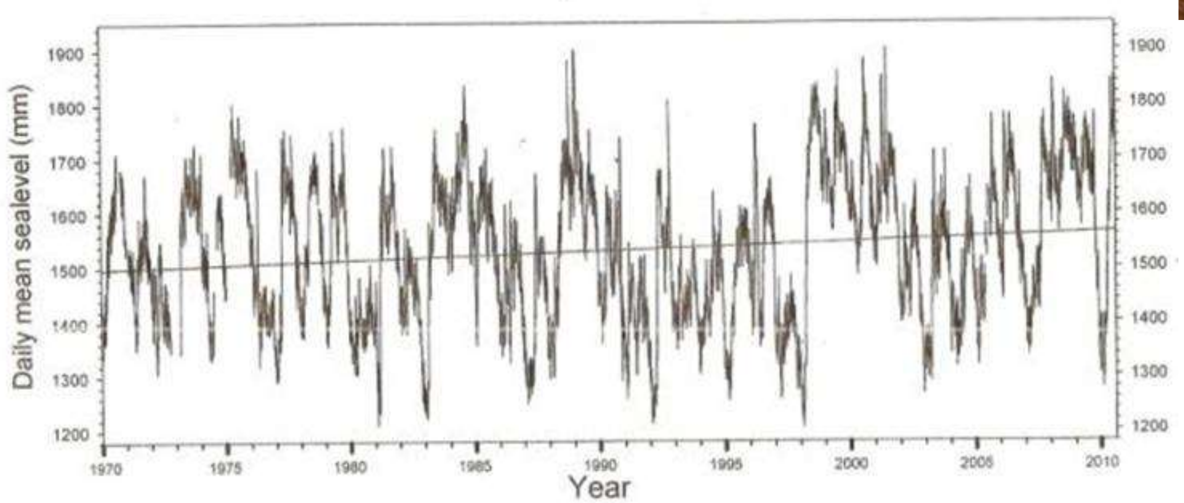
THE PALAU PACC FOOD SECURITYPROJECT: A BENEFIT COST ANALYSIS



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Contents

Executive Summary.....iv

List of Acronyms.....viii

The Problem:.....9

Climate change and food security in Palau.....9

Palau's food security situation.....9

Traditional agriculture and food security.....10

Under estimation of the value of food production.....10

Food imports.....12

Public health and nutrition.....12

Medium term climate projections for Palau.....14

Palau's climate.....14

Medium term projections.....15

Sea level rise and extreme tides.....15

Rainfall.....16

Temperature.....16

The Palau PACC food security pilot project.....16

The 'ridge' agroforestry applied research/demonstration pilot.....17

Current status of the Ksid 'ridge' applied research/demonstration site.....18

An assessment of the ridge pilot.....20

A reasonable time frame for an agroforestry demonstration pilot to generate useful results.....20

Recommendations for the 'ridge' applied agroforestry research/demonstration.....21

Wetland taro research and demonstration pilot.....22

The impact of extreme high tides of Palau wet land taro production.....22

The Ngimis village wetland taro pilot.....24

The current status of Ngmis pilot.....25

An assessment of the taro patch pilot.....28

A reasonable time frame for the taro patch research/demonstration to generate useful results.....29

Recommendations for the taro patch applied research/demonstration.....29

Overarching recommendations for the PACC activities.....30

Participation in FAO 'Soil Schools' Program.....30

Securing affordable sources of lime. 30
A benefit cost analysis for the PACC Palau terrestrial food security activities 31
A BCA for the PACC pilots to date 31
The Ngimis taro patch 31
The Ksid 'ridge' agro-forestry pilot 33
A BCA framework for evaluating the expansion of PACC pilot activities into a national food security program 35
Adaptation of the taro patches to extreme high tides 35
The benefits from expanding the wetland taro pilot 37
Identifying the benefits 37
Quantifying the benefits 37
The cost of expanding the wetland taro pilot 40
Comparing benefits with cost for the scaling up of the wetland taro pilot 41
Sustainable food production through upland agroforestry 41
The benefits from scaling up the sustainable upland agroforestry pilot 42
Identifying the benefits 42
Quantifying the benefits 44
The cost of expanding the agroforestry pilot 45
Comparing benefits with costs 46
A benefit cost analysis a consolidated sustainable food security development program 46
Overall conclusions 48
Annex 1: Budgets for assistance in the construction of earth dikes 49
Annex 2: Background information on Palau's potential sources of lime...................................50
Annex 3: Gross Margins for Small Scale Wetland Taro Production 52
Bibliography 53

Executive Summary

Palau is highly vulnerable to sea level rise and on-going climate extremes due to El Niño–Southern Oscillation (ENSO) events. The frequency and intensity of extreme climatic events (particularly extreme high tides) is also expected to increase under the pressures of climate change. This situation is already contributing to declining food production and is occurring at a time when Palau's income earning opportunities are decreasing.

Food security includes both physical and economic access to food that meets people's dietary and nutritional needs as well as their food preferences. Palau is facing increasing food security stress in all these respects.

The Pacific Adaptation to Climate Change Project (PACC) Palau Food Security Pilot encompasses a holistic 'ridge to reef' approach to food security. It involves three (3) components, all situated in Ngatpang State:

- **the 'ridge' component –** an agroforestry applied research/demonstration site situated on highly infertile, acidic and erodible soil;
- **the 'wetland taro' component** – an applied research/demonstration site that is subject to salt water incursion and;
- **the 'reef' component** – a mariculture demonstration site focussing on giant clams.

The overall justification for these components is to safeguard Palau's future food security, livelihoods and cultural identity in face of climate change. This benefit cost analysis (BCA) only covers the 'ridge' and 'wetland taro' components.

The 'ridge' agroforestry pilot has two broad long-term objectives:

- the development of sustainable food production systems on land that is not affected by extreme high tides and does not encroach on Palau's remaining primary forests and;

- the development of soil conservation systems that reduce erosion and runoff that damages Palau's marine environment.

The 'ridge' pilot has been initiated under difficult circumstances. The project is dealing with a particularly harsh agronomic environment. The task has been made all the more challenging by the delays in receiving approved funding for implementation. Given these circumstances, the Palau Community Action Agency (PCAA) implementation team has made a credible start-up to the pilot over its first five (5) months. An encouraging feature of the start-up has been the community involvement, including that of youth.

Recommendations for the 'ridge' applied agroforestry research/demonstration include:

- administrative issues be resolved immediately to ensure the timely flow PACC funds for implementation;
- continuation of the dry land pilot for at least another three (3) years;
- a detailed economic evaluation of the pilot be undertaken in 2017-18;

- undertaking baseline soil samples and analysis as a matter of priority;
- undertaking on-going data collection and evaluation;
- testing of alternative soil conservation methods;
- Initiation of parallel 'ridge' pilot on less harsh and more typical land; and
- The Bureau of Agriculture (BA) consider establishing an additional ridge pilot research station land in Aimeliik State.

Extreme high tides events are seriously undermining Palau's taro production. The objectives of the wetland taro pilot were to:

- evaluate tolerance and susceptibility of different taro varieties to salt water intrusion in a pilot patch in Ngimis, Ngatpang and;
- identify taro varieties that are resistant to saline conditions in taro patches.

All indications are that the Ngimis wetland pilot has been a well-managed joint effort between the Palau Community College/Cooperative Research and Extension (PCC/CRE) and PCAA. The pilot has generated encouraging preliminary results, with three (3) local varieties demonstrating a degree of salt tolerance. These will now be further evaluated in conjunction with improvements in the nutritional status of the soil.

It is unlikely the same results could have been achieved without the supplementary 'engineering' works; specifically the bolstering of the earth dike, improving water flows within the taro patch and the installation of a simple food gate. The introduction of salt tolerant varieties should not be seen as a sufficient condition to sustain wetland taro production.

The preliminary results achieved at the Ngimis taro patch are likely to be important for Palau. They are also potentially important for other Pacific island taro producers facing salinity problems, particularly those located on atolls.

Within its first year of implementation the taro patch pilot is already generating useful information on varietal salt tolerance and the effectiveness of appropriate 'engineering/hydrology' works. This compares with the 'ridge' pilot were it will take several years before useful data will be available. The difference can be explained by two (2) factors:

- the wetland taro pilot involves making adjustment to a well understood traditional cropping system producing a single short term crop and;
- the implementation of the wetland taro pilot has not been interrupted by inadequate and erratic funding.

More work at the Ngimis site is required to measure the impact of improving the nutritional status of the soil. However, the pilot has already justified the commencement of replication of the pilot with the expectation that this will be scaled up into a national program.

The main recommendations for the taro patch applied research/demonstrationare:

- continuation of the work at Ngimis site for confirmatory testing of varietal performance and to measure the impact of improving the nutritional status of the soil;
- initiate trials similar to Ngimis at two other locations identified by the PCC/PCAA team - only promising planting material from the initial trial should be utilised at the new sites; and,
- with the completion of the three (3) trials, and confirmation of the preliminary Ngimis results, the system should be roll out to interested taro growers.

It is anticipated that initial support will be required to ensure sufficient uptake of the system. This should be in form of:

- assistance in the enhancement of dikes and the construction of flow gates and flood gates; and,
- providingaccess to salt tolerant planting material and training (including participation in the 'soil school' program).

Three (3) major recommendations cut across both the 'ridge' agro forestry and taro patch development activities. These are:

- participation in the FAO funded 'Soil Schools' program;
- securing affordable sources of lime; and,
- improvingthe collection of agricultural production statistics to facilitate monitoring and evaluation.

A benefit cost analysis (BCA) is conducted at two (2) levels to determine if it is likely to be worthwhile:

- for farmers to adopt the findings of the pilots; and,
- investing private and public funds in a scaling up of the pilots into a national food security programbased on the PACC pilots.

Simulations are undertaken for four (4) climate scenarios facing wetland taro farmers. The benefits to the farmer(s) from adopting the package are the projected losses that would be incurred if the package had not been adopted. The benefits and costs are projected over a 25-year timeframe. The flow of benefits and costs are calculated in present value terms. The results obtained are summarised below:

	NPV (i=4%)	NPV (i=10%)	IRR
Scenario 1 (extreme high tide event every 5-years)	-15,390	-9,725	-
Scenario 2 (extreme high tide event every 4 years	-10,398	-6,582	-
Scenario 3 (extreme high tide event every 3 years)	-6,214	-4,698	-
Scenario 4 (extreme high tide event in years-1 and 4, and then adandoned if remedial years not taken	6,811	921	12%

These results indicate that it would not be financially viable for an individual farmer to invest in the Ngmis pilot capital investment and maintenance package, except in the extreme situation where salt water incursion forced the farmer to abandon the taro patch in a relatively short time frame. Based on these simulations it would seem unlikely that farmers would invest in the Ngmis pilot package without assistance (i.e. a subsidy) from government. Such a subsidy would be well justified, given the considerable flow on public good benefits arising from the protection of taro patches from salt water incursion. These are in the form of foreign exchange saved, improved nutrition, reduced health costs and cultural benefits.

The agro-forestry pilot commenced implementation in March 2012, with implementation constrained by an inadequate follow of funds. Given the nature of this agroforestry project, it will take several years before sufficient data will be available to undertake a meaningful BCA to determine if it is worthwhile for farmers to adopted the findings of the demonstration pilot. In order to undertake this BCA, it will be essential that the appropriate data be collected from the outset. The following data needs to be regularly collected:

- soil tests – pH and nutrient levels;
- quantity and type of soil additives and fertiliser applied;
- labor inputs and;
- crop yields and quality assessment.

