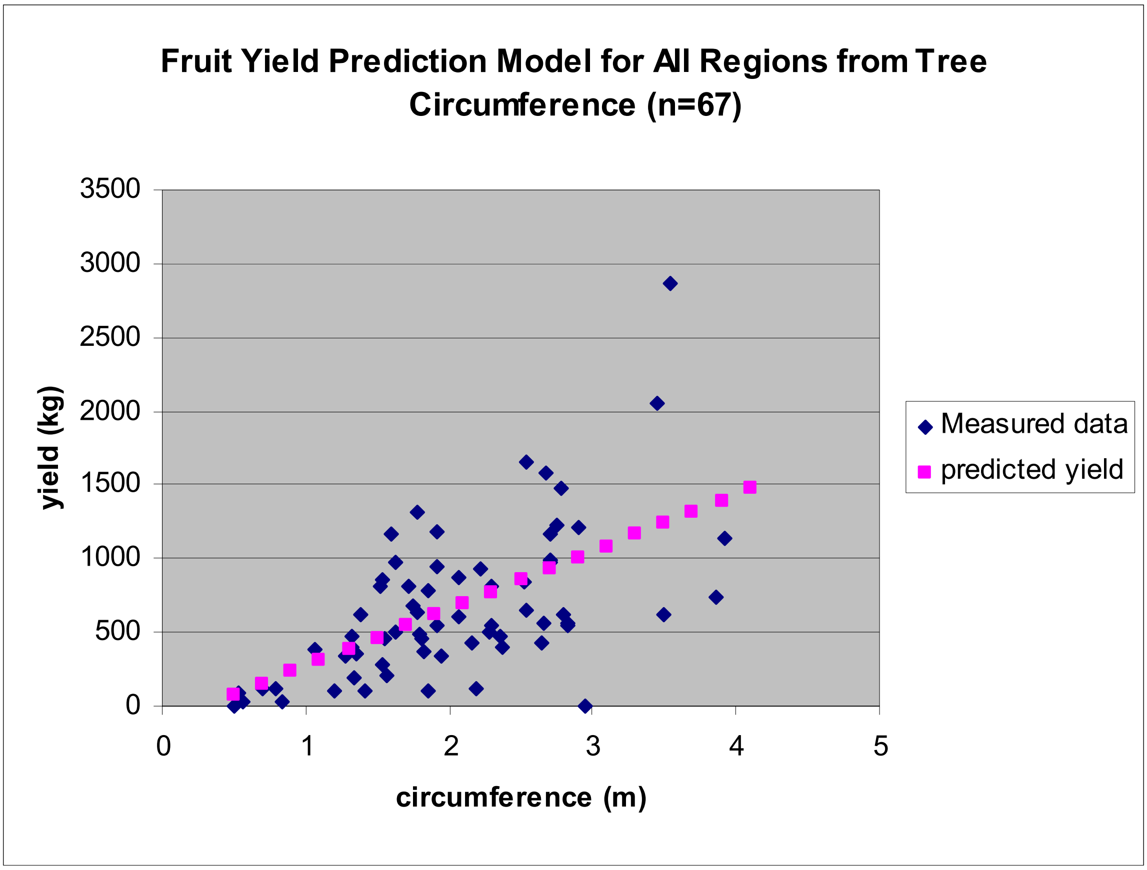
A 'Curve Expert' package was applied to test this hypothesis. It was found that as canopy size increases so yield improves relatively slowly. The best fit curve[2] produced a concave curve, describing a non-linear relationship between canopy size and fruit yield (refer to the graph above). With this curve formula applied there was an improved correlation coefficient, 0.79, compared with simple (linear) correlation of 0.67.

[2] The curve is defined as y=a*e (b/x) where; y=yield; a=1538.66; b=-31.06 (from the Excel package); x=canopy size

Fruit Yield Prediction Model Using Tree Circumference

The graph below shows the predicted fruit yield using measured tree trunk size. (Refer also to Appendix 5 for data sets, regression analysis output and prediction model statistics).

Figure 9: Fruit Yield Prediction Model Based on Trunk Circumference For All Regions



Using measured tree circumference sizes and related yield the regression analysis and the Curve Expert package both produced a prediction model with a straight line. Based on the results of this survey a linear relationship best represents the effect of trunk size on fruit yields.

CONCLUSIONS AND RECOMMENDATIONS FOR FUTURE RESEARCH

This study is the first of its kind to try to quantify marula fruit yields in North-Central Namibia.

Not surprisingly, the results of this survey reveal a direct relationship between tree size (trunk, canopy and height) and corresponding fruit yields.

As a starting point a random sampling method is recommended to ensure data collected is statistically valid. This data is not statistically valid because of the sampling method employed (refer to section on Methodology above) but there does appear to be a strong relationship between observed fruit yields and trunk size and fruit yields and canopy size.

Canopy size has a non-linear (curved) relationship and trunk size experiences a linear relationship.

Although the survey data used is considered reliable it is a small sample (less than 100 trees) of the population (estimated to be more than a million trees). In future it is recommended that a larger sample of trees be measured from a smaller number of locations, to minimize costs and to improve the reliability of data collection: it is quicker and easier and cheaper to train, say, three field workers (women harvesters) than numerous assistants spread across a large geographical area (as was the case with this survey). And better to gather very detailed data from specific sites than superficial data from a number of locations.

For example, the data from Ohangwena is suspect in that it does not correlate closely with what is known about marula trees in this important marula growing area. The results from Ohangwena have relatively low correlations and, more importantly, marula yields: tree size differs markedly from the results of the other two regions.

With a larger sample of trees and a more reliable data set to work from it is recommended that a multiple regression analysis be employed. This will enable researchers to test the relationship between more than two variables using, for example, trunk circumference, canopy size and tree height together with measured fruit yields to predict potential fruit yields with greater accuracy. This might improve the correlation coefficients, but does require more sophisticated software and a better understanding of the potentials and pitfalls of statistics. In this study we have only conducted simple regression using two tree parameters at any time: canopy size and yield; and trunk size and yield. This could be a worthwhile student project, unless there is funding available to conduct more detailed survey work through other organizations such as CRIAA SA-DC.

It is recommended that the prediction models developed here should be tested, refined and adapted using new data from future fruiting seasons. As they stand at the moment, these models are prototype predictions and have not been tested in the field. It could be the case that these results mask the true relationship between tree size and fruit yield; just because they fit the data sets of this survey does not mean they are true. It is simply the case that most of the basic data is statistically reliable and there is consistency in the results.

