Results of Land Cover Type Mapping and Coconut Resource Field Inventory Using World View-2 Image Data, Tonga

Vava'u Island

Draft Version 1st February, 2016

Field work in Vava'u Group measuring palms in selected sample plots

This draft report shows the results of field work and image analysis. A separate report explains the database and all calculations. A further paper explains how to establish the plots and n record all data. For questions contact Wolf Forstreuter at SPC-GSD wolff@spc.int +679-3249-237and Kataebati Bataua kataebatib@spc.int +679-3249-230.

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1 Introduction

The Forestry Division of the Ministry of Agriculture & Food, Forestry and Fisheries (MAFFF), is responsible for the conservation and sustainable management of forests, coconut, and fruit trees resource. Coconut and fruit trees are specifically mentioned to emphasize their ever increasing importance, among others, in view of food security, permanent source of livelihoods, social values, and better resilience to climate change impacts especially in rural terrestrial and isolated maritime communities. The Division asked for assistance to conduct a coconut resource inventory since long time. In June 2015, the USAID funded food security project provided funds and SPC conducted an inventory for the Vava'u Group in the north of Tonga.

The current report is still a draft as for example the area has to be adjusted. Currently coconut stocked area the land cover class “settlement area” is not counted but will be further delineated and corresponding parts will added to the productive coconut area.

This report concentrates on the calculated figures derived from the inventory work. A separate paper “Inventory Measurement Instructions Image Interpretation and Field Work” explains how the data is recorded. The “Database Manual” explains (i) how all figures are calculated and (ii) how to operate the database. These three reports are one inventory output. The database as such is an essential additional output of the inventory. The same applies to the digital land cover layers.

1.1 Purpose of the Coconut Resource Inventory

The Forestry Department in Tonga is within the Agriculture Department responsible for coconut production. Currently there are some indications that the coconut production area is declining and that in addition the production per area is declining as well. The reason seems to be that the coconut stands are over-aged due to insufficient regeneration.

There is a need to keep coconut resource in full production or even increase the production to: (i) create income in rural areas to avoid further decrease of rural population, (ii) keep the coconut resource as it is a very sustainable resource less sensitive to weather anomalies than other crops, (iii) keep the minimum of coconut palms to protect other crops growing underneath from sun and wind and (iv) keep coconut resource as food security.

To increase production farmers have to see direct financial benefits which only can be managed through an increased demand for coconuts. There are several possibilities such as: (i) virgin coconut oil production where a market has to be created, (ii) traditional copra production for coconut oil, (iii) bio fuel production, (iv) direct energy production. However, all these market possibilities need investment and all investors want to have a clear idea about the resource. They want to know: (i) the current area stratified into coconut palm densities, (ii) the production figures and age structure per hectare where the production figures include the amount of hybrids, the infection of natural reduction factors such as rhinoceros beetle, stick insect, etc., (iii) the amount of timber volume as dead trunks must be removed from the stands to avoid infection of rhinoceros beetle

It seems to be that the resource is over-aged as there were no regeneration programs since the copra price broke down. Most probably senile palms have to be removed and replaced by young more fertile ones.

Semi dense stands with 50 to 150 palms per hectare are the productive areas. In scattered stands it is uneconomic to collect nuts as the walking distance is to far between the nuts on the ground and in dense stands the movement is very restricted. Therefore the analysis is focussed on semi dense stands.

1.2 The Steps of the Coconut Resource Inventory

A new coconut inventory field design incorporating VHR satellite image data was developed and tested in Suva in late 2012. This was presented on the ACIAR SPC Pacific Coconut R&D Coconut Strategy Meeting. This inventory design is based on satellite image interpretation, GIS application, field measurements with high resolution GPS and forest measurement equipment and database application.

The first step of such an inventory is the ***mapping of the land use*** with focus on coconut palm stands. The coconut cover of Vavau islands in Tonga was stratified into dense, semi dense and scattered coconut cover. All mapping is based on visual interpretation at 1:5,000 working scale of geo-coded very high resolution image data. The mapping was carried out as on screen delineation, which creates a GIS layer. The result of this step was the area stocked with coconut stratified into three densities.

The next step of the design is the ***counting of palms*** which was conducted through a statistical sound number of randomly selected image plots. The interpreter marks all visible palms and a GIS program does the counting. The results are stored in a database. Plots were selected for all three strata and the average number of palms per stratum was calculated.