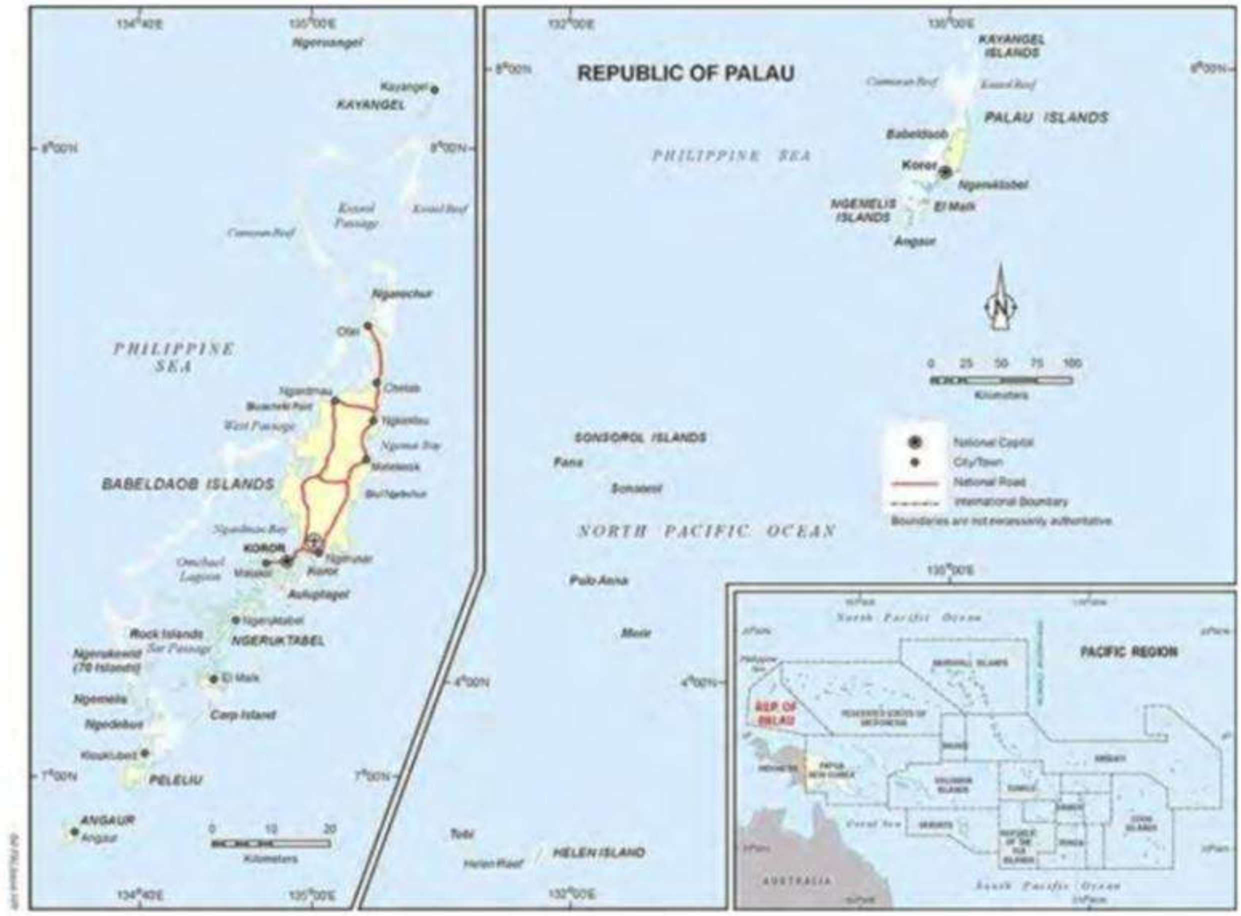
The overall conclusionsfrom the study are:

- The expansion of two terrestrial PACC pilot food security projects is justified and necessary.
- The expectation is, subject to the verification of the expanded pilots,it will be worthwhile investing private (farmer) and public (government and donor) funds in the scaling up of the pilots into a national sustainable food security program.

List of Acronyms

ABM	Australian Bureau of Meteorology
ACIAR	Australian Centre for International Agricultural Research
BA	Bureau of Agriculture
BCA	Benefit Cost Analysis
BCR	Benefit Cost Ratio
BMR	Bureau of Marine Resources
CePaCT	SPC Centre for Pacific Crops and Trees
CIRAD	Centre de cooperation internationale en recherché agronomique pour le dévelopement
CMIP3	Coupled Models Intercomparison Project Phase 3
CRE	Cooperative Research and Extension
CSIRO	The Commonwealth Scientific Industrial Research Organization
DSAP	SPC, Development of Sustainable Agriculture in the Pacific Project
ENSO	El Nino Southern Oscillation
FAO	Food and Agriculture Organization of the United Nations
FFS	Farmer Field School
HIES	Household Income and Expenditure Survey
IESL	National UNDP Informal Employment and Sustainable Livelihoods
IRR	Internal Rate of Return
NFTA	Nitrogen Fixing Tree Association
NGO	Non Governmental Organization
NOAA	National Oceanic and Atmospheric Administration
NPK	Nitrogen Phosphorous and Potassium Fertilizer
NVP	Net Present Value
OMV	Organic Matters Foundation
PAAC	SPREP, Pacific Adaptation to Climate Change Project
PCAA	Palau Community Action Association.
PCC	Palau Community College
PCCSP	Pacific Climate Change Science Program
SOPAC	Pacific Islands Applied Geoscience and Technology Division of SPC
SPC	Secretariat of the Pacific Community
SPCZ	South Pacific Convergence Zone
TTM	Taiwan Technical Mission
UNDP	United Nations Development Project
USDA	US Department of Agriculture

Map of Palau



Source: Government of Palau/SPC (2009)

The Problem:Climate change and food security in Palau

The islands of Palau are highly vulnerable to sea level rise and the on-going climate extremes due to El Niño–Southern Oscillation (ENSO) events. The frequency and intensity of extreme climatic events (such as prolonged droughts and cyclones) is also expected to increase under the pressures of climate change. This situation is already contributing to declining food production and is occurring at a time whenPalau's income earning opportunities are decreasing.

Palau's food security situation

Food security includes both physical and economic access to food that meets people's dietary and nutritional needs as well as their food preferences. The World Food Summit(2009)identified four pillarsof food security: adequacy (being able to grow your own food), access (having income to buy food), utilisation (knowledge of nutrition, storage and preservation) and safety. Palau is facing increasing food security stress across all four pillars.

Traditional agriculture and food security

Bishop (2001) describes Palau's traditional agriculture asbased on a multi-story agroforestry system, whereby tree crops provided a protective canopy to the intensive production of over 40 plant varieties. Under the traditional system, every Palauan woman had a garden (or gardens). Female-produced agricultural products together with communallyharvested marine and forest products provided a self-sufficient food system with in-built security against natural and economic disasters, pest intrusion, and old age.Today, remnants of the traditional system still remain although less than 3% of land is now under agro-forestry production. Most rural women and many urban women produce some of their household's food needs through cultivation of a garden or gardens. The taro gardens most closely resemble the traditional agro-forestry system although contemporary gardens are less intensively cultivated than those of the past. Although traditional methods of composting and mulching are still used, imported agricultural chemicals are also in use. Most crops produced in this informal economy are used for family food and customary exchange. Only small volumes reach the market and still smaller volumes are reflected in official economic statistics, which tend to paint a confusing picture of the actual level of food production. It is for this reason that agriculture's contribution is significantly under estimated. Estimation of the agricultural sector's contribution to GDP have been notoriously inaccurate in PIC national accounts and Palau is likely to be no exception.

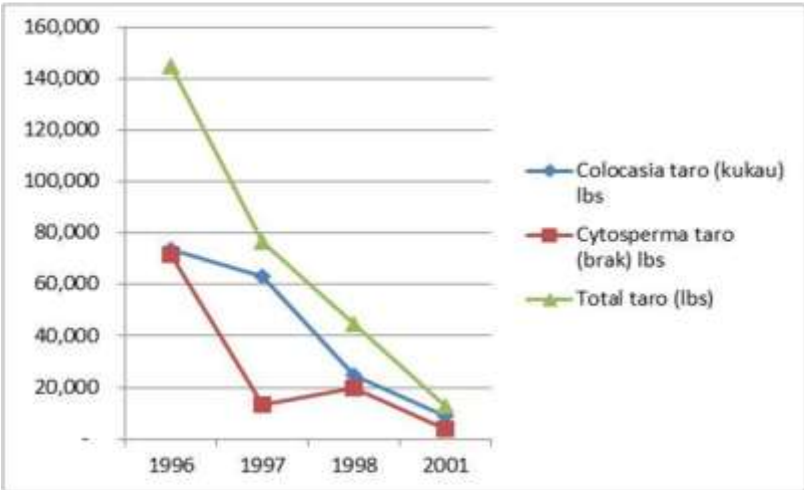
Under estimation of the value of food production

Subsistence crop production remains the predominant agricultural activity in Palau, with the main crops being taro, cassava, sweet potato, banana and coconut. Betel nut and betel pepper leaf are also commodities of considerable importance. 'Backyard' chickens and pigs are also important. Under-representation of informal production greatly complicates analysis of agriculture productivity. A 1996 survey by the Palau Informal Employment and Sustainable Livelihood Projectplaced the value of the informal sector (consisting primarily of agricultural products) at $5 million, or twice the value of agricultural products recorded in official economic statistics at the time. A significant proportion of the population earns a livelihood from the informal sector. This same survey reports an estimated almost 3,000 people generate income from the informal sector. Of this total, it was estimated that there were 665 persons involved in agricultural production and marketing, of which 86% were women.

Domestic trade in root crops also appears to be substantially underestimated by official statistics. The Office of Planning and Statisticsdata presented in the Palau Adaptation to Climate Change: Gap Analysis Report, indicates a collapse in taro production over the period 1996-2001 (table 1).

Table 1: Taro production estimates 1996-2001 (lbs)

	Colocasia taro (kakau)	Cytrosperma taro (prak)	Total
1996	73,723	71,526	145,249
1997	63,157	13,404	76,561
1998	24,545	19,957	44,502
2001	73,723	71,526	145,249

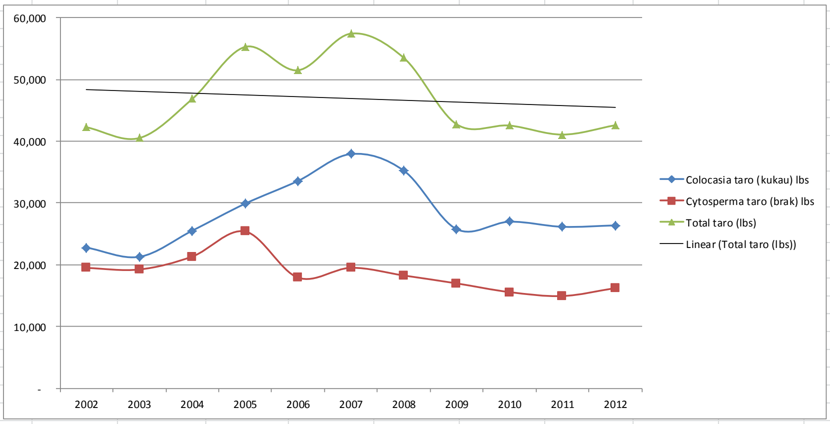


source: Kitalong Ann (2011). Palau Adaptation to Climate Change: Gap Analysis, Palau Bureau of Agriculture

Surprisingly there are no recent official estimates of Palau's taro production. However,data obtained in August 2012 from Palau's largest taro and root crop buyer show a quite different situation than that conveyed in "Gap Analysis" report (table 2). In 2002, Yano and Sons purchased 42,268 lbs of taro. This compares with the official estimate 12,583 lbs of total taro production in 2001. Yano and Sons are estimated to account for less than 50% of total taro purchased. Total taro production in that year is likely to be in excess of 200,000 lbs(90 tonnes) given that a significant portion of the taro grown is utilized by the household that grows the taro.