As well as tree size and fruit yield this study recommends a deeper analysis to test the relationship between rainfall and various soil/land classifications which, it is believed, are primary factors effecting fruit yield. Working with local farmers and their wives to classify soil/land types would be a good starting point. It would be extremely useful to include an assessment of soil depth above the water table, and to correlate this to time of fruiting and fruit yield.

It is hoped that in the future planners and researchers could estimate fruit production from marula trees in North-Central Namibia cheaply and quickly. This is important within the broader marula industry because it is important to estimate the potential production of fruit in a given area. If we can develop simple and effective prediction models based on a measured characteristics of marula trees (height, canopy size/health, trunk size, and alike, it will be relatively easy and cheap to estimate marula yield once the size and number of trees is known. Further down the line this could enable planners to accurately estimate the sustainable supply of marula fruit products to local and growing overseas markets. Currently there is no estimate of fruit yields or the potential (sustainable) supply of marula to these markets.

These are very preliminary figures, but based on the results of this survey, and supported by recent studies, the average marula tree produces 596 kilograms of fruit. Combined with (conservative) figures of one million marula trees (Botelle 2001), of which 80% are estimated to be female (Botelle 2001; Hangula 2000), the total marula fruit yield for the North-Central Regions is likely to be in the order of 450,000 to 500,000 metric tons per annum. This constitutes a huge potential resource.

It is recommended that the Directorate of Forestry in Namibia carry out an inventory of marula trees to find out how many there are. This project should begin in the most important marula growing area of Namibia, the North-Central Regions, and extend to the Kavango and Caprivi Regions.

Winners and Losers in the Commercialisation of Marula

Anecdotal and scientific evidence (Botelle, 2001; Leakey et al, forthcoming, and other research papers within this FRP research project) reveal a positive relationship between the local human population and fruiting (female) marula trees in North-Central Namibia.

Over centuries, intensive use and selection of the best marula fruiting trees has had a direct and positive impact on the marula resource. Today, fruiting marula trees have been integrated into local farming systems and domesticated; 95% of all marula occur in people's fields, with an average of 4-5 female trees per hectare. The best marula trees (those with the most desirable fruit) have been planted and/or protected to the point that they now occur throughout the region, particularly on the most productive farmland.

With the commercialisation of marula throughout the late 1990s, more and more local farmers and their wives are protecting and planting marula trees. And there are plans within Namibia's Directorate of Forestry to actively propagate high-yielding marula cultivars with exceptional fruiting qualities. As far as the marula resource is concerned then, they are one of the winners of the commercialisation of marula with better quality fruiting trees being planted more intensively throughout the region, particularly in people's fields and on the best soils.

Another winner must be the local farmer who can now sell marula fruit products for the first time to outside buyers at a reasonable price which is guaranteed through an international fair trade agreement with The Body Shop International, based in the UK. Urban populations, outside of marula growing areas, within Namibia are also able to buy marula products for the first time. They are also winners in the commercialisation of the marula trade. And overseas consumers are benefiting from the commercialisation of marula. They can now buy products they have never before seen or used before. The chain of positive spin-offs occurs at all levels.

The principal losers are the (non-fruiting) male marula trees which have seen a relative decline in numbers, although this is not a direct result of the commercialisation of marula but a longer term trend within the local farming system to select productive trees and reduce non-productive trees from arable fields which may compete with crops. Other potential losers are marula growing areas in northern Namibia – the Kavango and Caprivi Regions for example – which have so far been left out of the newly established international marula trade. As well, local producers within the North-Central Namibia not yet part of the commercial chain have not benefited directly from the commercialisation of the marula industry.

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Appendix 1: Marula Fruit Yield Survey Spread Sheet

Record No.	Farmer Name	Eudafano	Region of Namibia	Village/Town	Plot No.	Tree No.	Tree Age
1	Nelly Haitembu	No	Oshana (Oshakati north)	Ohambungu-Omukunda	1	1	64
2					1	2	80
3					1	3	80
4					1	4	80
5					1	5	74
6					1	6	80
7					1	7	80
8					1	8	70
9					1	9	80
10					1	10	50
11							
12	Valelia Mumbala	No	Oshana, oshakati N	Oikango	2	11	70
13					2	12	55
14					2	13	22
15					2	14	30
16					2	15	30
17					2	16	40
18					2	17	30
19							
20	Inge Nandjebo	No	Oshana, Oshakati N	Efi	3	18	45
21					3	19	31
22					3	20	34
23					3	21	10
24							
25	Amaria Katokene	No	Oshana (Oshakati N)	Eefa/Omukunda vill	4	22	29
26							
27	Otto Kankondi	Yes	Omusati (Okahao)	Ongozi	5	23	20
28					5	24	5
29					5	25	50
30							
31	Matheus Angula	Yes	Omusati (Okahao)	Ongozi	6	26	16
32							

33	Imanuel Ipinge	No	Omusati (Okahao)	Ongozi	7	27	15
34					7	28	35
35					7	29	12
36					7	30	40
37					7	31	100
38							
39	Jacob Kashuna	No	Omusati (Okahao)	Okahao	8	32	12
40					8	33	25
41					8	34	100
42					8	35	10
43					8	36	18
44					8	37	100
45					8	38	100
46					8	39	20
47					8	40	20
48					8	41	100
49					8	42	12
50							
51	Ndamonahenda Shaimemanya	Yes	Ohangwena	Ondobe	9	43	80
52					9	44	
53					9	45	80
54					9	46	80
55					9	47	90
56					9	48	40
57					9	49	80
58					9	50	80
59					9	51	
60					9	52	100
61							
62	Josefina Udjombala	No	Ohangwena	Endola ((Omakango)	10	53	60
63					10	54	50
64					10	55	55
65					10	56	90
66					10	57	75
67					10	58	80
68					10	59	60

69					10	60	50
70							
71	Maria Kafula	No	Ohangwena	Endola (Omakango)	11	61	26
72					11	62	20
73							
74	Rauna Kapiya		Ohangwena	Endola	12	63	55
75					12	64	?
76					12	65	?
77					12	66	?
78					12	67	?
79							
80	Lucia Petrus	yes	Ohangwena	Endola	13	68	?
81					13	69	?
82					13	70	?
83					13	71	?
84					13	72	?
85							
86	??	??	ohangwena	endola	??	??	??
87							
88	Kakonda/Secilia Moses	yes	ohangwena	ohangwena (omaliata = dev	14	73	35
89					14	74	65
90					14	75	50
91							
92	Karina Nailonga	no	oshana	ondangwa town	15	76	
93					15	77	
94							
95	Seima Heita	no	oshana	ondangwa town	16	78	
96					16	79	
97					16	80	
98					16	81	
99					16	82	
100							
101	Julia Nuuyoma	no	oshana	ondangwa town	17	83	80
102					17	84	
103					17	85	
104					17	86	