The third step of the design is the ***field work*** where randomly image plots were selected and visited in the field to conduct measurements and counting on the ground. The field work was carried out from 6 July 2015 to 2 of August, there were two teams with different assignment. The first team concentrated on measuring dead palms to establish a form factor and basic data for age calculation of palms while the second team carried out inventory field measurements for 100 selected sample plots. At the same time the team was trained on how to use the equipment to measure palms.

2 Summary Results

The results are explained in more detail below. This chapter provides an overview only.

Stratum	Outside	Within Settlements	Sum
Dense coconut	1,099	7	1,106
Semi dense coconut	3,697	18	3,715
Scattered coconut	1,135	18	1,153
Sum:	**5,931**		**5,974**

Table 02.01: *Coconut Area*

2.1 Coconut Palm Area

Area estimation is based on satellite image interpretation.

2.2 Number of Coconut Palms

Class	Area [HA]	Palms/ha	Palms
Dense coconut	1,099	252	276,948
Medium dense coconut	3,697	71	262,487
Scattered coconut	1,135	31	35,185
Sum			**574,620**

Table 02.02: *Number of palms*

The number of coconut palms per hectare were estimated with satellite image data and later adjusted in the field through comparison of sample plots in the image data and on the ground. Table 02.02 represents the number of palms counted within the field plots only.

2.3 Coconut Production

The coconut production was estimated (i) as production per hectare per stratum and multiplied with the area (table 02.03) and (ii) as average production per palm per stratum and multiplied with the number of palms (table 02.04). The methods produce slightly different results.

Stratum	Area [ha]	Nuts / ha	Nuts
Dense	1,099	4,643	5,102,657
Semi Dense	3,697	3,002	11,098,394
Scattered	1,135	1,192	1,352,920

Table 02.03: *Coconut production, calculated from nuts/ha/plot*

Stratum	Area [ha]	Palms/ha	Palms	Nuts / Palm	Nuts
Dense	1,099	162	178,038	29	5,163,102
Semi Dense	3,697	87	261,209	34	8,881,106
Scattered	1,135	33	37,455	36	1,348,380
Sum	5,931		476,702		15,392,588

Table 02.04: *Coconut production, calculated from nuts/palm/palms/ha*

2.4 Available Timber Volume

The timber volume was calculated as area calculated from the diameter in breast height (1.3m) times height of trunk times form factor. The form factor was established in Tonga. There is no bark reduction and separation of timber density.

Stratum	Plots	Area [ha]	m3 / ha	Sum m3
Dense	5	1,099	65.2	71,655
Semi Dense	82	3,697	38.1	140,856
Scattered	13	1,135	14.4	16,344
Sum		5,931		228,855

Table 02.05: *Available timber volume [m^3]*

3 Area Delineation and Calculation

The mapping was an essential part of the task which also fits other purpose than coconut resource inventory only. The mapping can be utilised for other parts food security mapping such as available bread fruit in village areas.

3.1 The Satellite Image Data

The interpretation is based on pan-sharpened World View 2 providing 40 cm spatial resolution and colour, recorded in 2015. The image data arrived as band combination blue, green, red and as band combination green, red, infra-red. So far only the natural colour combination of blue, green, red was utilised for the interpretation.

3.2 The Land Use and Coconut Palm Cover

The image interpretation delineated six vegetation classes and four none vegetation classes. The four vegetation classes are:

1. Left over patches of forest;
2. Mangrove areas;
3. Dense coconut palm stands, areas with more than 150 palms per hectare;
4. Medium dense coconut stands, areas with 51 to 150 palms per hectare;
5. Scattered coconut stands, areas with 25 to 50 palms per hectare;

The none vegetations classes are:

1. Settlement areas, which are areas dominated by houses with a buffer zone 75 metres around;
2. Bare land or land with short grass cover;
3. Inland water bodies;
4. The class “unclear” which are areas covered by clouds or strong cloud shadow for which any interpretation was difficult.

The area analysis was carried out in Access as area database. The actual area calculation for every polygon was performed in GIS environment and afterwards the MapInfo table was copied to Access. Table 03.01 provides an overview. The land cover class “Settlement Areas” also contains coconut. These coconut areas within settlement have to be added to the main coconut areas which will be performed for the next version of the report.