Table 2: Taro and other root crop purchases by Yano and Son – 2002 to 2012 (lbs)

	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	est. 2012
Colcasia taro (kukau) -fresh	3,556.5	2,615.0	8,003.5	13,509.8	13,789.0	17,399.0	12,968.0	10,033.8	11,295.0	10,695.0	9,822.4
Colcasia taro (kukau) -cooked	17,222.3	16,673.8	15,515.5	14,384.0	17,787.5	18,522.8	20,266.5	13,724.5	13,666.8	13,443.0	14,545.6
Colocasia taro - total	22,780.8	21,291.8	25,523.0	29,898.8	33,582.5	37,928.8	35,242.5	25,767.3	26,971.8	26,149.0	24,368.0
Cytrosperma taro (brak) - fresh	66.0	156.0	213.0	398.8	-	104.0	92.0	-	-	-	-
Cytrosperma taro (brak) - cooked	19,420.8	19,081.5	21,121.5	24,990.8	17,917.0	19,402.3	18,172.5	16,983.3	15,574.5	14,935.5	16,219.2
Cytrosperma - total	19,486.8	19,237.5	21,334.5	25,389.5	17,917.0	19,506.3	18,264.5	16,983.3	15,574.5	14,935.5	16,219.2
Total taro	42,267.5	40,529.3	46,857.5	55,288.3	51,499.5	57,435.0	53,507.0	42,750.5	42,546.3	41,084.5	40,587.2
Cassava (diokang)	14,303.0	18,028.0	19,416.0	20,020.0	15,806.0	17,800.0	17,481.0	14,981.3	13,338.5	8,993.0	9,708.8
Sweet potato (emuti)	528.8	225.5	1,696.3	378.5	449.8	109.5	579.5	704.3	386.3	299.3	221.6
Total root crop purchases (lbs)	57,099.3	58,782.8	67,969.8	75,686.8	67,755.3	75,344.5	71,567.5	58,436.0	56,271.0	50,376.8	50,517.6
Total root crop purchases (tonnes)	25.5	26.2	30.3	33.8	30.2	33.6	31.9	26.1	25.1	22.5	22.6
Yano and Sons total taro purchases											
	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Colocasia taro (kukau) lbs	22,781	21,292	25,523	29,899	33,583	37,929	35,243	25,767	26,972	26,149	26,380
Cytosperma taro (brak) lbs	19,487	19,238	21,335	25,390	17,917	19,506	18,265	16,983	15,575	14,936	16,219
Total taro (lbs)	42,268	40,529	46,858	55,288	51,500	57,435	53,507	42,751	42,546	41,085	42,599



source: Data supplied by Yano and Sonsto the Palau PACC BCA team

Importantly,the Yano and Sons taro purchase data indicate that Palau still retains a critical mass of taro production and would justify the investment in the PACC wetland taro research/demonstration pilot. Whereas the official taro production figures suggest that wet land taro might have reached an irreversible state of decline and there would be little point in investing in taro production. There is clear need to improve official agricultural production statistics to improve public policy decision making.

Food imports

Palau has high and increasing levels of food imports. Ryan (2009) notes that food imports have grown by 133 % in the last decade, while the population has increased by 20% (p.1). In 2010, the total value of food imports was $24.5 million, of which rice, wheat flour and pasta and noodles were value at $2.4 million (10%) (table 3). Palau's food imports constitute over 10% of GDP.

Table 3: The value for customs purposes of Palau grain imports, 2007 – 2010 (USD)

	2007	2008	2009	2010
Rice (1006)	1,177,625	1,779,569	2,084,345	1,645,367
Wheat flour (1101)	102,283	162,949	146,895	123,561
Pasta/noodles (1902)	611,574	672,138	701,852	673,427
	1,891,482	2,614,656	2,933,092	2,442,355

Source: Palau Bureau of Revenue Customs and Taxation

The 2006 Household Income and Expenditure Survey (HIES) shows imported food constituting between 81% - 84% of total food consumption - making Palau one the least food secure Pacific island country [1]. These results confirmed the findings of Judy Otto in 2000 that imported food constitutes more than 90% of the average household diet in Palau. To date, Palau has been able to bridge the food import gap with foreign exchange earned through services (largely tourism) and aid transfers.

Public health and nutrition

Palau enjoys low infant mortality (20 deaths per 1,000 live births) and high life expectancy (71.8 years) (SPC PRISM). These excellent health indicators are the result of good sanitation, education, and public health services standards, which have communicable diseases under control. However, the Palau National Committee on Population and Children(CoPopChi) noted back in 1999 that Palau was at a transitional stage with respect to health that relates to diet and life style. To quote the CoPopChi report:

[1] Estimates of the proportion of Imported Food in Total Food Expenditure derived from HIES include:

- Solomon Islands, 35–44% (2006)
- Samoa, 56% (2002)
- Tonga 45% (2001)
- Federated States of Micronesia, 39% (2005)
- Kiribati, 36% (2006)

> changing lifestyles and **dietary patterns** combined with alcohol, tobacco and betel nut use and abuse threaten to spawn an epidemic of non-communicable diseases which create new challenges for both public health and curative services (1999 p. 109).

The CoPopChi concluded that besides tobacco, the single greatest factor affecting the health of Palauans is diet and related obesity. The prevailing dietary patterns, which contribute to weight problems and associated ill heath were listed as:

- a general pattern of over-consumption relative to exercise;
- over-consumption of protein in general and low quality protein in particular (e.g. canned meats high in salts, fats and preservatives);
- low consumption of fruit and vegetables;
- high consumption of rice and declining consumption of more nutritious taro;
- a preference for imported processed food; and,
- low levels of nutritional awareness.

Obesity, combined with high sugar and salt intake, results in increasing prevalence of chronic diet-related diseases – hypertension, diabetes, gout, renal disease and cardiovascular diseases. The 1999 Palau National Plan for Action in Nutrition points to the particularly dramatic increase in diabetes. The Plan further notes that specific micro-nutritional deficiency problems are now becoming apparent – notably nutritional anaemia amongst women of reproductive age and vitamin A deficiency amongst children. The scale of the problem has now reached such a level that it prompted President Toribiong, in 2011, todeclared a “State of Emergency” in relation to the rising cases of NCDs in Palau.

The nutritionaldeficiencies that result from the substitution rice and other imported grains for traditional taro can be seen table 4.

Table 4: Comparison of nutrients in 100 gm edible portions of boiled taros and white rice

Food item	Kcal*	Fibre (g)	Calcium (mg)	Iron (mg)	Zinc (mg)	β-carotene equiv. (μg)	Thiamin (mg)	Vitamin C (mg)
Taro corm, *Colocasia*, white	99	0.8	34	1.0	0.8	38	0.08	5
Taro corm, *Colocasia*, yellow	126	1.0	44	1.3	1.0	38	0.11	7
Giant swamp taro corm, *Cyrtosperma*, color unspec.	72	2.5	165	0.6	1.9	27	0.02	7.9
—white/cream colored	na	na	na	na	na	55–300	na	na
—yellow-colored	na	na	240–1,440	1.4–3.6	4.1–63	460–4,486	na	na
Taro corm, *Alocasia*	79	1.8	169	0.9	na	na	0.10	1.1
Taro leaves, *Colocasia*	28	2.5	214	1.7	0.3	4,973	0.06	20
Taro stalk, *Colocasia*	26	0.7	114	1.9	0.4	94	0.00	2
Rice, white	123	0.8	4	0.3	0.6	0	0.03	0

* Energy expressed as kilocalories. Note: one heaped cup of cooked taro corm or rice weighs ≈250 g

source: SPC2006, Taro, Pacific Food Leaflet No. 5. Healthy Pacific LifestylesinManner 2011, p.12

Palau’s nutritional problems relating to starch consumption are further compounded by a low overall consumption of fruit and fleshy vegetables. In large measure, this can be attributed to damage caused by Oriental fruit fly(McGregor 2000). The Oriental fruit fly (*Bactroceradorsalis*) is arelatively recentintroduction to Palau, dating back only to the mid – 1990s. It is reported that prior to its arrival, fruit flies in Palau did little obvious damage (Allwood*et.al*. 1999).

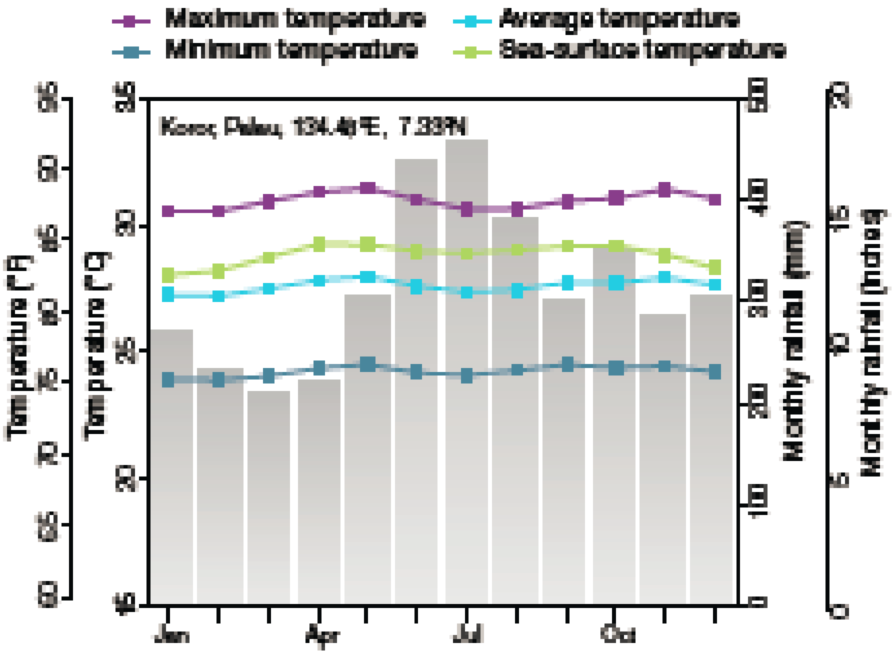
Collectively, theselifestyle and diet related health problems significantly reduce the wellbeing of individuals and households. The adequate consumption of root crops and fruit and vegetables has a critical contribution to make in addressinghealth problems and reducing their cost to society.

Medium term climate projections for Palau

Palau's climate

Palau has a tropical moist climate. The maximum and minimum temperatures do not fluctuate markedly through the year (Figure 2). However, rainfall is highly variable, with a distinct wet season (May to November) and dry season (December through April).

Figure 1.Koror mean annual temperature and rainfall



source:Australian Bureau of Meteorology and CSIRO 2011, p. 158.

Relative humidity averages about 90 % at night and 75-80% during the day (National Oceanic and Atmospheric Administration, Hawaii). The average annual rain fall for Koror lies between 3,500 to 3,700 mm. However, there is considerable annual variability in rainfall ranging from 3150 mm to 4400 mm.

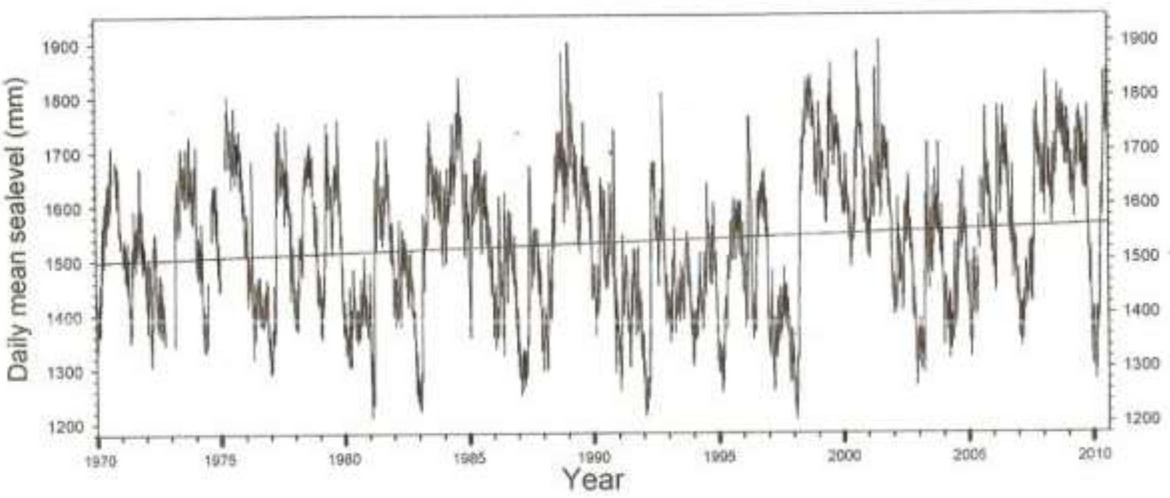
Palau's proximity to the equator means that it is outside the normal typhoon zone. The El Niño–Southern Oscillation (ENSO) has a major influence on Palau's climate. Archaeological studies on Angaur refer to an extreme El Niño in the 16th Century (Clark and Wright 2005). ENSO events occur every 3–8 years or so and are usually accompanied by periods of low rainfall (during the El Niño phase) followed by periods of high rainfall (during the La Niña phase) of the cycle.