105					17	87
106					17	88
107						
108	Wilhelm Kalumbu	no	omusati	Onekukume village, ombala	18	89
109					18	90
110					18	91
111					18	92
112					18	93
113					18	94
114					18	95
115					18	96
116					18	97
117					18	98
118						
119	Elsabet Ndiili	no	omussati	Okapuka village, Utapi	19	99
120					19	100
121						
122	Timoteus Mwafyufyu	no	omusati	okulongadhi, Eunda	20	101
123	Angula Mumbandja		omusati	okulongadhi, eunda	20	102
124	Selma Hambiya		omusati	okulongadhi, eunda	20	103
					20	104

Record No.	Tree Name	Tree Name Meaning	GPS - S	GPS - E	Stem Circumference	Combined Circumference	Record No.
1	shikututu	hard to cut/extract (kernel)	17 43.187	15 49.820	1.63	1.63	1
2	shapa	sour			0.7 & 0.75		2
3	nameya	juicy			1.2	1.2	3
4	nandjila	on the path			1.36 (0.63 + 1.10 + .077)	3.86	4
5		short			1.60 + 1.07	2.67	5
6	nakapale				1.72	1.72	6
7	nangubu				1.01		7
8	tala kola	glance to the side (next to path)			1.78	1.78	8
9	nadahafa	i'm happy			3.54	3.54	9
10					1.95		10
11							11
12	mundola	name of original owner	17 45.221	15 48.902	2.78	2.78	12
13					1.52	1.52	13
14					1.06	1.06	14
15					1.92	1.92	15
16	nakufu	winter time			1.63	1.63	16
17	nameya	juicy			1.78	1.78	17
18	nandjila	on path			1.75	1.75	18
19							19
20	shikututu	very hard nuts	17 44.058	15 48.686	1.91	1.91	20
21	nameya				1.82	1.82	21
22	nangubu	in the thornbrush fence			1.81	1.81	22
23					0.5	0.5	23
24							24
25	djamotofi	get out or you will die/if you drink this omaong	17 44.615	15 48.045	1.35	1.35	25
26							26
27	kalulu	sour	17 52.277	15 05.431	0.95		27
28					0.32		28
29	Namulyo	taste			1.56	1.56	29
30							30
31			17 52.408	15 05.422	0.83	0.83	31
32							32

33			17 52.032	15 05.606		1.17		33
34						2.08		34
35						0.83		35
36						1.81		36
37						2.85		37
38								38
39			17 54.553	15 05.036	0.59+0.15+0.13			39
40						1.33	1.33	40
41	nakale	tall (oblong fruit)				1.55	1.55	41
42						0.53	0.53	42
43						0.56	0.56	43
44						1.32	1.32	44
45						1.85	1.85	45
46						1.28	1.28	46
47					0.98+1.08		2.06	47
48						1.95	1.95	48
49			17 54.499	15 05.013		0.79	0.79	49
50								50
51	nakapala	just a name				2.54	2.54	51
52	siisandjala	we eat it bc we have it not bc it's special				1.97	1.97	52
53	Andy	after me				3.25	3.25	53
54	Elongo	triplets (3 trunks)			1.82+2.2			54
55	nashenga	previous owner had 3 wives. this tree in kitchen of 3rd wife				3.35		55
56	omhandakani	fused with omwandi	17 32.047	16 02.572		1.6	1.6	56
57	namaluni	mole tree: they used to live in this tree for long time				3.09		57
58	naupapi	heart-shaped nut and light weight				2.16	2.16	58
59	naluvanda	pathway for cows and goats	17 32.157	16 02.599		1.85	1.85	59
60	nakale	tall	17 32.079	16 02.553		3.92	3.92	60
61								61
62	ponhu	entrance to homestead	17 36.927	15 45.469		2.82	2.82	62
63	namtaku	name of another tree species found in that location				2.5	2.5	63
64	chorororo	having lots of juice - sound of ongholo (horn) is used to extract juice				2.52	2.52	64
65	kashjteni	named after owner (miriam kafula)				2.22	2.22	65
66	nandjila	on path				2.54	2.54	66
67	shitapako	omwiyu - odjove/omaxuku soup				3.5	3.5	67
68	natalia	named after natalia (as with tree 56)				2.37	2.37	68

69	josephina	named after owner of hse				2.36	2.36	69
70								70
71	depu	sound of plank falling				1.4		71
72	katatu	born same time katatu, young woman in hse				1.42		72
73								73
74	nakapale	close to olupale where thresh corn	17 38.222	15 43.529		3.35		74
75	shiweda	man's name				2.88		75
76	netala	under shadow - ie for shade			1.84+1.2+1.2			76
77	nakale	tall				2.91		77
78	eleva	forge (place where blacksmith used to work)				2.15		78
79								79
80	Ongobe Ilaula	black cow	17 37.748	15 43.055		3.33		80
81	nandjila	on the path				2.26		81
82	?	?	17 37.729	15 43.155	2.15+1.63			82
83	?	?				1.97		83
84	?	?				1.25		84
85								85
86	nandjila	on path	17 38.127	15 43.145		1.2		86
87								87
88	naluxanda	?	17 29.888	15 55.063		1.54	1.54	88
89	onaludiva	water settles/ponds here				2.71	2.71	89
90	aulewa nandji	small edible insect (live in tree)				2.06		90
91								91
92			17 54.809	15 58.132		1.79	1.79	92
93						2.65	2.65	93
94								94
95			17 54.842	15 58.131		2.82	2.82	95
96						1.92	1.92	96
97						1.38	1.38	97
98						0.7	0.7	98
99						2.28	2.28	99
100								100
101			17 54.938	15 58.051		2.66	2.66	101
102						2.79	2.79	102
103						1.32	1.32	103
104						2.29	2.29	104

105					0.69+1.5		2.19	105
106	shilulu	not sweet				2.3	2.3	106
107								107
108	nameya	juicy	17 27.244	15 07.897		2.75	2.75	108
109	n/a					2.7	2.7	109
110	nakale	tall				4.25		110
111	n/a	n/a				3.25		111
112	nakufa (1)	winter	17 27.307	15 07.785		2.42		112
113	n/a	n/a	17 27.335	15 07.741		1.53	1.53	113
114	nakufa (2)	winter	17 27.251	15 07.830		3.04		114
115	okadona	girl				2.9	2.9	115
116	selma	name of person				3.28		116
117	njima	monkey				2.22	2.22	117
118								118
119	Naita	wartime	17 02.192	15 01.572		3.45	3.45	119
120						2.95	2.95	120
121								121
122								122
123								123
124								124