Vegetation Cover	Area [hectare]	% Sum
Forest	1196	10.35
Shrub	4,104	35.5
Scattered Coconut	1,113	9.6
Semi Dense Coconut	3,671	31.8
Dense Coconut	1,103	9.5
Mangrove	371	3.2
Sum Vegetation	**11,558**	**100.0**
Settlement	658	33.3
Water Body	835	42.2
Bare Land	333	16.8
Not clear	151	7.6
Sum None Vegetation	**1,977**	**100.0**
Total:	**13,535**	

Table 03.01: *Land cover summary of Vava'u Islands, Tonga*

Vegetation Cover	Area [hectare]	% Sum
Forest	10	4.76
Shrub	152	72.4
Scattered Coconut	18	8.6
Semi Dense Coconut	18	8.6
Dense Coconut	7	3.3
Mangrove	5	2.4
Sum Vegetation	**210**	**100.0**
Settlement	279	62.3
Water Body	0	0
Bare Land	119	26.6
Not clear	50	11.2
Sum None Vegetation	**448**	**100.0**
Total:	**658**	

Table 03.02: *Land cover summary within settlement area of Vava'u Islands, Tonga*

11,558 hectares or 85 % of Vava'u Island in Tonga are covered by vegetation where 51 % is coconut cover and out of this 42 % or 4774 hectare are dense or semi dense ("plantation") stands, which are the areas economically to harvest.

15 % or 1,977 hectares of Vava'u Islands have non vegetation cover where 333 hectares or 16.8 % are water bodies.

Currently the coconut palms within settlement areas are not counted. This has to be added.

4 Counting Number of Palms

The the counting of coconuts palms is a semi-automatic process based on the number of palms visible in 50 x 50m grid cells (UTM) displayed over the image data. Table 04.01. shows the three different strata all coconut cover of low lying islands is delineated. The stratification process is explained in detail in the methodology chapter (not included in the current report). There was a detailed comparison between the number of coconut palms visible in the image data and measured in the field which leaded to a correction factor of 10.5 % for dense coconut stands as only the palms can be counted with image data which are part of the top layer of canopy. Surprisingly a factor of 4.4 % had to be added to semi dense coconut stands. There are obviously a few palms under the canopy of the dominating ones. The method and result will be explained in a separate chapter.

Stratum	Abbreviation	Palms / ha	Palms / cell
Scattered	SC	25 – 50	7 - 12
Semi Dense	SD	51 – 150	13 – 37
Dense	DE	> 150	38 plus

Figure 04.01: *The three coconut palm strata based on number of palms per hectare*

Stratum	Plots	Min	Max	Avg	StDev	StErr	StdEr %
Dense	5	84	192	162	44.7	20.0	12.4
Semi Dense	82	56	140	87	21.3	2.4	2.7
Scattered	13	24	48	33	7.3	2.0	6.2

Table 04.02: *Measured palms per ha per plot in different strata*

Stratum	Area [ha]	Avg Palms / ha	Palms
Dense	1,099	162	178,038
Semi Dense	3,697	87	261,209
Scattered	1,135	33	37,455
Sum			476,702

Table 04.03: *Estimated coconut palm resource in Vava'u Islands*

The table 04.02 represents the number of palms measured within the field sample plots calculated to palms per hectare from the 50 x 50 metre plot. Table 04.03 shows the estimated number of coconut palms in Vava'u group based on the average number of palms in the field plots (table 04.02).

5 Age of Coconut Palms

In Vava'u Island coconut palms were actively planted. The age was estimated for every palm. However, the method of age estimation had to be revised. Nearly ¼ of the plots, for which the planting age was known, the method explained as “old method of age estimation” calculated the age to young for areas were the planting year is known.

5.1 Old Method of Age Estimation

The Age of coconut palms were estimated by measuring the length of the stem covered by 11 leave scars. This measurement starts from 1.5m upwards[1]. Assuming that produces 11 scars per year and that leave scars a distributed equally over the trunk the age is calculated by dividing the total length of the trunk by the length of the measured 11 leave scars. As a coconut palm does nut produce leave scars during the first 5 years, which are visible later, 5 is added to the age.

Age = length of trunk / length of 11 leave scars + 5

1 Details see “Inventory Measurement Instructions Image Interpretation and Field Work”

5.2 Adjusted Method of Age Estimation

For the form factor establishment the diameter was measured every metre for 62 palm trunks. At the same time the number of leave scars were counted for every section. This dataset allowed a comparison between the old method of age calculation and the real number of leave scars per trunk. The dataset is showing that the assumption: "the distance of leave scars is similar on all parts of the stem" is wrong. Leave scars on top are denser than on the lower part of the trunk. The method just dividing the trunk length by the length of 11 leave scars measured at the bottom had to be adjusted.