Highest tides tend to occur around the equinoxes, with the September peak the larger of the two. Hourly tidal measurements taken in Malakal Harbour show little variation in the average seasonal cycle. However, there is a strong ENSO influence with sea level by over 0.3 ft (0.1m) during La Niña years and the increase is most pronounced from July to January (PCCSP, p. 162). The seasonal and tidal components combine to create the highest likelihood of extreme high tides from August to

October. Such extremes were demonstrated in the tidal events of September 2011 and August 2012.

Underlying these extreme tidal fluctuations has been a gradual increase in the average annual sea level(figure 2). The Pacific Climate Change Science Program (PCCSP)report that sea-level rise near Palau since 1993 has been over 0.3 inches (9mm) per year, larger than the global average of 0.125 ± 0.015 inches (± 0.4mm) per year (p. 61). The PCCSP Report notes that this rise is 'partly linked to a pattern related to climate variability from year to year and decade to decade.'

Figure 2: Palau's extreme tidal fluctuations illustrated by the daily mean sea level for Koror harbour



source: Hawaii Sea Level Center data – supplied by Patrick L. Colin Coral Reef Research Foundation, Koror Palau.

Medium term projections

It is expected that future ENSO cycles are likely to continue to be a significant contributor to climate variability for Palau and the region as a whole. However, it is unclear whether global climate change will affect the strength or occurrence of these ENSO cycles in the future (Solomon and Newman, 2012).

Sea level rise and extreme tides

There is a high level of certainty that the seasonal and tidal components that combine to create extreme water levels from August to October will continue into the foreseeable future. Underlying this ongoing cycle, an increase in average sea levels can be expected with a high level of confidence during the course of the 21st century. This projection of average overall sea level is based on two factors listed in thePCCSP Report:

- Sea-level rise is a physically consistent response to increasing ocean and atmospheric temperatures, due to the thermal expansion of the water and the melting of glaciers and ice caps.
- Projections arising from all the models cited agree the direction of the change[2].

[2]Coupled Models IntercomparisonProject Phase 3 (CMIP3)

The models used by PCCSP Report simulate rises of between 5-15 cm by 2030, with increases of 20-60 cm indicated by 2090, under the higher emission scenarios.

Rainfall

For Palau, wet season (May-October), dry season (November-April) and annual average rainfall are projected to increase over the course of the 21st century, with the PCCSP indicatingmoderate confidence in this direction of change (p. 164). Increased intensity of rainfall means more soil erosion and runoff on Babeldaob'sdegraded erodible soils. This has adverse implications for both Palau's terrestrial and marine food security and undermines future income earning opportunities from tourism unless remedial measures are taken.The PCCSP expects the frequency of moderate and severe drought to remain approximately stable.What is less clear for the Pacific islands,is the association of extreme drought conditions with ENSO events.[3]Prolonged droughts have serious implications for traditional staple crops such as*Colocasia*taro which have low tolerance for moisture stress when they are grown in dry-land conditions. It is not possible to grow vegetables under water stressed conditions without some form of supplementary irrigation.

Temperature

Warming trends have been evident in both annual and seasonal mean airtemperature since the 1950s (PCCSP 2011). The surface air and sea-surface temperature are projected, with a very high degree of confidence, to continue to increase over the course of the 21st century[4].

Increasing temperature, particularly minimum night time temperature, has major implications for Pacific islands agriculture. Spence and Humphries (in Lebot 2009) found that sweet potato produces the greatest increase in storage weight when grown over a constant soil temperature of 30^{o}C, combined with a night air temperature of24°C (p.132).Bourke and Harwood (2009) report that tuber production in PNG is reduced significantly at temperatures above 34°C. They also indicate the possibility of increased incidence of some diseases with increasing temperature, particularly those influenced by rainfall and humidity (2009, p.79)[5].

The Palau PACC food security pilot project

The PACC Palau Food Security Pilot Project has adopted a holistic ''ridge to reef'' approach to food security. It involves 3 components, all situated in Ngatpang State on Babeldaob.

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[3]For much of the region there is an evident correlation between severe drought and El Niño events. For the atoll countries in the equatorial Pacific Ocean (Kiribati, Tuvalu and Nauru) the La Niña phase can be accompanied by below average rainfall. The extreme drought conditions experienced in Kiribati in 2010-11 corresponded with a prolonged La Niña. The La Niña that prevailed between late 2010 and early 2011 was one of the strongest observed, in a record dating from the late 1800s (pers. comm. Neville Koop). The 2010-11 period saw above average rainfall in Fiji, the Solomon Islands and Samoa and drought in Kiribati and Tuvalu.

[4] The majority of CMIP3 models simulate a slight increase (<1.8°F; <1°C) in annual and seasonal mean temperature by 2030, however by 2090 under the A2 (high) emissions scenario temperature increases of greater than 4.5°F (2.5°C) are simulated by almost all models

[5]Taro leaf blight (*Phytophthora colocasiae*), is a clear case in point, where the incidence of the disease is highly correlated to minimum night time temperature and relative humidity (McGregor et.al. 2011, p. 10).

- **The 'ridge' component –** Ksid ridge. This is an agroforestry applied research/demonstration site situated on volcanic soil that can be described as highly infertile, acidic and erodible. The'ridge'componentis being Palau Community Action Agency (PCAA).
- **The'wetland taro' component** – Ngimis Village taro patch. This applied research/demonstration site is situated adjacent to a mangrove swamp and thus subject to salt water incursion. The focus is on managing salt was incursion and varietal testing for salt water tolerance. This component is being jointly implemented by the Cooperative Research and Extension (CRE) Department of the Palau Community College (PCC) and the PCAA.
- **The 'reef' component**. This mariculture demonstration site focusses on giant clams and is being implemented by the Bureau of Marine Resources (BMR).

The overall justification for these components is to safeguard Palau's future food security, livelihoods and cultural identity in face of climate change and other economic and demographic factors.

This benefit cost analysis (BCA) only covers the 'ridge' and the'wetland taro'components.

The 'ridge' agroforestry applied research/demonstration pilot

The agroforestry pilot has two broad long term objectives:

• The development of sustainable food production systems on land that are not affected by extreme high tides and do not encroach on Palau's remaining primary forests.

• The development of soil conservation systems that reduce erosion and runoff that damages Palau's valuable but fragile marine environment.

The traditional approach to dry land farming in Palau has been one of shifting cultivation. Forest areas were cleared, farmed and left in prolonged fallow once the soil fertility was lost. Bob Bishop, President of the of the Palau Organic Growers Association, notes "Palauans rarely planted on slopes however they did have techniques e.g. terracing, 'stab' and plant, biochar, mulching, trench composting, debris across slope, etc. for planting on slopes when necessary. They planted in forested slopes when they felt the need" (*per. comm*. August 2012). The clearing of primary forest areas to grow food is no longer an option.

The underlying technical justification for an applied research demonstration trial can be found in the USDA, Soil Conservation Service (1983) Palau Soil Survey:

> Organic matter is the most important part of soil fertility in Palau soils. It increases the ability of the soil to retain nutrients and water. It improves soil structure and tilth. It also provides a home for soil organisms that are an important part of nutrient cycles. Increasing the content of organic matter through mulching and other means also decreases the negative effects of soil acidity on crop production by making soluble aluminum less available to plants. In most of the soils on uplands and marine terraces of the volcanic islands, the upper 10 to 15 cm (4 to 6 inches) has the most nutrients for plant growth. These include Aimeliik, Babelthuap, Ngardmau, Ngatpang, Palau, and Tabechedingsoils. Of these, Aimeliik soils are the most fertile and the Babelthuap and Ngardmausoils

are the least fertile. Nutrient management on upland soils in Palau is difficult. The soils in non-forested areas have low fertility in both the topsoil and subsoil. They are low in content of organic matter, are generally acidic, and lack sufficient phosphorus for adequate plant growth. Also, they generally are low in other macronutrients, including potassium and nitrogen. Forested soils in Palau (primarily Aimeliik soils) have relatively fertile topsoil, but they can quickly lose their fertility after forest clearing, burning, and then cultivation, which can lower the content of organic matter Increasing the content of organic matter through mulching and other means also decreases the negative effects of soil acidity on crop production by making soluble aluminum less available to plants. For most of the upland soils, the soil pH needs to be raised to only about 5.5 in order to remove soluble aluminum as a problem for plant growth. On many acid soils, between 2 and 4 tons of lime per hectare are required to raise the soil pH to 5.5 or higher(pp 144-145).

Current status of the Ksid 'ridge' applied research/demonstration site

Figure 3: Colocasia taro planted on the Ksid ridge responding to soil amendments

Figure 4: Coconuts planted on the Ksid ridge, responding to the addition of organic matter

The pilot is located in Ngatpang State on site adjacent to the BA's Taiwan Technical Mission (TTM) coconut trial plot. Most soils found on Babeldaob are degraded volcanic soils with high acidity and low fertility. The Ksid 'ridge' has particularly poor soil[6] - but was chosen because of its availability and reasonable accessibility.

[6] The USDA Soil Survey classify the soil as Tabecheding silty loam, 12 to 30 slopes, severely eroded. This unit is poorly suited to crop production. It is limited mainly by very low soil fertility, slope, and the hazard of erosion. If lime and large amounts of compost and other organic fertilizer are added to the soil and drainage provided, moderate yields of many subsistence crops can be obtained. This unit is moderately suited to certain woodland species adapted to wetness, high acidity, and very low soil fertility (p, 38).

Soils test are required to guide the planning of the pilot and to provide a bench mark to measure the impact of the measures undertaken. These tests are now urgentlyrequired.

The implementation of thepilotcommenced in April 2012 under the management of the PCAA's Extension Officer Leonard Basilius. The pilot has involved the initiation of an alley cropping system on a 94 sq metre block. The youth from the Ngatpangvillagehave been mobilised to provide labour and to receive hands on training in agro-forestry practices. Contours were marked along which ferns were removed and trees planted. The trees planted were predominately fruit and timber species, including coconuts, mahogany,soursop, rambutan, avocado, topical almond and banana. The trees were planted in cm planting holes with the addition of top soil secured from nearby forest areas. A small quantity of commercially availablefertiliser NPK (10-30-10) was added after planting. Lime, seaweed and animal manure were not added at the time planting because they could not be accessed. These are to be included in all future tree plantings provided sufficient funds are made available at the time required.

Unfortunately, nitrogen fixing leguminous trees were not planted with the initial planting phase. Manager Leonard Basiliushas expressed interest in planting *Leucaenaleucocephala*and *Gliricidiasepium.* The desirable properties of these tree species are as follows: they have

- high leaf nitrogen concentration;
- tolerance to excessive soil acidity[7];
- tolerance to excessive soil salinity;
- relatively high leaf tannin content[8]; .
- repeated and vigorous resproutingandregrowth after pruning; and,
- multi-purpose application (firewood/charcoal, pig fodder, and timber or poles for construction).