Total fruit yield (kg)	Distance (m)	Height (angle degrees)	Tree Height	Canopy Size	Plot size (Circ in m)
501.5	12.43	31.9			1,450 metres
	9.45	34.8			
98.5	10.3	38.8			
739	9.32	35.8			
1585	13.25	35.9			
806	14.4	33.3			
	14.4	30.1			
634	15	31.9			
2862.25	28	32.4			
	13	38.8			
1481.5	17.7	32.2		53.63	1,200 m
811.6	16	24.1		33.41	
385.5	13.2	25.8		23.1	
944	14.8	37		45.38	
973	16.4	33.8		33	
1307	19	25.5		33.41	
680	16.8	31.3		41.25	
1181	18.3	25.8		48.26	1.18 (epya) + 510m
368.5	16.6	29.8		41.25	
452	16.4	26.8		33	
3	7.2	27.4		1.65	
349	14	38.3		17.33	1,530 m
	9.65	28.7		4.5	853 m
0			3.10 (actual	8	
209	14.15	28.7		21	
25	9.15	27.3		13.5	957m

	11.1	28.2		13.5	N/A
	17.7	28.2		52.5	
	10.45	22		13.13	
	18.6	24.9		50	
	16	25.5		47.25	
12	7.7	12.3		4.5	1,780m
185.7	11.5	19.6		18	
454	13.85	25.5		36	
91	6.1	22		4.5	
23	8.05	23.9		7.5	
469.2	13	22.3		22.5	
100	10.65	25.7		10.5	
340	10.05	26		18	
600.5	10.2	29.3		20.25	
334	16.4	20		22.5	
115.5	8.75	30.6		11.25	
1653	22	27.7		66	1,660 m
232	19	29.2		45.38	
108.5	21.4	29.9		67.5	
	19.3	29.8		56.25	
	24.5	31.3		106.88	
1171.5	16.5	32.5		53.63	
	25.2	28.4		106.88	
424	19	26.6		76.5	
789	16.85	22.8		28.88	
1130	36.8	30.8		231	
568	19.5	33.1			1,400m
1814	19.75	28	n/a		
843	21.55	26	n/a		
447	18.1	27.1	n/a		
657	22.4	22		49	
620	12	25.3		31	
402	14.75	35.3	n/a		

475	17.65	27.8		49.73	
	8.7	29.3			1,430m
	14.05	23.2		13.13	
	22.87	29.3	n/a		1,660m
	27.38	26.9	n/a		
	12.35	33.8	n/a		
	29.3	28.8	n/a		
	10.2	33.9	n/a		
	22.4	27			1,990m
	26.5	31.4			
	24.7	28.3			
	14	25.5			
	10.6	32.9			
	9	33.9			1,200 m
852.5	21.95	22		41.25	1,460m
973	28.5	28.6		79	
873.5	21	24.8		45.4	
489	15.95	26.4		36.3	1,150m
434	17.3	19.8		34.7	
546	17	28.1		40.8	497m
553	15.6	31.7		40.8	
613	15.4	39.8		22.3	
121	12.9	25			
503	19.35	29.2		52	
555.75	21.4	30.3		54.45	847m
625	17	33.2			
394.75	12.65	31.5		33	
813.75	16.1	30.6		52	

125	9.8	29.8	14.9
547	15.65	26	
1221	29.35	27	115.6
991	24.4	30.4	125
	34.2	30	137.7
	18	33.8	134.4
	21.75	32.4	100
284	18.8	24.4	46.1
	21.3	32	226.8
1215	25.1	27.5	168
	30.7	29.6	233.3
926	29.25	25	126
2055.5	21.1	21.5	145.8
7	15	24.6	27
16			
2253			
212			

Record No.	Weight Usable fruit yield (kg)	Average Mass (150 fruits)	Weight Unuseable fruit
1	461.5	6.42 (43g/fruit)	40
2			
3	98.5	5.66 (38g/fruit)	
4	739	7.5 (50g/fruit)	1.5
5	1475.5	5.13 (34g/fruit)	109.5
6	806	6.69 (45g/fruit)	
7			
8	588.75	5.83 39g/fruit)	45.25
9	2862.25	9.96 (66g/fruit)	0
10			
11			
12	1392	6.6 (44g/fruit)	89.5
13	140	3.98 (26.5g/fruit)	671.6
14	385.5	6.0 (40g/fruit)	0
15	576	4.66 (31g/fruit)	368
16	867.5	4.7 (31g/fruit)	105.5
17	882	4.26 (28.38g/fruit)	425
18	569	6.45 (43g/fruit)	111
19			
20	1172	n/a	9
21	365.5	n/a	3
22	452	n/a	0
23	3	n/a	0
24			
25	349	n/a	n/a
26			
27	40 (n/a)	n/a	9.5 (n/a)
28	less than 10	n/a	0
29	207	4 (27g/fruit)	2
30			
31	25	4.25 (28g/fruit)	0
32			

33					
34					
35					
36					
37					
38					
39		12	1.2 (8g/fruit)		
40		115	4.9 (33g/fruit)		70.7
41	**** 363		3.53 (24g/fruit)		91
42		46	2.35 (16g/fruit)		45
43	***** 21		1.2 (8g fruit)		2
44		412	3.57 (24g/fruit)		57.2
45		60	3.2 (21g/fruit)		40
46		217	5.73 (38g/fruit)		123
47	*** 560.5		4.7 21g/fruit)		40
48	*** 305		4.0 (27g/fruit)		29
49	*** 112.5		1.8 (12g/fruit)		3
50					
51		1653	6.46 (43g/fruit)		527
52		232	5,33 (36g/fruit)		0
53		108.5	6.00 (40g/fruit)		0
54					
55	n/a		n/a	n/a	
56		1171.5	3.25 (22g/fruit)		418
57	n/a		n/a	n/a	
58		424	4.00 (27g/fruit)		114
59		789	3.83 (26g/fruit)		345
60		559	3.o (20g/fruit)		571
61					
62		568	n/a	n/a	
63		1814	n/a	n/a	
64		843	n/a	n/a	
65		447	n/a	n/a	
66		657	n/a	n/a	
67		613	n/a		7
68		475	n/a	n/a	