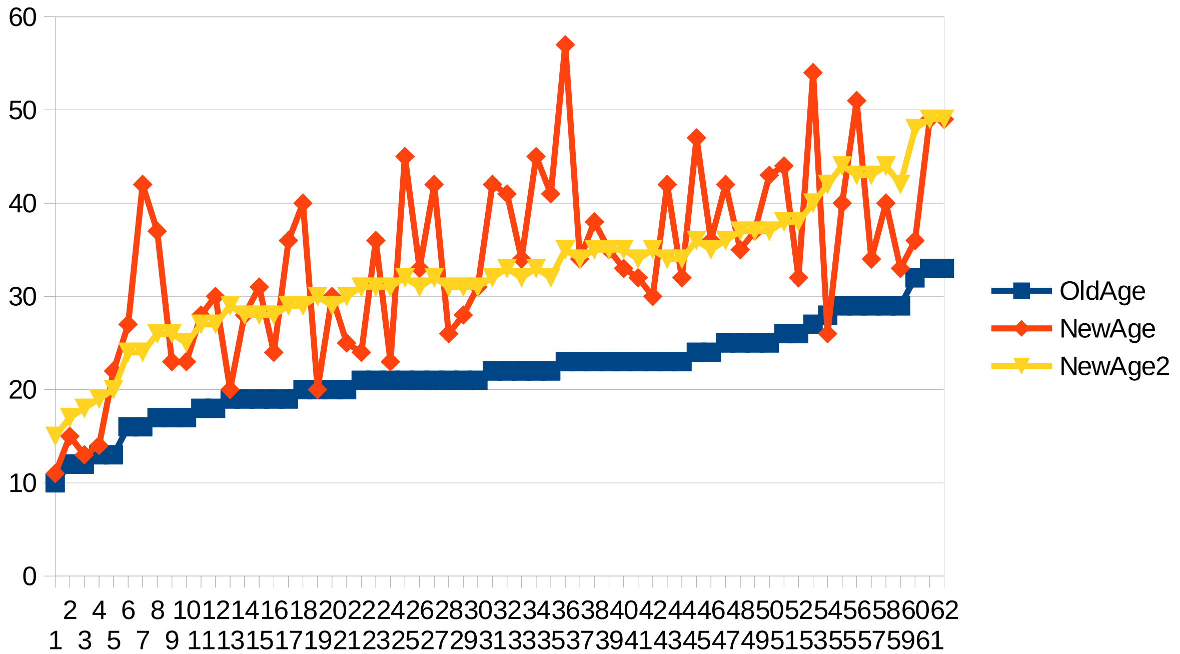


Figure 05.01: *Age of 62 palms "Old Age" = age estimated by old method, "New Age" = age estimated by counting leave scars of the complete trunk, "New Age2" = age calculated by adjusted method.*

The age difference between the age calculated with the old method and age calculated counting the leave scars of the total trunk has an average of 12 years. However, the age difference is greater for old palms ~16 years than for young ones < 1 year. The age difference of 16 years for 33 years old palms was taken as ration (2.06) to adjust the age calculated with the old method to a more reliable age.

Age (adjusted) = Age old method + (age old method / 2.06)

Figure 05.01 shows the age calculated for 62 palms for which the trunk was measured and the leave scars were counted. "Age old" is the age calculated by the old method (blue) NewAge is the age calculated by counting the leave scars of the total trunk and NewAge2 is the age calculated by the adjusted method.

5.3 Age Distribution

In all sample plots together 2091 palms were measured and the age estimated as explained above. The age distribution for all palms is shown in figure 05.02 where the palms were not stratified into different densities. There is a concentration in the productive age classes, however, young age classes are missing. This could result in a declining coconut production in the near future.