Leonard Basiliusis aware of these desirable properties but hasbeen reluctant to plant these species because he had no certainty of the period of the pilot and the flow of funds. *Leucaenasp*. and*Gliricidiasp*.have a reputation for weediness, unless well managed. Accordingly, there was concern that the site may become a weed source, should the pilot be prematurely abandoned.

Between the rows of treesa 45 m^2 (150 ft^2)patch of *Colocasia*(kukau) taro has been planted. A smaller block of sweet potato and pineapples hasalso been planted. The land was prepared with a hand tiller. At the time of planting the taro, commercial dolomite (lime) and NPK (10-30-10) was added at the rate of one handful per planting hole. There have been no soil amendments for the sweet potato or pineapples[9]. The taro block has included both tissue culture and non-tissue culture planting material. Land is now being prepared for the planting of cassava and *xanthosoma*taro.

[7]Bob Bishop (President of the of the Palau Organic Growers Association) indicated that the *Leucaena* sp. common in Palau is not tolerant to highly acid soils. However, the imported 'acid ipil' is tolerant to highly acid soils however it is rare.

[8]This is desirable in very humid, warm environments where the rapid break-down of organic matter prevents the build-up of a protective mulch or humus layer.

[9] This is likely to lead to production problems. Bob Bishop notes that "traditional knowledge in Palau states to grow on that type of soil well sweet potato requires the addition of dried grass and weeds and pineapple requires dipping in ash with a supplemental addition of one handful of ash".

Figure 4: Local youth preparing land for planting root crops on the Ksid ridge

An assessment of the ridge pilot

The Ksid 'ridge' pilot has been initiated under difficult circumstances. This is a particularly harsh agronomic environment. The task has been made all the more challenging by the reported significant delays in receiving funding that had already been approved. A particular constraint for the manager is not having access to a reliable vehicle. Given these circumstances, the PCAA team has made a credible start-up to the pilot over its first 5-months[10]. The following observations were made from two site visits:

- Relatively healthy coconut trees compared to the coconuts planted on adjacent BA block - which had received no soil amendments (figure 4).

- Healthy looking taro – particularly the tissue culture material (figure 3). Not surprisingly the sweet potato displays significant nutrient deficiency.

- Pineapples, a crop suited to acid soils, were faring well – although they too would have benefited from application of soil amendments.

An encouraging feature of the start-up has been the community involvement, including that of youth.

The estimated budget for the satisfactory completingthe Ksid 'ridge' agro-forestry pilot is $34,350 , which includes $8,000 provision for a flat-bed truck (table 5). There is an additional cost for training, which includes participating in the FAO funded 'soil school' program.

A reasonable time frame for anagroforestry demonstration pilot to generate useful results

A successful 'ridge' pilot needs to build on local agroforestry knowledge and international experience to achieve economic and sustainable production from infertile acid soils. Palau does not have alluvial flats lands. Thus attention, by necessity, has to be focussed on more difficult upland

[10]The following was observed during two visits to the site:

soils. The pilot needs to demonstrate that under these conditions suitable root crops, fruit trees and timber species can be grown as part of viable farming system. The pilot needs to specifically evaluate and demonstrate such things as:

- alley cropping systems using various nitrogen fixing trees;
- soil capturing grasses to eliminate polluting impacts on Palau's marine environment; and,
- economic soil amendments – particularly lime applications and composting systems.

Areasonable timefor such a pilot to generate useful results under favourable implementation circumstances is three to five years. This extends beyond the life time of the current PACC project, which has been extended mid-2014.There are three interrelated reasons why such an extended time period is necessary:

- Limited traditional dry land agricultural knowledge upon which the pilot is based –this contrasts to the situation with the wet land taro pilot.
- Restoring soil health is a gradual organic process.
- Agroforestry by definition involves the planting and trialling longer term tree crops.

Under these circumstances a short term pilot agroforestry project will be little value and prove a waste of donor, government and community resources. Thus consideration needs to be given to extending the 'ridge' pilot into **PACC plus.**

Recommendations for the 'ridge' applied agroforestry research/demonstration.

- **The dry land pilot needs to continue for at least another three (3) years.**This recommendation presupposes an adequate and timely flow of funds. If this does not occur, there is little point in continuing with this activity as it will not deliver meaningful results.
- **Baseline soil samples need to be taken at the Ksid site and sent for analysis as a matter of priority.**
- **Systematic data collection and evaluation.** To successfully evaluate the pilot, soil tests need to be regularly taken and systematically analysed. Data needs also to collected on soil additives and fertiliser applied, labour inputs and crop yields.
- **Testing alternative soil conservation methods.** Consideration should be given to incorporating *Vetiveria zizanoides* (Vetiver grass) rows into the pilot for soil conservationand as a measure to reduce runoff into the marine environment[11]**.**

[11] It reported that past efforts to establish vetiver grass in Palau were unsuccessful. The likely reason for this is that required small amount of fertilizer was not applied during the critical initial establishment phase. Don Miller, who established a successful rehabilitation program on severely eroded soils in Aneityum Vanuatu, noted the following: "The soil conditions in Palau appear to be very similar to those found on Aneityum - the vetiver didn't do well on Palau as the wrong fertilisers were applied in the wrong way. My initial plantings didn't do well either until I spent 4 years trialling a number of fertiliser regimes. I have used only 500kg of NPK on Aneityum over a 10 year period and I can bet virtually none of it ever reached the sea. However, the vetiver grass has prevented a very large amount of soil runoffinto the marine environment" (*Pers. comm*, Aug 2012). The photographs of land rehabilitation on Aneityum using vetiver grass over a 5-year are presented in annex 4.

Table 5: The estimated budget for the satisfactory completion of the Ksid 'ridge' agro-forestry pilot*

Activity	Description	Units	$
Equipment rental	Dump truck for delivery of course rock for the construction of road to the project site	truck hire @$100/delivery X 5	500
	Back hoe for road repair	back-hoe hire @$100/hr X8	800
	Dump truck for delivery of liming material	truck hire @$100/delivery X 10	1,000
Fuel	Transportation for implementation and monitoring of activies	$50 per trip x 20	1,000
Purchase of inputs	liming materials	average $25/yard^3 x 200	5,000
	NPK for the establishment of vettiver grass	$50/50 lb bag X 5	250
	Planting material acquisition		1,000
	Shredder and accessories	$900X2	1,800
	Construction of composting facility - for farmer training and to supply compost to "ridge" pilot.	Cost of materials only, labor will be supplied by the youth and the in-kind contribution of State Gov	5,000
Labor	Hired labour (max 5)	$40x5x50 days	10,000
Vehicle	A used flat-bed truck to support the pilot		8,000
Total			**34,350**

* based on information provided Leonard Basilius

- **A parallel 'ridge' pilot should be initiated on less harsh and more typical land.**The Aimeliiksoil classification is seen as being more typical[12] and with a greater probability of the demonstration succeeding. This parallel pilotshould also be implemented by the PACC – utilizing the community, particularly youth, from the State in which the parallel pilot is located.
- **Consideration be given to the BA establishing an additional ridge pilot research station land in Aimeliik State**. This would provide a broader base and a wider demonstration of the agroforestry findings.

Wetland taroresearch and demonstration pilot

The impact of extreme high tides of Palau wet land taro production

Extreme high tides events are seriously undermining taro production. The 2012 PACC Palau Farm Survey Report estimated that there were 575 wetland taro patches (*mesei*) with a total area of 761, 174 m3 (PALARIS 2012 p, 5).

The description below of wetland taro production in Palau is provided by Basilius (2007).

> By far most taro grows in swamps. Taro swamps are arranged very skilfully and thoughtfully, usually near mangrove swamps. The various fields are irrigated by running water and resemble

[12] According to the USDA, Soil Conservation Service, Aimeliik soils make up 45 percent of Palau soils.

> the rice fields in that they are terraces and one is always slightly higher than the next. They are separated from each other by small embankment with paths. Narrow water channels are found next to these paths and sometimes on them. The fields had been laid out long time ago by the fore parents, probably designed and constructed by the men from the whole village. The patch (mesei) is very important not only for food security but as a pride, a family that does not have a mesei is considered poor or lazy. The mesei is inherited through maternal linage and sometimes marriage. The taro patch was the main source of staple food (Ongraol) for the families. There are four sections that make up a taro patch (Ulecharo, Bluu, Urars and Uleboel), each of which has its own function. Ulecharo –grown for the purpose of daily consumption; Bluu -reserved for special occasions or custom; Urars -household consumptions, given away or sold for income; and Uleboel -for exceptional events or sold for money
>
> Any particular taro swamp will be subdivided into as many as thirty or more fields (mesei). These fields in turn will be sub-divided units which farmers can easily recognize and keep apart.

Basilius (2007) taro vulnerability assessment further notes:

- All states in Palau except Sonsorol have taro patches.
- Each State has two (2) or more taro plots ranging from a ½ to 5 acres. These larger plots are subdivided into smaller patches.
- Each village will have its own taro patch plots or share one large plot with another village.
- Each taro patch varies between 250 to 2000 square feet.
- Taro patches are owned byclans, families and individuals.
- Taro patches that were establishedmany years ago are still maintained today.
- There are very few low lands that were not at one time converted into a taro patch.

The Damage Assessment Report of the National Emergency Office on the extreme high tides experienced in September 1998 describes process of saltation of taro patches and its impact.

> **Koror and Beldaob**: In these areas , taro patches close to mangroves and in low-lying areas were affected the most. Almost eighty percent of the crop in reported taro patched was destroyed . Its appears that most of the salt water entered the taro patches by ways of streams and channels which then inundate the drainage ditches surrounding the taro patches and get into taro patches . Only the States of Ngardmau and Ngeremlengui appears that the water enters through rivers and get over the dikes, which than flooded the taro patches. This phenomenon apparently occurred during high tides. In fact , some of the taro patches that were visited during high tide were completely flooded with salt water.
>
> Due to recent heavy rains, some of the crops still have green leaves and show no visible adverse signs of salt-water inundation. However ,upon digging to the taro tubers, we discovered that most of purple taros (dait) had already rotten away . The tubers of both types of taro emitted stagnant odors.
>
> Some local residence transplanted their taros from this low-lying areas to a higher ground after they discovered the salt water inundation . Others actually harvested their immature crops. Those who did not have an alternate replanting locations simply watched their immature crops wither.

In that same year the Coordinator of the National Informal Employment and Sustainable Livelihoods (IESL) Project undertook a taro damage survey. He found that large areas of low-lying and inadequately maintained plots were still inundated with salt water – with crop losses between 75 - 100% (Bishop 1998 p, 1). In discussing future mitigation measure it was noted:

> In traditional times, the taro patches is intricate agroforestry system. A component of this system was an ingenious water flow/control network .This network only fully work when its elements: flow gates, flood gates, stop damps ,bongs: ditches, kllaeb:furrows,buffer zones, etc , were fully operational . The taro patch was a community work, a food bank, and a source of community pride. Everyone pitched in. Many are quit fond of saying the taro patch is 'Women work only'. However, German records and oral history do not bear this out. Men not perform the heavy work for which they are better suited for, for example, making and maintaining the deep ditches, clearing fallen trees blocking the water networks, building stops dams, etc. Children cleared the water networks of weeds, brought plant food, provided company, etc.

So there was more at play causing the damage than the extreme high tide and the salt water inundation.

More than a decade later it was a similar extreme high tide event in September 2011 that prompted the initiation of the Ngimis Village taro patch applied research/demonstration pilot.

The Ngimis village wetland taro pilot

Figure 5: The Ngimis taro patch after the Sept 2011 extreme high tide

Figure 6: Traditional mulching at the taro patch

The wetland taro pilot is located at the Ngimis Village taro patch. This is an active taro patch that had suffered the ill effects of salt water intrusion during extreme high tide of September 2011. The pilot project commenced implementation in January 2012 as joint initiative between the PCC/CRE and the PCAA.

The two (2) objectives of the wet land taro pilot was according to the Palau Community College Second Quarterly Report (2012):

- To evaluate tolerance/susceptibility of different varieties of taro to salt water intrusion.
- To identify taro varieties that are resistant to saline conditions in taro patches.