69	475	n/a	n/a	
70				
71	930	5.63 (38g/fruit)	n/a	
72	100	n/a	n/a	
73				
74	502	n/a	n/a	
75	1807	n/a	n/a	
76	556	n/a	n/a	
77	1117	n/a	n/a	
78	190	n/a	n/a	
79				
80	809	n/a	n/a	
81	945	n/a	n/a	
82	1003	n/a	n/a	
83	294	n/a	n/a	
84	147	n/a	n/a	
85				
86				
87				
88	708.5	3.77 (25g/fruit)		144
89	973	4.06 (27g/fruit)	***189	
90				
91				
92	489	4.75 (32g/fruit)		0
93	415	5.18 (35g/fruit)		19
94				
95	529	4.06 (27g/fruit)		17
96	536	4.5 (30g/fruit)		17
97	606	4.22 (28g/fruit)		7
98	118	4.15 (28g/fruit)		3
99	503	4.38 (29g/fruit)		0
100				
101	552	4.66 (31g/fruit)		3.75
102	615	n/a		10
103	380	4.38 (29g/fruit)		14.75
104	801	4.66 (31g/fruit		12.75

105		125	4.00 (27g/fruit		0
106		513	4.68 (31g/fruit)		34
107					
108		813	n/a		408
109		672	n/a		319
110					
111					
112					
113		260	n/a		24
114					
115		715	n/a		500
116					
117		546	n/a		380
118					
119		1899.5	n/a		156
120		7	n/a		0
121					
122		957	n/a		16
123		3543	n/a		2253
124		786	5.00 (33g/fruit)		212
	n/a		n/a	n/a	

Record No.	comments
1	All trees in fields, good soil
2	
3	
4	
5	
6	
7	winter tree - April-June
8	
9	favourite tree. v. large and sweet/juicy fruit
10	
11	
12	lot/large omaxuku
13	weighed over 5-day period only
14	
15	
16	April begins to fruit
17	
18	
19	
20	small nut, lots kernel often single piece, sometimes 2
21	seedlings from this tree transplanted to fence line bc juice great, "will be like the mother"
22	
23	
24	
25	
26	
27	
28	
29	lots sweetjuice
30	
31	first time fruiting
32	

33	3rd yr fruiting (ie 13th yr)
34	super/sweetjuice, extra omaxuku, parasite
35	parasite, started fruiting 12 yrs old
36	parasite
37	
38	
39	1st yr fruiting, last to fruit, late season from April, often spoiled
40	best omaxuku of all trees
41	name describes fruit. like rugby ball
42	second season to fruit
43	
44	loved one among all, 2nd best omaxuku, special shape like rugby ball, sweet
45	branches cut bc elec line
46	
47	
48	
49	2nd yr. to fruit. Sweet juice
50	
51	sweet omaxuku, extra large fruit
52	sour taste. Stopped measuring bc fruit poor quality and bc snake moved into tree
53	she cut this tree down after I left, lots juice, sour, no omaxuku. Stopped measuring bc fruit became dry - unusable
54	3 trunks: definitely same tree cos all produce same size and taste of fruit/nut, ie same root
55	
56	
57	high yield, lots sweet juice, lots omaxuku. Goats got fruit - did not weigh
58	good juice, omaxuku
59	good quality and lot fruit
60	omaxuku good, no juice
61	
62	parasites
63	
64	
65	
66	
67	
68	parasite

69	
70	
71	namatanga = big fruits, she exclaimed - too right. The 38g/fruit is what I measured while there on one occassion
72	
73	
74	
75	wind broke many branches
76	
77	
78	
79	
80	
81	
82	
83	
84	
85	
86	already fruiting - count innacurate. very sweet, special fruit. parasite
87	
88	easy to decorticate
89	
90	
91	
92	I bought great omaongo here @N$ 4-00/litre
93	parasite. old, patchy canopy
94	
95	parasite - she used to cut it out
96	
97	parasite
98	parasite
99	parasite
100	
101	parasite - cut them otherwise tree dies. boys climb and cut out, otherwise will stop fruiting
102	parasite
103	
104	parasite

105	parasite
106	no parasite bc not sweet and birds don't like it - simon Angombe (owner) hypothesis
107	
108	
109	parasites, looking sick. Use bark for medicine-coughing, anti-vomiting
110	
111	parasites, looking sick
112	few aprasites. sweet, good omaxuku
113	fruit not used. Too far from hgomestead, evewn though it's big, sweet & juicy
114	starts fruiting in april
115	
116	Lots of parasites. Fruits intermittantly, eg not at all 1997-2000
117	
118	
119	*** pierre **** large, sweet fruit. Truncheon trials
120	Parasites. Very old, broken branches, sparse canopy, fruiting intermittantly eg last yr no fruit
121	
122	not surveyed, just weighed
123	not surveyed
124	not surveyed
	not surveyed, weighed?

Appendix 2: Averages

Canopy Size (m)	Trunk Circumference (m)	Total Fruit Yield (kg)	Tree Height (m)	Tree Age (Yrs)	Average Fruit Mass (g)
53.63	1.63	1481.5	8.57	64	43
33.41		811.6	7.39	80	38
23.1	1.2	385.5	8.63	80	50
45.38	3.86	944	7.47	80	34
33	2.67	973	9.95	74	45
33.41	1.72	1307	10.02	80	39
41.25	1.78	680	9.21	80	66
48.26	3.54	1181	10.00	70	44
41.25	2.78	368.5	17.48	80	26.5
33	1.52	452	10.45	50	40
1.65	1.06	3	11.60	70	31
17.33	1.92	349	8.38	55	31
36.3	1.63	489	7.59	22	28.4
34.7	1.78	434	11.21	30	43
40.8	1.75	546	11.32	30	27
40.8	1.91	553	10.11	40	28
22.3	1.82	613	10.83	30	8
52	1.81	503	9.89	45	33
54.45	0.5	555.75	10.28	31	24
33	1.35	394.75	9.32	34	16
52	1.79	813.75	5.09	10	8
14.9	2.65	125	11.01	29	24
66	2.82	1653	6.48	20	21
53.63	1.92	1171.5	8.74	5	38
76.5	1.38	424	6.01	50	21
28.88	0.7	789	7.11	16	27
231	2.28	1130	10.36	15	12
49	2.66	657	5.66	35	43
31	2.79	406	9.73	40	36
49.73	1.32	475	8.77	100	40
13.13	2.29	100	3.30	12	22
41.25	2.19	852.5	5.58	100	27
79	2.3	1162	7.81	10	26
45.4	2.54	873.5	3.99	18	20
4.5	1.6	49.5	5.01	100	38
8	2.82	10	6.71	100	25