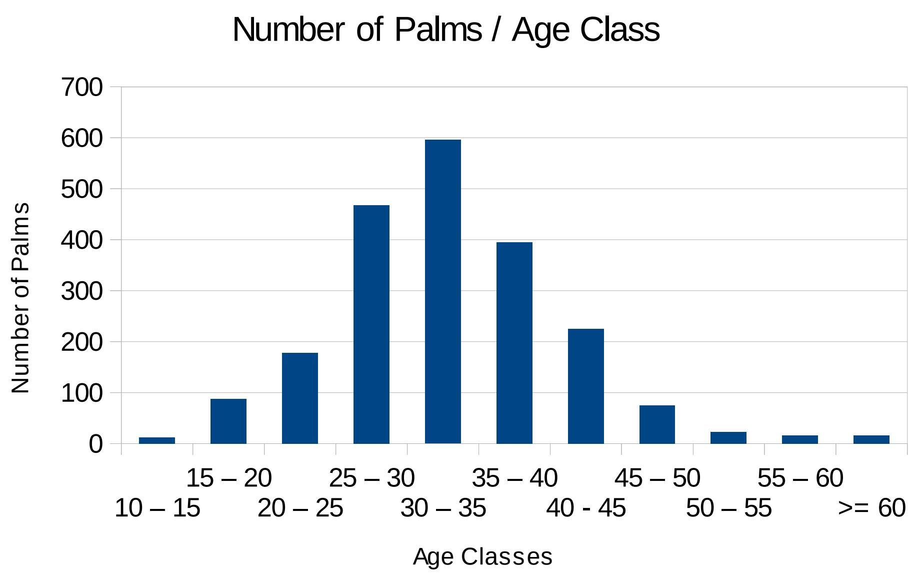


Figure 05.02: *Palm age distribution, most of the palms are between 25 and 40 years. Young palms are missing.*

> 10	10 – 15	15 – 20	20 – 25	25 – 30	30 – 35	35 – 40	40 - 45	45 – 50	50 – 55	55 – 60	>= 60
22	12	87	178	468	596	395	225	75	23	16	16

Figure 05.03: *Palm age distribution regeneration included.*

6 Timber Volume of Palm Trunks

The timber volume was measured for every palm of all sample plots.

6.1 Purpose of Coconut Timber Volume Estimation

If senile coconut palms have to be cut and replaced by young palms the stems cannot be left in the field as the rotten stems are an ideal breeding ground for the rhinoceros beetle which would spread and decline the production.

There are several possibilities to eliminate the timber and not allow the rhinoceros beetle to breed, the trunks can be: (i) buried in the ground, (ii) they can be burned or (iii) they can be utilised as fence posts or construction timber. The last solution is normally the most cost effective one, where the most successful way would be a transportable saw mill.

The access to the coconut palms is granted in Vava'u as the infrastructure in terms of road network is recently upgraded. At a later stage the inventory results with 100 sample plots randomly distributed over Vava'u can be linked to GIS and can explain where the coconut timber has to be removed and how far the transport distance is. When the first trunks are utilised a figure can be produced showing how much of the gross timber volume can be used for construction. The percentages of usable timber within one trunk published by Wulf Killmann have to be verified in Vava'u.

6.2 Need of Form Factor

To calculate the overall timber, including the non usable part, the trunk volume has to be measured in sections, which can be preformed by measuring the diameter every metre and calculating the volumes of the sections and adding these together. The volume calculation is based on the formula of the truncated cone. Using this formula it is assumed that the outside of the cone is straight which is not the case, however, having diameter measurements every metre this is negligible. This formula can also be applied if the upper diameter R2 is bigger than the lower diameter R1 which is often the case. This is also the reason that applying a spline function will create difficulties. Such measurements cannot be performed for every trunk by the inventory team. However, the inventory team records the DBH (diameter at breast height, 1.3m), which is an international forest calculation figure, and the height of the trunk. This allows to estimate the real volume.

The corresponding code of the database calculates a cylinder with the measurements diameter and trunk height. Then the code reduces this volume by the ***form factor*** to the real volume. The purpose of the field work was to establish this form factor. This is performed by measuring the sections every metre for a statistical sound number of palms and calculate the form factor, which then can be applied to all other palm trunks where only DBH and height was measured.

6.3 Form Factor in Vava'u

During the field work 62 trunks were measured including a few hybrids. The form factor reducing the cylinder calculated from DBH and trunk height to the "real[2]" volume has an average of 0.72 with a range of between 0.57 and 0.88 and a standard deviation of 0.09. The standard error is calculated with 0.0135.

Another result is the knowledge that the percentage of palms having trunks where the section diameters increase in the middle of the trunk, which could be related to optimal water supply during this period. So far only 1.6% had a trunk which was counted as "normal" where the diameters did decrease with height on the trunk. It was counted as "normal" if even several section diameter had the same measurement and did not decrease with height. If the diameters increase somewhere on the trunk the trunks was counted as "others".

6.4 Volume Measurement

The timber volume measurement calculates the volume of the total trunk regardless of the wood

2 The real volume has to be measured by putting the trunk into a basin with liquid and measuring the overflow, which is very difficult for palm trunks. The calculation of sections is the closest to the real volume.

density. For timber utilisation purpose the different densities of the palm trunk have to be accessed.