Figure 8: A simple flood gate installed at Ngmis

Figure 7: Earth dike built at Ngmis

Importantly this varietal evaluation pilot was undertaken in conjunction with onsite program to enhance the earth dikes, repair internal channels and install simple flood and water flow gates. This supporting works were undertaken to prevent salt water intrusion and to hasten the flow of salt water from the taro patch.

The current status of Ngmis pilot

The current status of wetland taro pilot is described briefly below based on The Palau Community College Second Quarterly Report 2012.

> It was following the extreme high tide of Sept 2011 that the pilotNgimis Village taro patch was initiated
>
> The PCC-CRE held negotiations were made with the farmers working in the area affected by the salt water intrusion and a Memorandum of Understanding was signed and executed stating the objectives of the project and the role and responsibilities of PCC-CRE and the farmers.A small area (45 m x 13 m) in the taro patch (mesei) was identified. This area was situated closest to the mangrove swamp and the source of the salt water and where the salt water damage was likely greatest. Work on the site commenced in November 1, 2011, with the division of the selected area into 37 small section (bluu). The earthen levy facing the mangrove was enhanced , the internal water channels were repaired and simple flood gate was installed. PCC-CRE staff and farm workers prepared the area for planting in the traditional manner. Soil samples were taken from the different areas in the mesei and were submitted for soil analysis to determine the nutritional status of the soil. Soil and water samples were taken from different bluu and the conductivity measurements were taken. Different varieties of local and introduced taro varieties were planted in the different bluu. The area was traditionally mulched after the taro was planted.

> In total thirteen popular and widely grown taro Palauan varieties and six introduced taro hybrids were planted to evaluate for salt tolerance[13]. The introduced hybrids were from the SPC-CePaCTgermplasam collection. Data on survival and height of the taro plants were taken at 3 months and 7 months after planting. Also, total corm weight of the different varieties of taro in each section was taken at harvest time 7 months after planting.

The PCC-CRE Second Quarterly Report 2012 reports the following results as of July 2012.

> Soil in the wetland taro patch in Ngimis is acidic (relatively low pH) with fairly high level of organic matter. However, nitrogen levels are relatively low for the needs of the taro, with phosphorus and potassium levels are very minimal to support optimum growth of taro in the mesei. Salt water coming into the taro patch during events of high tide is reflected in the relatively high levels of sodium and chlorine in the soil. Calcium seem to be in adequate levels while very high and toxic levels iron are was shown to be present in the soil.

The taro was evaluated at 3 and 7 months after planting. Three of the local varieties performed well (figure 9). Notably the varieties that were sourced from SPC/CePaCT performed poorly in terms of yield and survival rates. These SPC originated from Samoa, Malaysia, Indonesia and Hawaii. A variety known as Kirang was best of the local varieties, as described by the PCC-CRE Quarterly Rpt.

> Kirangshowed the highest growth and survival and thus, seem to be quite strong to the saline soil conditions. Kirang seem to be least affected by the saline soil condition in the Ngimis taro patch as shown by the highest survival of 90.3% and the highest yield of 18.5 kg of corm at 7 months after planting.

Based on these preliminary results the three strong local varieties will be further evaluated in conjunction with improvements in the nutritional status of the soil. Nitrogen, phosphorus and potassium in the soil will be enhanced.

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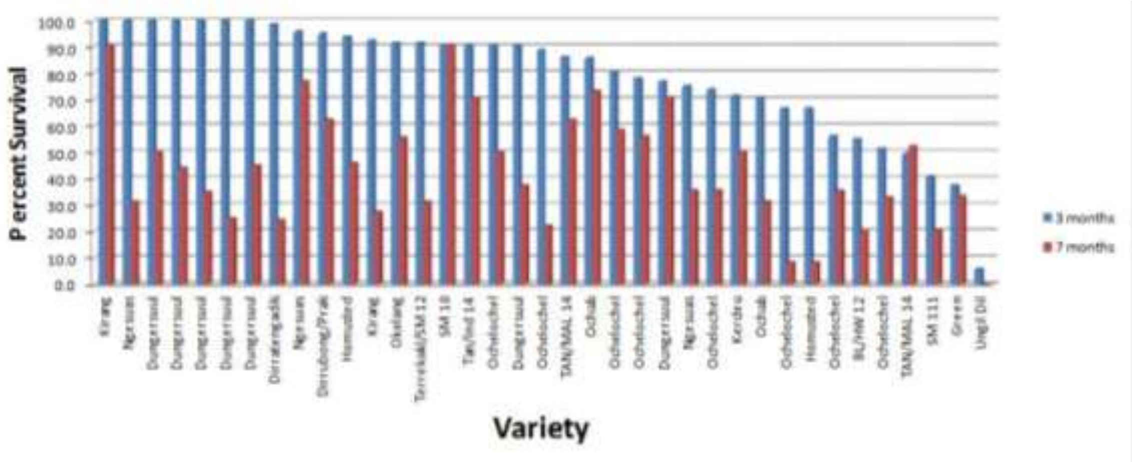
[13] The varieties planted at the Ngimispilot were:

Local Varieties	Introduced Varieties
Ochelochel	TAN/IND 14
Kirang	TAN/MAL 14
Ungil Dil	BL/HW 12
Okelang	BL/SM 10
Dungersuul	BL/SM 12
Ngesuas	BL/SM 111
Homusted	
Dirrubong	
Prak	
Terrekakl	
Kerdeu	
Ochab	
Dirratengadik	

Figure 9: Survival of different taro varieties in Ngimis wetland taro patch 3 to 7 months after planting



The total cost of the Ngimis demonstration site as of July 2012 $9,361 (table 6).The budget for completing the pilot over the next 12 months is $12,100 (table 7).   This will involve a more than doubling the pilot area.

Table 6: The cost of the Ngimis taro patch demonstration site*

Labour	
CRE staff	2,560
Hired labour	800
Equipment	
2 vehicles @ $40/day	800
Fuel	
$80/week x 2 weeks	160
Fertiliser	
Lime $35/50 lb bag x 3	105
NPK (16-16-16) $48/bag x 6	288
Manure $11/bag x 18	198
Planting material	
@63 cents/sucker	500
Maintenance and data collection	
Maintenance	500
Data collection	350
Harvesting	500
Sub-total	6,761
Construction of dikes, ditches and gates	
Laboor	1,200
Equipment	600
Rentals	500
Materials	300
Sub-total	2,600
Total cost	**9,361**

*Source: PCC CRE

Table 7: Budget for completing the Ngimis taro patch pilot*

Activity	Description	Units	$
Equipment rental	hire of dump truck to deliver of earth material to increase the height and width of the existing dike to present salt water intrusion	truck hire @$100 per delivery x 10	1,000
	Hire of dump truck to deliver rock to stabilse dike	truck hire @$100 per delivery x 10	1,000
	Hire back hoe/loader to construct dike	back hoe/loader hire @$100/hr X 10	1,000
Fuel	Transportation for implementation, monitoring and evaluation	$50/trip X 48 trips	2,400
Hired labour	Improving the waterways in the existing and the expanded taro patch	7X $40 X 24 days	6,720
Total			**12,120**

* supplied by LeonardBasilius

An assessment of the taro patch pilot

All indications are that the Ngimis pilot has been a well-managed joint effort between the PCC/CRE and PCAA. This pilot has not suffered from the insufficient and erratic flow of funds that impeded the implementation of the'ridge' pilot.

The pilot has generated encouraging preliminary result with three local varieties demonstrating a degree of salt tolerance. These will be further evaluated in conjunction with improvements in the nutritional status of the soil. It is unlikely the same results could have been achieved without the supplementary 'engineering' works– bolstering the earth dike , improving water flows within the taro patch and the installation of a simple food gate. These measures have reduced the intrusion of salt water and enhanced the capacity of flush salinity out of the taro patch. It seems unlikely that the introduction of salt tolerant varieties would have been asufficient condition to sustain wetland taro production. Investment is also required in appropriate supplementary 'engineering/hydrology works' and soil nutritional improvements

The preliminary results achieved at the Ngimisare significant. They are important for Palau and potentially important other Pacific island taro producers facing salinity problems, particularly those located on atolls.

Expectations for the future availability of 'climate ready'/salt tolerant root crop varieties are probably over optimistic. Expert opinion was sought on the status and likely effectiveness of salt tolerant root crop germplasm from three of the region's root crop authorities:

- Dr Mary Taylor (MaryT@spc.int) - until recently Genetic Resources Coordinator and Manager of the SPC's Pacific's regional genebank, the Centre for Pacific Crops and Trees. Mary is now an Advisor on Agrobiodiversity, Livelihoods and Climate Change Adaptation

- Dr Vincent Lebot(lebot@vanuatu.com.vu) –CIRAD's Vanuatu based author of *Tropical Roots and Tuber Crops: Cassava, Sweet Potato, Yams and Aroid,* 2009 CAB International
- Dr Grahame Jackson (gjackson@zip.com.au)-root crop pathologist and long standing authority on Solomon Island agriculture – Dr Jackson is the founder and coordinator of Pestnet.

The consensus is that there is a long way to go in breeding significant salt tolerance into root crops. It took over 15 years for the Samoan program breeding program to achieve the desired resultsin terms of tolerance to taro leaf blight (McGregor et.al 2011). The highly successful Samoan breeding program is only now turning its attention to drought tolerance with a time horizon of another decade to achieve significant result. Salt tolerance is likely to be an even more difficult breeding objective. However, the preliminary findingsof the Ngimis pilot indicate that some Palauantaro varieties may be able make a significant contribution to this long term process. The Ngimas finding support the view that efficientbreeding programmes must be done locally. Lebot notes that for Vanuatu "all the sweet potato 'megaclones' introduced from the International Potato Centre (CIP) were very disappointing, to say the least, so genotype x environment interaction is unfortunately a real constraint for these crops". The failure of the CePacT sourced taro cultivars at the Ngimispilot support this view.

A reasonable time frame for the taro patch research/demonstration to generate useful results.

The taro patch pilot, within its first year of implementation, is already generating useful information on varietal salt tolerance and the effectiveness of appropriate 'engineering/hydrology' works. This compares with the 'ridge' pilotwere it will take several years before useful data will be available.

The differencecan be explained by two factors:

- The wet land taro pilot involves making adjustment to a well understood traditional cropping system producing a single short term crop
- The implementation of the wet land taro pilot has not been interrupted by an inadequate flow of funds.

More work at the Ngimis site is required to measure the impact of improving the nutritional status of the soil. However, the pilot has already justified the replication of the pilot. Suitable sites have been identified by PCC-CRE in Koror and Ngaraard States for this next stage.

Recommendations for the taro patch applied research/demonstration.

- A continuation of the work at Ngimis siteto confirm varietal performance and to measure the impact of improving the nutritional status of the soil. The estimated budget for completing this work is approximately $12,000 (table 6).
- A trial similar to Ngimisshould now be initiated attwo other locations identified by the PCC/PCAA team. Only promising planting material from the Ngimis trial should be utilised at these new sites.
- With the completion of these 3 trials, and the preliminary results from the Ngimis pilot verified, the roll out to interested taro growers should commence.
- Initial support to growers should be provided to growers to ensure sufficient uptake.

- The main direct assistance to growers should be in enhancing dikes (figure 10) and the construction of flow gates and flood gates that protect the taro patch from salt water inundation.

Figure 10: A dike made of suitable material and of suitable height and width

- Growers should receive assistance in accessing salt tolerant planting material and training (including participation in the 'soil school' program).
- As a condition for receiving support growers should be required to contribute their own labour.

Overarching recommendations for the PACC activities.

Three (3) major recommendations cut across both the 'ridge' agro forestry and taro patch development activities. These are:

- participation in the FAO funded 'Soil Schools' program;
- securing affordable sources of lime; and,
- improvingthe collection of agricultural production statistics to facilitate monitoring and evaluation.