21	2.52	209	6.43	20	27
13.5	2.54	25	6.21	20	32
4.5	3.5	12	6.87	100	35
18	2.37	185.7	7.37	12	27
36	2.36	454	6.32	80	30
4.5	1.54	91	12.29	80	28
7.5	2.71	23	11.33	90	28
22.5	1.56	469.2	12.82	40	29
10.5	0.83	100	11.69	80	29
18	1.33	340	15.03	80	31
20.25	1.55	600.5	11.01	100	27
22.5	0.53	334	14.14	60	31
11.25	0.56	115.5	10.47	50	33
115.6	1.32	1221	8.36	55	
125	1.85	991	21.43	90	**Average = 30.81 grams**
46.1	1.28	284	12.92	75	
168	2.06	1215	11.30	80	
126	1.95	926	11.43	60	
145.8	0.79	2055.5	10.21	50	
27	2.75	7	10.25	26	
	2.7		6.95	20	
	1.53	**595.9776786**	10.74	35	
45.12	2.9		10.21	65	
	2.22	**Standard Dev. 465 kg**	6.10	50	
	3.45	**median 482 kg**	7.34	80	
	2.95		13.35	12	
			14.50	25	
	1.998852		8.94	80	
			16.38	55	
			7.68		
			12.21	**Average = 53.15 yrs.**	
			16.17		
			13.85		
			7.88		
			7.74		
			6.97		
			10.08		
			15.88		
			10.74		

9.00
7.63
9.99
10.28
12.35
7.28
11.51
12.97
11.50
8.60
10.25
6.75
8.75
15.48
14.60
19.56
12.27
13.95
9.66
13.55
13.70
17.51
14.41
9.57
8.09

Average = 10.22 metres

Appendix 3: Simple Correlation between Canopy Size (w*h) and Fruit Yield (kg)

Oshana Region

	total fruit sum	Canopy Size
	1481.5	53.63
	811.6	33.41
	385.5	23.1
	944	45.38
	973	33
	1307	33.41
	680	41.25
	1181	48.26
	368.5	41.25
	452	33
	3	1.65
	349	17.33
	489	36.3
	434	34.7
	546	40.8
	553	40.8
	613	22.3
	503	52
	555.75	54.45
	394.75	33
	813.75	52
	125	14.9

Correlation = 0.59

Omusati Region

	total fruit sum	Canopy Size
	49.5	4.5
	10	8
	209	21
	25	13.5
	12	4.5
	185.7	18
	454	36
	91	4.5
	23	7.5
	469.2	22.5
	100	10.5
	340	18
	600.5	20.25
	334	22.5
	115.5	11.25
	1221	115.6
	991	125
	284	46.1
	1215	168
	926	126
	2055.5	145.8
	7	27

Correlation = 0.9

Ohangwena Region

	total fruit sum	Canopy Size
	1653	66
	1171.5	53.63
	424	76.5
	789	28.88
	1130	231
	657	49
	613	31
	475	49.73
	100	13.13
	852.5	41.25
	1162	79
	873.5	45.4

Correlation = 0.4

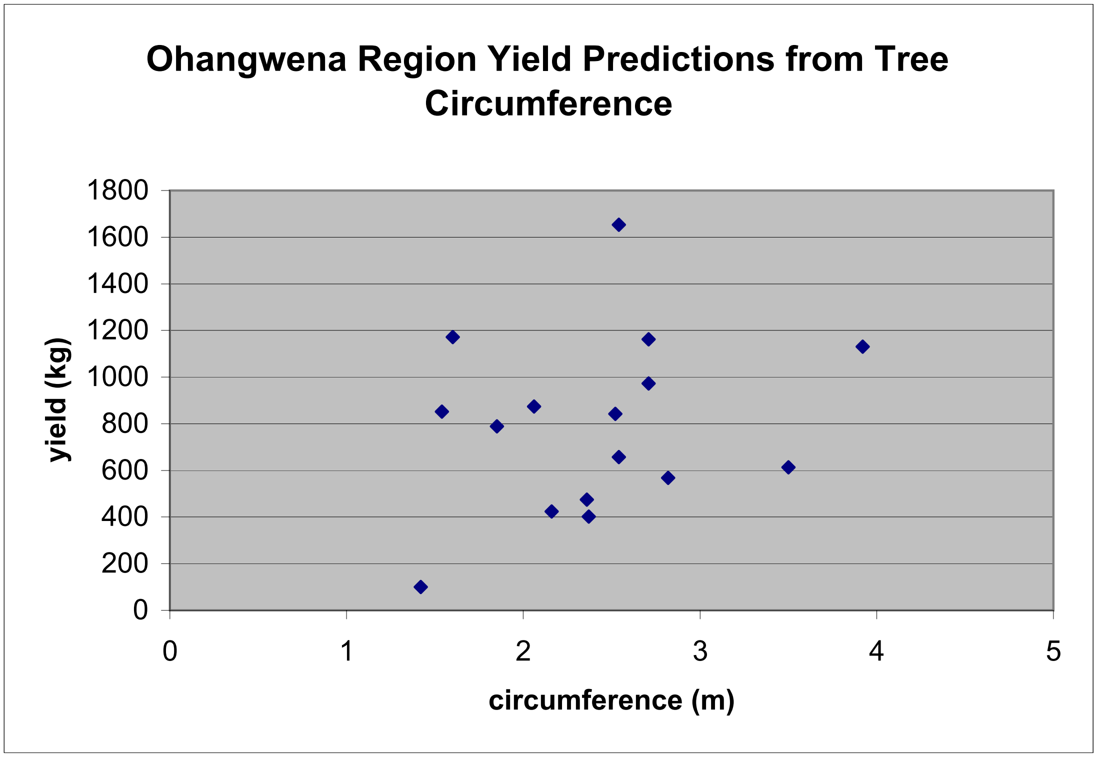
Simple Correlation Coefficient =

= 0.67

Appendix 4: Simple Correlation between Trunk Size (m) and Fruit Yield (kg)