The volume calculation is based on (i) diameter at 1.3m, (ii) trunk height and (iii) form factor[3]. All palms of a plot above 5 metre height were measured. The diameter is measured over bark in in cm with two digits behind the point. The trunk height is calculated from the measured (i) angle the bottom, (ii) measured angle to the top of the trunk, where both measurement were read in per cent, and measured (iii) distance from view point to the tree in metre with two digits behind the point. The form factor was established from palms on the ground where every metre the diameter was recorded. Measurement were taken from 62 palms over all diameters resulting in a factor of 0.74.

The calculation transforms the diameter to area of a circle and multiplies this with the trunk height resulting in a volume of cylinder. This volume is reduced to the volume of a cone by applying the form factor.

6.5 Timber Volume of Palms in Vava'u

The timber volume were measured for 100 plots or 2,091 palms. The smallest one with 00.3 m^3 in plot 043 with 11cm DBH and 4.5 m eight. The biggest palm in plot 035 of 5.45 m^3 with a DBH of 58 cm and an extreme height of 28.7 m.

Stratum	Plots	Area [ha]	m3 / ha	Sum m3
Dense	5	1,099	65.2	71,655
Semi Dense	82	3,697	38.1	140,856
Scattered	13	1,135	14.4	16,344
Sum		5,931		228,855

Table 06.02: *Timber volume of coconut stands in Vava'u*

Stratum	Plots	Min	Max	Avg	StDev	StErr	StdEr %
Dense	5	37.2	103.9	65.2	24.4	10.9	16.7
Semi Dense	82	14.4	89.4	38.1	13.9	1.5	4.0
Scattered	13	8.6	20.5	14.4	3.5	1.0	6.8

Table 06.01: *Timber volume per hectare of plots established in Vava'u Group, Tonga.*

Table 06.01 shows the timber volume per hectare in m^3 for the plot with the lowest value, the highest value and the average. The table also shows the standard deviation of the average and the standard error which the standard deviation divided by the square root of the number of plots. The standard error % sets the standard error in percent of the average to make the standard error comparable to other inventories.

Table 06.02 shows the total available timber volume in Vava'u and the timber volume of the three different coconut strata. These figures might be utilised to define the carbon stock of the land cover “coconut palms”.

In case a regeneration program wants to remove the old and senile palms the amount of timber volume of palms over 40 or over 50 can be calculated with the database.

3 Details see “Inventory Measurement Instructions Image Interpretation and Field Work”

7 Coconut Production

To estimate the coconut production in 100 field plots the available nut production of all palms were investigated. The nuts on the three oldest branches were counted divided by three and multiplied by 12.[4]

Normally healthy coconut production ranges between 70 and 100 nuts per year and per palm (FAO). During the field plots in Vava'u Island, Tonga the production calculated as shown in 07.01.

Stratum	Palms	Min	Max	Avg	StDev	StErr	StdEr %
Dense	162	0	104	29	19.0	1.3	4.7
Semi Dense	87	0	160	34	20.6	0.5	1.4
Scattered	33	0	80	36	21.0	2.1	5.7

Table 07.01: *Estimated coconut production per palm in Vava'u Island*

From the average production per palm the total production in Vava'u can be calculated see Table 07.02 There is another way to calculate the coconut production by calculating the average production per plot for the different strata.

Stratum	Area [ha]	Palms/ha	Palms	Nuts / Palm	Nuts
Dense	1,099	162	178,038	29	5,163,102
Semi Dense	3,697	87	261,209	34	8,881,106
Scattered	1,135	33	37,455	36	1,348,380
Sum	5,931		476,702		15,392,588

Table 07.02: *Estimated coconut per year in Vava'u calculated from the average production per palm.*

From the average production per plot the production per hectare can be calculated. The table 07.03 shows the minimum, maximum and average production per hectare for the different strata. The table also shows the standard deviation of the average and the standard error which the standard deviation divided by the square root of the number of plots. The standard error % sets the standard error in percent of the average to make the standard error comparable to other inventories.

Stratum	Plots	Min	Max	Avg	StDev	StErr	StdEr %
Dense	5	2,832	6,752	4,643	1,750.8	783.0	16.9
Semi Dense	82	192	5,424	3,002	1,071.5	118.3	3.9
Scattered	13	384	2,016	1,192	554.3	153.7	12.9

Table 07.03: *Calculated coconut production per hectare on plot basis.*

The standard error percent is below 5 for semi dense plots which is statistically acceptable. The standard error percent for dense plots is above acceptance but dense plots are not that important for coconut production.