Participation in FAO 'Soil Schools' Program

The pilot project participants should be part of the FAO funded 'Soil Schools' program that is due to commence in early 2013. Training and garnering the enthusiasm of households, particularly youth, will be critical for the up-take of these pilot initiatives. Based on the a farmer field school (FFF) methodology,farmers are trained to do their own soil tests and to evaluate the results and to design appropriate corrective action. It is empowering for farmers to be able to understand the problem and to realise they can do something about solving it. The average cost per participant of the soil school is around $500 per participant.

Securing affordable sources of lime.

The addition of lime improves acidic soils, adds calcium, reduces fungi and increases the availability of many plant foods. High soil acidity is a major limiting factor in both the 'ridge' and taro patch pilots. The pH for the three soil samples at Ngimis were 5.3, 4.5 and 4.5 respectively. Unfortunately no soil samples were taken at the. However, the USDA Soil Survey describes the soils 'as very strongly' acid (p, 39). According to Soil Survey for Palau's upland soils, 'the pH needs to be raised to only about 5.5 in order to remove soluble aluminium as a problem for plant growth. Experience has shown that for many tropical acid soils, between 2 and 4 tonnes of lime per ha is required to raise the soil pH to 5.5 and higher. After the soil pH has been raised to the desired level, additional applications should be made for as long as 5 years or more'.

For the two pilot activities to have a substantial and sustainable longer term impact it will be necessary to secure affordable local sources of lime. This particularly applies to upland agroforestry development. Palau is fortunate to have a number of local lime resources. It is recommended that the PACC Project has an important role to play in facilitating access to these. Background information on local potential sources of lime is presented in annex 2.

A benefit cost analysis for the PACC Palau terrestrial food security activities

A benefit cost analysis (BCA) is conducted at two levels to determine if it would be worthwhile:

- for farmers to adopt the findings of the demonstration pilot; and,
- investing private (farmers) and public funds (government and donors) in a scaling up of the pilots into a national food security program

A BCA for the PACC pilots to date

The Ngimis taro patch

The Ngimis taro patch pilot involved safeguarding a 585 m^2 area from salt water intrusion and the testing of 19 taro varieties for their salt tolerance. To date, a total of approximately $9,361 has been spent on the pilot (table 6). The research component (CRE staff, CRE staff travel and data collection) is estimated at $3,710. The difference of $5,921 is the estimated amount a farmer would have to pay to replicate the Ngimis pilot. This amount is broken down into capital investment (building dikes and gates and acquiring salt tolerant planting material) and operating costs (planting, maintenance, fertiliser and harvesting).

The farmer(s) could expect to produce approximate 1090 kg of taro from a 585 m^2 patch that was well maintained and did not suffer salt water inundation.[14] Typically, this taro would be sold,

[14]This estimate is based on information provided by Bob Bishop and in particular the taro budget below:

consumed at home or used for custom purposes. The total value of this taro is $2,750, based on current retail of $2.50/kg.

Had the rehabilitation investment not been made, it could be expected that the consequences of September 2012 would have been a repeat of the extreme high tide events of September 2011 and 1998. As the experience of 1998 showed, there was no taro production in the affected plots in the year following the salt water intrusion and it took two (2) years for taro production to recover to pre-salt water intrusion levels.

Simulations are undertaken for four scenarios facing a farmer(s) emulating the Ngimis pilot investment and maintenance package.

- **Scenario 1**: There is an extreme high tide event every five (5) years – commencing in first year. If the investment is not made in the dikes and salt tolerant varieties there would be no taro production in the year immediately following the extreme high tide event and only 50% of normal production two (2) years after the event. Production then returns to normal.
- **Scenario 2**: There is an extreme high tide event every four (4) years – commencing in first year.
- **Scenario 3**: There is an extreme high tide event every three (3) years – commencing in first year.
- **Scenario 4**: There is an extreme high tide event every five (5) years – commencing in first year. After the third extreme high tide event the taro patch is abandoned if the investment is not made in the dikes and salt tolerant varieties.

The benefits to the farmer(s) from adopting the package are the projected losses that would be incurred if the package had not been adopted.

The investment cost by the farmer(s) is $4,300, which is all incurred in the first year. There are no more investment costs to be incurred. A substantial well-built traditional earth dike can be expected to last four or five generations. The farmer will also be self-sufficient in salt tolerant

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Gross margin for a taro 'bluu' (27 m^2) hiring labour and using family labour		
Ngatoang State		
Production	**50**	**kgs**
Gross Income	**$170.00**	
Sold	45	kgs
Subsistence/custom	5	kgs
Unit value	3.4	$/kg
Variable costs	**$27.50**	
transportation (fuel)	2.5	$
Hired labor	25	
1/2 day planting @$25/day		
1/2 day harvesting		
Family labour	8	hour
Gross margin	**$142.50**	
Gross margin per hour of family labor effort	**$18**	

planting material after the purchase of material in the first year. The annual operating cost for farmer(s) is $1,600 based on the experience of the Ngimis pilot.

The benefits and costs are projected over a 25-year timeframe in table 8. The flow of benefits and cost are calculated in present value terms by using two discounting rates:

• 4% - the rate used in all PACC Project BCAs. This is a relatively low discount rate, that is justified for community-orientated long term public investment projects where the benefits are expected to flow beyond the current generation.

• 10% - a rate more appropriate for a private investor (a farmer) who has a shorter time horizon.

The difference between the present value of the benefits and cost provides the estimate of the net present value (NPV) for the two discount rates. The ratio of the two provides the benefit cost ratio (B/C) for the two discount rates. An internal rate of return is calculated for scenario 4 (this being the only case were the discounted benefits exceed costs). These results are presented in table 8 and summarised in table 9.

These results indicate that it would not be financially viable for an individual farmer to invest the Ngmis pilot capital investment and maintenance package, except in the extreme situation where salt water incursion forced the farmer to abandon the taro patch in a relatively short time frame. In the situation simulated in scenario 4 (taro patch abandoned in year 7) the NPV from the investment is a meagre $921 at a private discount rate of 10%. Based on these simulations it is unlikely that farmers would invest in the Ngmis pilot package without assistance (i.e. a subsidy) from government. Such a subsidy would be well justified, given the considerable flow on public good benefits arising from the protection of taro patches from salt water incursion. These are in the form of foreign exchange saved, improved nutrition, reduced health costs and cultural benefits. These are discussed is some detail where the benefits from scaling up the pilot are analysed.

The Ksid 'ridge' agro-forestry pilot

This agroforestry pilot commenced implementation in March 2012, with implementation constrained by an inadequate follow of funds. It is assumed that the impediments to the flow of funds will now be rectified. However, given the nature of this agroforestry project it will take several years before sufficient data will be available to determine if it is worthwhile for farmers to adopted the findings of the demonstration pilot. In order to undertake this BCA, it will be essential that the appropriate data be collected from the outset. The following data needs to be regularly collected:

- Soil tests – pH and nutrient levels
- Quantity and type of soil additives and fertiliser applied
- Labor inputs
- Crop yields and quality assessment

Provided this data is collected, it would be reasonable to carry out a BCA in 2017-18.

Table 8: Simulated returns to a farmer(s) adopting the Ngmis pilot investment and maintenance package

Scenario 1		**An extreme high tide event every 5 years**																							
Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Benefits (B)	2,750	1,375	-	-	-	2,750	1,375	-	-	-	2,750	1,375	-	-	-	2,750	1,375	-	-	-	2,750	1,375	-	-	0
Costs (C)	5,900	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600
Capital	4,300																								
Operating	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600
B-C	-3,150	-225	-1,600	-1,600	-1,600	1,150	-225	-1,600	-1,600	-1,600	1,150	-225	-1,600	-1,600	-1,600	1,150	-225	-1,600	-1,600	-1,600	1,150	-225	-1,600	-1,600	-1,600
PV benefits (i=4%)	**13,740**																								
PV costs (i=4%)	**29,130**	**NPV (i=4%)**	-15,390																						
PV benefits (i=10%)	**8,707**																								
PV costs (i=10%)	**18,432**	**NPV (i=10%**	-9,725																						

Scenario 2		**An extreme high tide event every 4 years**																							
Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Benefits (B)	2,750	1,375	-	-	2,750	1,375		-	2,750	1,375			2,750	1,375	-		2,750	1,375	-	-	2,750	1,375	-	-	2,750
Costs (C)	5,900	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600
Capital	4,300																								
Operating	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600
B-C	-3,150	-225	-1,600	-1,600	1,150	-225	-1,600	-1,600	1,150	-225	-1,600	-1,600	1,150	-225	-1,600	-1,600	1,150	-225	-1,600	-1,600	1,150	-225	-1,600	-1,600	1,150
PV benefits (i=4%)	**18,732**																								
PV costs (i=4%)	**29,130**	**NPV (i=4%)**	-10,398																						
PV benefits (i=10%)	**11,850**																								
PV costs (i=10%)	**18,432**	**NPV (i=10%**	-6,582																						

Scenario 3		**An extreme high tide event every 3 years**																							
Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Benefits (B)	2,750	1,375	-	2,750	1,375	-	2,750	1,375	-	2,750	1,375		2,750	1,375	-	2,750	1,375	-	2,750	1,375	-	2,750	1,375	-	2,750
Costs (C)	5,900	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600
Capital	4,300																								
Operating	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600
B-C	-3,150	-225	-1,600	1,150	-225	-1,600	1,150	-225	-1,600	1,150	-225	-1,600	1,150	-225	-1,600	1,150	-225	-1,600	1,150	-225	-1,600	1,150	-225	-1,600	1,150
PV benefits (i=4%)	**22,916**																								
PV costs (i=4%)	**29,130**	**NPV (i=4%)**	-6,214																						
PV benefits (i=10%)	**13,734**																								
PV costs (i=10%)	**18,432**	**NPV (i=10%**	-4,698																						

Scenario 4		**An extreme high tide event in year 1 and 4 and then the plot abandoned of the remedial measures not taken**																							
Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Benefits (B)	2,750	1,375	-	2,750	1,375	-	2,750	2,750	2,750	2,750	2,750	2,750	2,750	2,750	2,750	2,750	2,750	2,750	2,750	2,750	2,750	2,750	2,750	2,750	2,750
Costs (C)	5,900	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600
Capital	4,300																								
Operating	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600	1,600
B-C	-3,150	-225	-1,600	1,150	-225	-1,600	1,150	1,150	1,150	1,150	1,150	1,150	1,150	1,150	1,150	1,150	1,150	1,150	1,150	1,150	1,150	1,150	1,150	1,150	1,150
PV benefits (i=4%)	**35,941**																								
PV costs (i=4%)	**29,130**	**NPV (i=4%)**	6,811																						
PV benefits (i=10%)	**19,353**																								
PV costs (i=10%)	**18,432**	**NPV (i=10%**	921																						
IRR=			12%																						

Table 9: A summary of the simulated returns to a farmer(s) adopting the Ngmis pilot investment and maintenance package

	NPV (i=4%)	NPV (i=10%)	IRR
Scenario 1 (extreme high tide event every 5-years)	-15,390	-9,725	-
Scenario 2 (extreme high tide event every 4 years	-10,398	-6,582	-
Scenario 3 (extreme high tide event every 3 years)	-6,214	-4,698	-
Scenario 4 (extreme high tide event in years-1 and 4, and then adandoned if remedial years not taken	6,811	921	12%

A BCA framework for evaluating the expansion of PACC pilot activities into a national food security program

The purpose of this exercise is to determine if investing in a national food security program based on the PACC pilots worthwhile. This is based on the assumption that the pilots prove to be technically successful. Indications are that this will be the case for the taro patch pilot. It is too early to reach such a conclusion in the case of the "ridge" pilot.

Projections are made for scaling-up the pilots into a national food security program over a 15-year time frame. These projections takes into account the expansion of the existing pilots as recommended above. It is not envisaged that all the necessary financial resources will come from the PACC Project - significant supplementary resources will inevitably need to be obtained from other sources. It is assumed that if a successful start-up can be demonstrated the required investment will be made available from other climate change adaptation initiatives.