Omusati Region	Total Fruit (kg)	Circumference (m)
	209	1.56

Ohangwena Region	Total Fruit (kg)	Circumference (m)
	1653	2.54



This data set is so random that no prediction yield was developed

Appendix 6: Prediction Model Data From Trunk Circumference

Total Fruit (kg)	Circumference
501.5	1.63
98.5	1.2
739	3.86
1585	2.67
806	1.72
634	1.78
2862.25	3.54
1481.5	2.78
811.6	1.52
385.5	1.06
944	1.92
973	1.63
1307	1.78
680	1.75
1181	1.91
368.5	1.82
452	1.81
3	0.5
349	1.35
489	1.79
434	2.65
546	2.82
553	1.92
613	1.38
121	0.7
503	2.28
555.75	2.66
625	2.79
394.75	1.32
813.75	2.29
125	2.19
547	2.3
209	1.56
25	0.83
185.7	1.33
454	1.55
91	0.53
23	0.56
469.2	1.32
100	1.85
340	1.28
600.5	2.06
334	1.95
115.5	0.79
1221	2.75
991	2.7
284	1.53

Total Fruit (kg)	Circumference
1215	2.9
926	2.22
2055.5	3.45
7	2.95
1653	2.54
1171.5	1.6
568	2.82
843	2.52
657	2.54
620	3.5
402	2.37
475	2.36
852.5	1.54
973	2.71
424	2.16
789	1.85
1130	3.92
100	1.42
1162	2.71
873.5	2.06

Overall Simple Correlation Coefficient = 0.59

Appendix 6: Prediction Model Data From Trunk Circumference continued…. P.2

SUMMARY OUTPUT

Regression Statistics	
Multiple R	**0.5910625**
R Square	0.3493549
Adjusted R Squ	0.3393449
Standard Error	417.4222
Observations	67

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	6081168.991	6081169	34.90084816	1.39481E-07
Residual	65	11325684.2	174241.3		
Total	66	17406853.19			

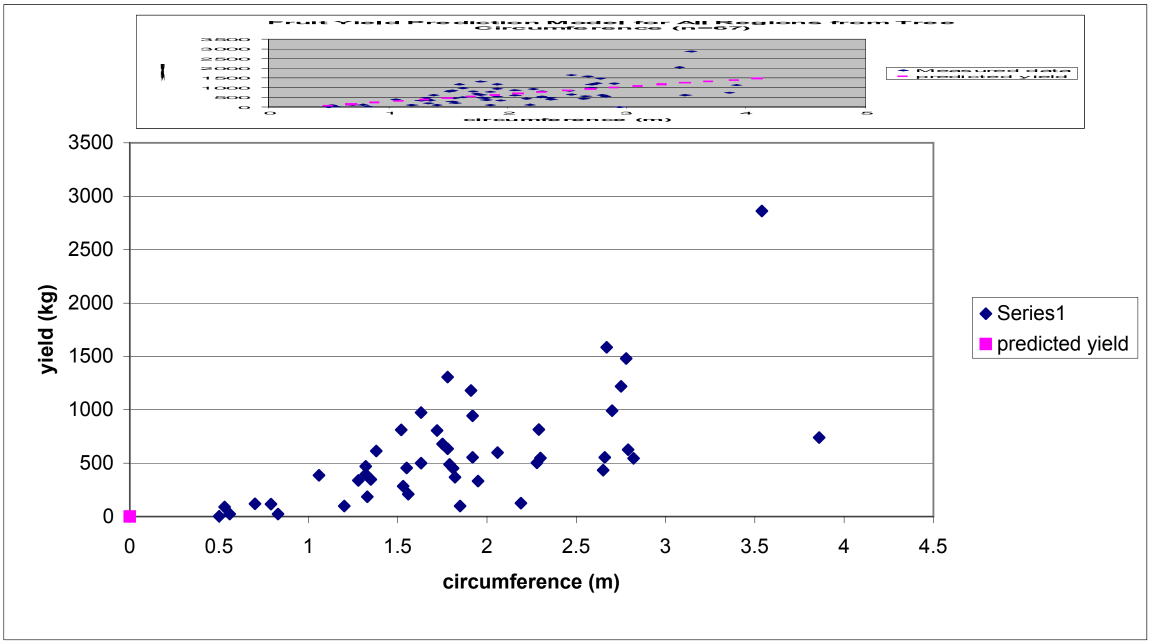
	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	**-118.5073**	**142.7224558**	-0.830334	**0.409389257**	-403.5435989	166.5289	-403.5436	166.5289
X Variable 1	**387.81692**	**65.64607505**	5.907694	**1.39481E-07**	256.7127381	518.9211	256.7127	518.9211

Standard error is the same as standard deviation

P-value - the lower the value the higher the significance on the model.
Simple linear regression: shows whether the x-variable is significant

Circumference	Predicted yield
0.5	75.395
0.7	152.955
0.9	230.515
1.1	308.075
1.3	385.635
1.5	463.195
1.7	540.755
1.9	618.315
2.1	695.875
2.3	773.435
2.5	850.995
2.7	928.555
2.9	1006.115
3.1	1083.675
3.3	1161.235
3.5	1238.795
3.7	1316.355
3.9	1393.915
4.1	1471.475

Appendix 6: Prediction Model Data From Trunk Circumference contd. P.3



Appendix 5: Prediction Model Data From Canopy Size

Total Fruit (kg)	Canopy Size (m)
1481.5	53.63
811.6	33.41
385.5	23.1
944	45.38
973	33
1307	33.41
680	41.25
1181	48.26
368.5	41.25
452	33
3	1.65
349	17.33
489	36.3
434	34.7
546	40.8
553	40.8
613	22.3
503	52
555.75	54.45
394.75	33
813.75	52
125	14.9
1653	66
1171.5	53.63
424	76.5
789	28.88
1130	231
657	49
613	31
475	49.73
100	13.13
852.5	41.25
1162	79
873.5	45.4
49.5	4.5
10	8
209	21
25	13.5
12	4.5
185.7	18
454	36
91	4.5
23	7.5
469.2	22.5
100	10.5
340	18
600.5	20.25
334	22.5

Appendix 5: Prediction Model Data From Canopy Size continued… P.2

115.5	11.25
1221	115.6
991	125
284	46.1
1215	168
926	126
2055.5	145.8
7	27

Linear Predition		**Non-linear Predic**	Nonlin. Pred Yield
Canopy Size (m)	predicted yield all	Canopy Size (m)	23.03
1	282.8	1	214.19
10	347.6	10	396.05
20	419.6	20	550.47
30	491.6	30	681.59
40	563.6	40	792.92
50	635.6	50	887.45
60	707.6	60	967.71
70	779.6	70	1035.86
80	851.6	80	1093.73
90	923.6	90	1093.73
90	923.6	90	1142.86
100	995.6	100	1184.58
110	1067.6	110	1220.00
120	1139.6	120	1250.08
130	1211.6	130	1275.61
140	1283.6	140	1297.30
150	1355.6	150	1315.71
160	1427.6	160	1331.34
170	1499.6	170	