If there is additional field work possible it should concentrate on semi dense coconut cover.

Stratum	Area [ha]	Nuts / ha	Nuts
Dense	1,099	4,643	5,102,657
Semi Dense	3,697	3,002	11,098,394
Scattered	1,135	1,192	1,352,920

Table 07.04: *Estimated nut production for Vava'u calculated from the production per hectare on plot basis.*

4 Details see “Inventory Measurement Instructions Image Interpretation and Field Work”

8 Dead Palm Trunks in Vava'u

Stratum	Min	Max	Average
Dense	0	68	4
Semi dense	0	36	1
Scattered	0	16	0.4

Table 08.01: *Estimated Dead palms per hectare in Vava'u Island*

The field work was carried out and found out that from the one hundred plot was investigated in Vava'u Island the number of dead palms. Dead palms were only found in 29% of all plots, however, related to the infrastructure improvement dead palms are beside the roads, where the plots are not located. The figures of recorded palms within the plots is therefore low in relation to the actually available dead palms in the area. There is the danger of a further increase of Rhinoceros beetle population which reduces the palm productivity.

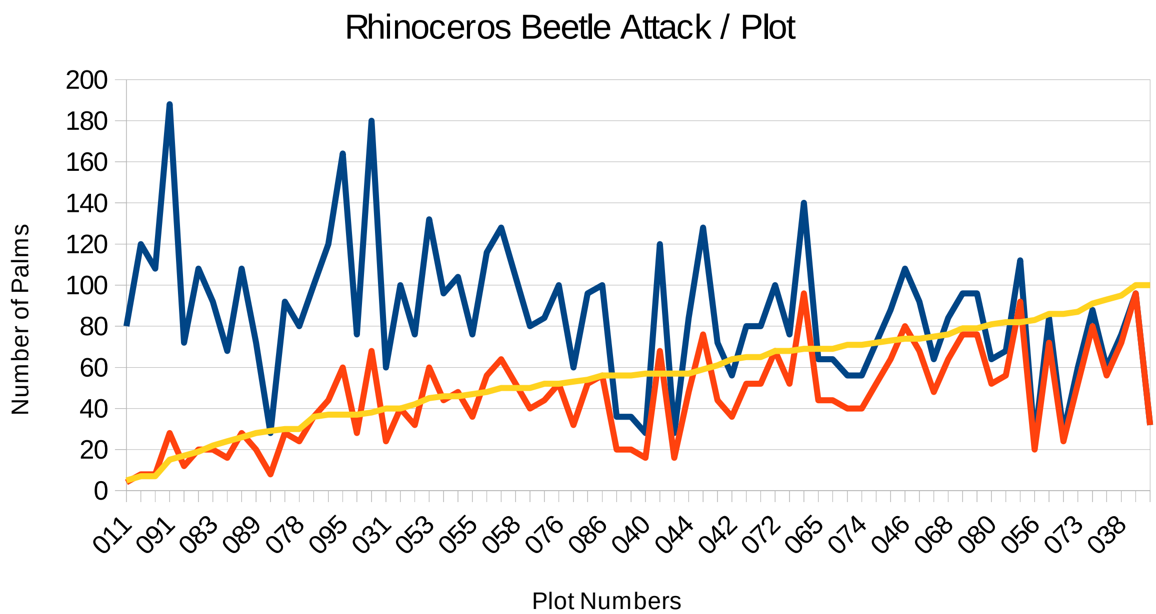
9 Health Condition of Coconut Palms

During the field the team was also look into the healthy condition of palms, the 100 plot was investigated In Vava'u island and found that most palms was already affected by Rhinoceros beetle and stick insect disease. Out of 2091 palms 814 or 39% were affected by beetle attack. Table 09.01 shows in the first row the number of affected leaves in the second row the number of palms.

No. of leaves	0	1	2	3	4	5	6	7	8	9
No. of palms	1277	814	661	444	260	146	72	27	9	2
Percentage	61.1	38.9	31.6	21.2	12.4	7.0	3.4	1.3	0.4	0.1

Table 09.01: *Number of palms affected by Rhinoceros beetle damage sorted by number of leaves affected.*

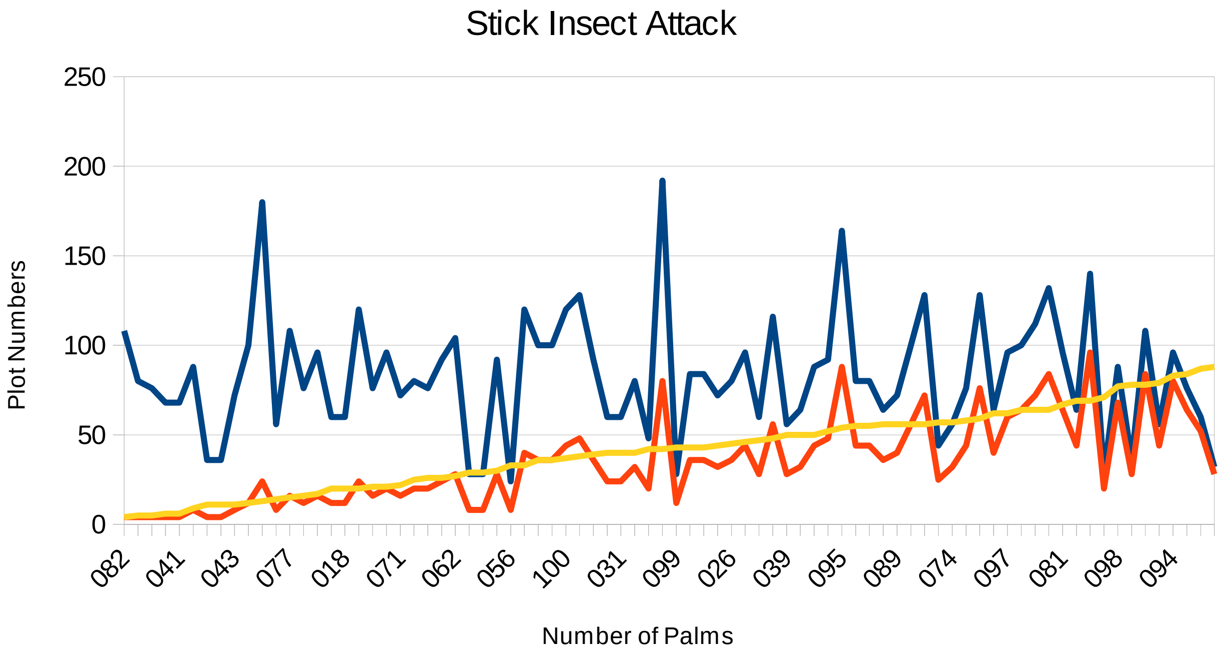
The third row shows the percentage of affected palms out of 2091 investigated palms. The ~40% of affected palms are distributed within 72% of all plots measured



Graph 09.02: *Number of palms / ha within plots affected by Rhinoceros beetle (red line) number of palms / ha (blue line). The yellow line shows the percentage of affected palms*

and this is the critical fact. The beetle seems has spread all over the coconut cover.

The other natural coconut palm enemy is the so called stick insect[5]. 80% of all plots are affected, the insect is spread all over the coconut cover of the Vava'u group.



Graph 09.03: *Number of palms / ha within plots affected by stick insect (red line) number of palms / ha (blue line). The yellow line shows the percentage of affected palms*

10 Amount of Hybrids in Vava'u

The hybrids in Vava'u island was investigated during the field work.

	Min	Max	Avg	Palms/HA	% of Palms
Dense	0	88	9	99	9.1
Semi dense	0	44	6	54	11.1
Scattered	0	24	5	30	16.7

Table 10.01: *Number of hybrids per hectare in different coconut strata and % of palm cover*

11 Regeneration

Stratum	Min	Max	Avg
Dense	0	88	22
Semi Dense	0	344	24
Scattered	0	72	14
All Strata	0	344	22

Table 11.01: *Number of counted young palms per hectare*

Only in 28 plots regeneration was counted 72 plots had no generation. 344 young palms per hectare were counted in plot number 018 in semi dense coconut cover. There is very little regeneration. Considering the age structure this situation is already like this since about 20 years.

5 Images of Rhinoceros and stick insect damage see Field Measurement Instruction

12 Recommendations

To increase the coconut production in the Vava'u group a planting seems to be essential. There is very little regeneration and there are very few palms in the young age groups (see figure 05.02). There is the danger of declining of production during the next years.

Another factor of declining coconut production could be caused by increasing Rhinoceros beetle population. There might be ways to utilise the coconut trunks lying on the ground. These trunks are still in good condition and should be removed from the area before they will be ideal breeding place for the beetle.

Figure 12.01: *Coconut trunks besides the road*