Appendix 5: Prediction Model Data From Canopy Size   continued P.3

SUMMARY OUTPUT

Regression Statistics	
Multiple R	**0.669636**
R Square	0.4484124
Adjusted R Squ	0.4381978
Standard Error	347.75103
Observations	56

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	5308767.722	5308767.7	43.89922608	1.6688E-08
Residual	54	6530262.208	120930.78		
Total	55	11839029.93			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*.ower 95.0%*	*Jpper 95.0%*
Intercept	**275.57058**	**67.47074619**	4.0842973	**0.000147346**	140.299766	410.8414	140.2998	410.8414
X Variable 1	**7.1839415**	**1.084262299**	6.6256491	**1.6688E-08**	5.010124623	9.357758	5.010125	9.357758

Standard error is the same as standard deviation

P-value - the lower the value the higher the significance on the model.
Simple linear regression: shows that the x-variable is very significant

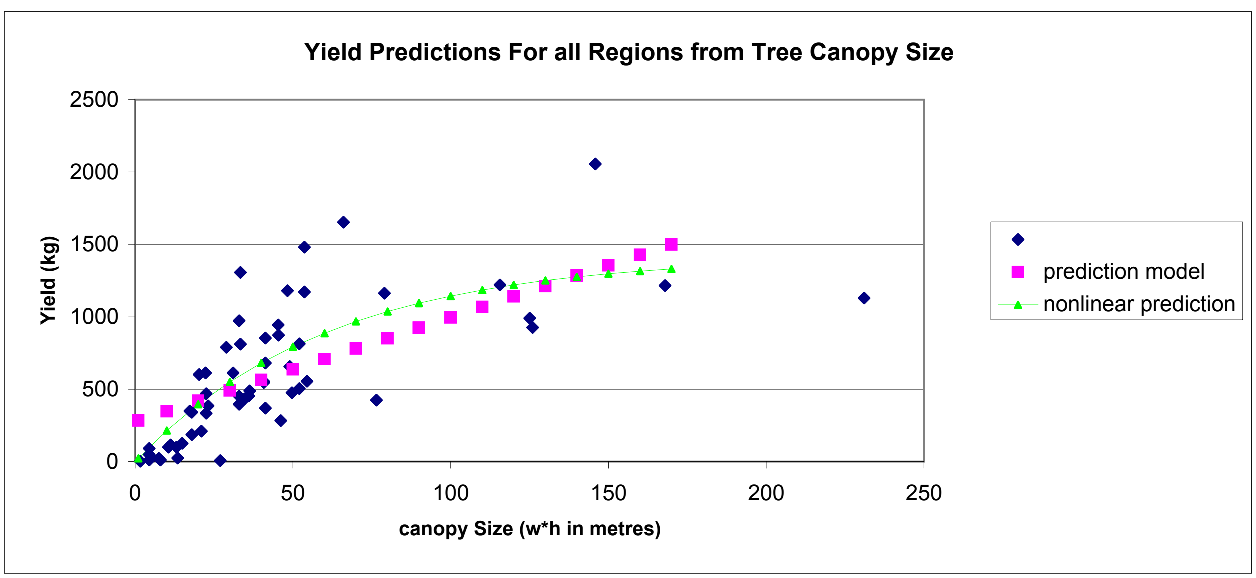


Photo 1: The shape of marula trees varies enormously from tree to tree. Here two trees of the same age on the same soil have very different trunk shapes. Trunk diameter was supposed to be measured at exactly 50 cm above ground level. In this example, the closest tree was measured at the point above where the root stems converge. In other examples, some marula trees had two, three or even four main trunks, some were hollow, and others were the same tree, growing from the same underground root system of a mother tree, but located 10 or 20 metres away. Sometimes it can be difficult to know exactly how to measure a given characteristic of a marula tree because they can grow in unpredictable and unusual ways.

Photo 2 and 3: Inge Nandjebo, Efi village, Oshakati North, Oshana Region. In Northern Namibia marula trees have been domesticated for centuries. Inge is showing us one of the seedlings she has taken from a desirable mother tree in one of her fields and transplanted it next to her fence. Her plan is to grow a hedge of fruiting marula trees around her arable plot. The hedge will act as a windbreak, will provide some shade, and will supply her with plenty of marula fruits.

Photo 3 (see previous)

Photo 4: Endola, Ohangwena Region, Northern Namibia. A plant parasite, most likely the mistletoe *Erianthenum dregei* (Loranthaceae), killed this tree called "Nakatuna" in 1997.

Photo 5: This tree, on the same plot in Endola, looks sick; it is beginning to suffer from the same plant parasite. Some of its branches are completely bare of leaves. According to the owner, in 1999, this tree gave a lot of fruit. Although the quality of fruit remains the same the quantity of fruit is decreasing. It is hypothesised that this reduced yield is the result parasitic attack rather than lack of rainfall or other negative influences.

Photo 6: Ondangwa Town, Oshana Region, Northern Namibia. This tree, at 12 years old, was second youngest fruiting tree recorded during this study. This tree too is infected with the same plant parasite and is already losing its leaves. According to the owner, "fruit yields are still good but it will decrease if I don't cut out the parasite". Most owners combat the parasite by cutting off affected branches during autumn, after the marula fruits have finished abscising.

Photo 7
(see next)

Photos 7 & 8: Exceptionally large fruits (averaging more than 50 grams per fruit) from “Depu” and her sister tree “Mwanunaldeni” on the same plot in Endola the Ohangwena Region. These are examples of fruits from highly desirable trees. The trees themselves are small and compact, and produce large quantities of large, sweet, juicy fruit with large kernels; ideal candidates for propagation trials to try and improve marula fruit yields in the marula growing areas of north-central Namibia.

Photo 9: Although young, just 26 years old, this female marula tree is famous in the local area. Her name, "Depu" describes the sound a plank of wood makes when it hits the sand. As the owner Maria Kafula explained, "When you drink the marula wine made from the fruit of this tree, it is so strong you will not be able to walk home, and you will fall down with a big bang; "Depu!".

Photo 10: Small, sour fruits from a male marula tree in the Ohangwena Region. These fruits have no practical use other than being an interesting anomaly.

Photos 11 & 12: Surveyed marula trees, 10 years old (first year fruiting), Photo 11, and 80 years old (still fruiting), Photo 12. Both very old and very young female marula trees produce low yields, less than 100 kilograms per annum, compared with the norm of around 400-600 kilograms.

Photo 12 (see previous)