Indicative benefits from scaling up are identified and where possible, quantified. The quantified benefits are then compared with the projected costs.

Adaptation of the taro patches to extreme high tides

The size of the existing Ngimis taro patch pilot will be approximately doubled over the next year. There will be a consolidation of earthen dike defence systems (height and width) against salt water intrusion and a further improvement of the internal water flows system. There will also be soil quality amendment measures taken within the taro patch and confirmatory data will be collected on varieties that showed promising salt water tolerance in the initial trial. A further $12,600 has been budgeted to complete the Ngimis taro patch pilot.

Over the next year, it is expected that the existing pilot project will be extended to two new sites. Suitable sites have been provisionally identified in Koror and Ngaraard States. The expanded pilot will cover an area of approximately 1,500 sq. m (5,000 sq. ft), applying the same methodology as the Ngimis taro patch. However, based on the Ngimis experience, a much shorter list of taro varieties will trialled to obtain confirmation of their salt water tolerance and yield performance. This verification needs to be undertaken before these varieties are made more widely available to growers.

The PACC taro patch pilot is due to be completed by the end of 2013. It is proposed that a further 3 years of direct support to farmers and communities wishing to adopt the findings of the taro patch pilot be provided. It is recommended that this support be in the form of assistance to enhance dike systems. This assistance should be provided at three levels, depending on the grower's location:

- Level 1 - Farmers with good road access to be provided with material and the use of a digger to enhance their dikes.
- Level 2: Farmers with limited road access to be provided with material for the enhancement of their dikes
- Level 3: Farmers with no road access to be provided with on-site manual labour assistance to build up their dikes utilising materials from the immediate vicinity.

All participating farmers should receive assistance in the form of:

- Upgrading to internal ditches to improve water flows;
- access to salt tolerant planting material; and,
- training (including participation in the 'soil school' program).

The replication program is projected to support 3,000 sq. m of taro patches per annum over the four-year period. To this would be added area covered by the proposed Koror and Ngaraard research and demonstration pilots. Thus the total area coveredwould be approximately 15,000 sq. m.

It is anticipated thatthe demonstrated impact of the program will encourage other growers to adopt the measures taken without necessarily receiving any direct support from the program. The expectation is that the rate of adoption would steadily increase over time as the measures taken became accepted practice. A review of the taro production gross margins provides some confidence that the rate of adoption could be quite high if it can be effectively demonstrated that investing in these measures will have a significant impact on taro production. It is assumed that after a 15 year period 30% of the existing taro patches[15] will have adopted the measures in varying degrees.

[15]The 2012 PACC Palau Farm Survey Report estimated that there were 575 wetland taro patches (*mesei*) in Palau with a total area of 761, 174 sq. m (PALARIS p. 5).

The benefits from expanding the wetland taro pilot

Identifying the benefits

The direct benefit from a scaling up program is the difference between the value of Palau's wetland taro production **with the** program and the value of Palau's wetland taro production **with-out** the program.

There areadditional flow-on benefits in terms of foreign exchange saved and improved nutrition when taro is consumed instead of imported grain products. There are also important cultural[16], social and amenity benefits associated with the maintenance of the taro patch - although these are probably unquantifiable.

Promising results are being achieved in the identification of Palauan taro varieties that display a degree of salinity tolerance. These cultivars may eventually find a place in wetland taro patches of other Pacific island farmers (particularly subsistence farmers in atoll locations) who are grappling with the same problem of saltwater inundation from extreme high tides. This would result significant regional benefits arising from the Palau wetland taro pilot.

Quantifying the benefits

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[16]Taro features prominently in Palau's legends, stories, songs, chants and proverbs, that it is a central element in defining Palau's culture. Robert Bishop in his paper 'Taro Production and Value Adding in Palau' notes:

> The cultural significance of taro is illustrated well by the oft-quoted proverb: 'A mesei a delal a telid.' This is usually translated to 'The taro patch is the mother of our life.' Traditionally, taro was the most important and most prominent and most revered(prestige) food and crop in Palau. As with most Palauan proverbs, stories and legends, this proverb has different levels of meaning. A more literal translation of the proverb renders it: 'The taro patch is the mother of our breath.' This implies that at the end of the last day that the last Palauan woman goes to the taro patch, Palau's culture will have breathed its last breath. The highly productive taro patch system enabled and sustained Palau's 'way of life.'
>
> In traditional Palau, a woman's skill level and how well and how diligently she tended her family's the clan's and the community's taro patches and her provision and preparation of food and other resources from the patches to others was crucial in determining her position and status in the family, clan and village. It provided one of the few vehicles for advancement and wealth accumulation. Advancement and wealth accumulation are important driving forces in Palau's culture. To illustrate, the adept and hard-working a woman was in the taro patch the more say she had in the selection of her husband.
>
> The taro patch was the 'school' where mothers taught their family's closely guarded secrets, especially privilege knowledge of the taro patch. The taro patch was also the 'school' where mother's taught their children especially their daughters: life skills, what it is to be 'Palauan', who they are, what their roles were and social values such as deference, reciprocity, thrift, diligence, and responsibility. This traditional education was devalued, ignored and discouraged by formal educators. Moreover, since younger people are increasingly disinterested in agriculture, there are less and less opportunities to pass on knowledge, values and skills.

The market value of the additional taro produced

Current wetland taro production is estimated at 132,000 lbs (60 tonnes). This estimate is based on the actual colocasia (*kukau*) sales of Yano and Sons the largest taro buyer[17]. A downward trend in wetland taro production can be expected without the sustainable taro production program. There will be year to year fluctuations around a downward trend depending on the impact of an extreme high tide in a particular year. The simulation presented assumes an average annual decline of 3% in wetland taro production without the program.

The introduction of a sustainable wetland production program reduces the overall rate of decline. For the first few years the coverage of the program is small and thus the amelioration of the overall decline in production is limited. It is assumed that after 10-years, 30% of existing taro patches will have adopted, in varying degrees, the proposed measures. By such time it is projected that the overall decline in taro production will have been reversed.

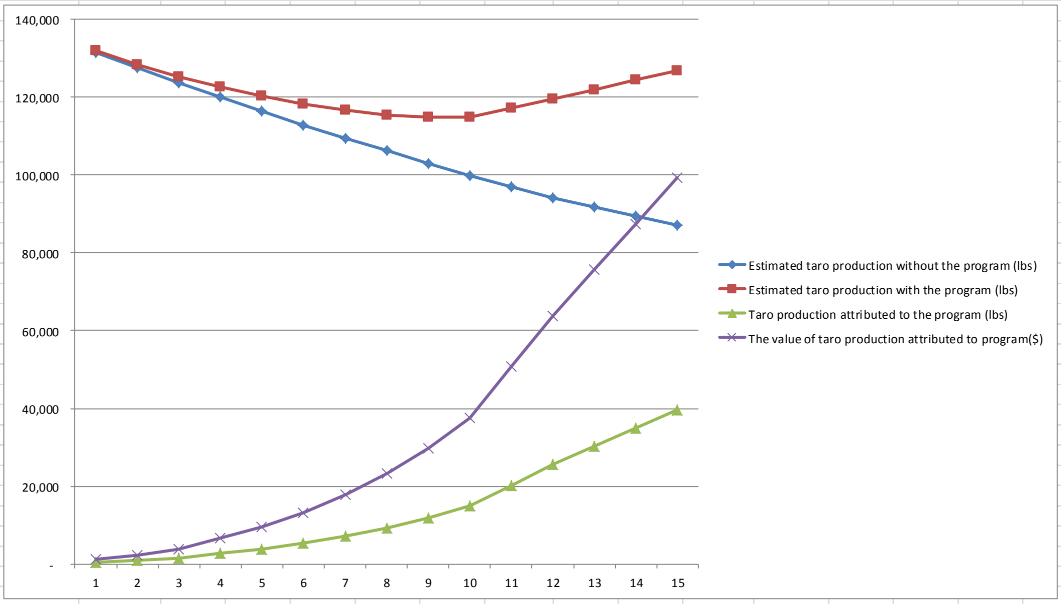
It is projected that with the implementation of the program, wetland taro production after 15 years will stand at 127,000 lb (58 tonnes) compared with the current estimated annual production of 132,000 lb (60 tonnes) However, if the sustainable production program had not existed it is projected that wetland taro production after 15-years will have slumped to 88,000 lb (40 tonnes). In any particular year, production impact of the program is calculated as the difference between the estimated total production 'with' and 'without' the program.

This production impact is valued at the current retail price of taro (approx. $2.50/lb or $5.50/kg. In the simulation presented in table 10 the value of the taro production resulting from the program, increases from an insignificant $1,300 in the first year to nearly $100,000 by year-15. If a higher rate of adoption is achieved over the period the expected benefits will increase accordingly.

[17]The assumption is that Yano and Sons account for about 40% of taro sales and approximately 50% of taro produced enters the market.

Table 10: The projected direct benefits from the program for the sustainable enhancement of wet land taro production

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Estimated taro production **without** the program (lbs)	131,500	127,555	123,728	120,016	116,416	112,924	109,536	106,250	103,062	99,970	96,971	94,062	91,711	89,418	87,182
Estimated taro production **with** the program (lbs)	132,000	128,436	125,225	122,721	120,266	118,222	116,685	115,518	114,940	114,940	117,239	119,584	121,976	124,415	126,903
Taro production **attributed** to the program (lbs)	500	881	1,497	2,704	3,850	5,298	7,149	9,268	11,878	14,970	20,268	25,522	30,265	34,997	39,721
The **value** of taro production attributed to program($)	1,250	2,203	3,742	6,760	9,625	13,245	17,872	23,170	29,695	37,425	50,670	63,804	75,663	87,493	99,303



Foreign exchange savings

Approximately 2.9 lbs of taro are required to produce the calorie equivalent of 1 lb of white rice (SPC, Nutritional Tables). The resulting foreign exchange saving estimates are presented in table 11. These projections are based on an estimated land price of rice of 60c/lb ($1.30/kg). These saving are quite small (reaching around $10,000/annum) in context of Palau's large rice imports ($1.6 million in 2010). It nevertheless it makes a contribution to reducing Palau's exceptionally high vulnerability to food imports.

Table 11: Estimated foreign exchange saving resulting from sustainable wetland taro production

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Taro production **attributed** to the program (lbs)	500	881	1,497	2,704	3,850	5,298	7,149	9,268	11,878	14,970	20,268	25,522	30,265	34,997	39,721
White rice equivalent (lbs)	172	304	516	932	1,328	1,827	2,465	3,196	4,096	5,162	6,989	8,801	10,436	12,068	13,697
Value (@70c/lb)	121	213	361	653	929	1,279	1,726	2,237	2,867	3,613	4,892	6,160	7,305	8,448	9,588

Nutritional and public health benefits from substituting taro for imported grain

Any program that results in increased taro consumption brings with it both private and public health benefits. The nutritional and health consequences of substituting rice and other imported grains for traditional taro are well documented (Otto 2000). Healthier individuals are more productive, live longer and spend less on health care. The overall productivity of the work force is increased and public expenditure on health care is reduced. In principle, the health benefits from reversing, or at least reducing, the trend of substituting imported grains for taro can be quantified. However, it is beyond the scope and resources of this study. Suffice to say that these are important, albeit unquantified, supplementary benefits.

Cultural benefits from maintaining taro patches

The taro patch has played a key role in the culture and traditions of the Palauan people and thus the maintenance of wetland taro production brings with it benefits. However, as important these benefits are, it does not make sense to try and assign a dollar value to them. These should be considered as a non-quantifiable supplementary benefit.

The cost of expanding the wetland taro pilot

In its first year, the Ngimis taro patch pilot cost $9,400 and is estimated that it will cost a further $12,000 in the second year to complete the pilot. It is recommended that a further two demonstration trials also be established in the second year as part of expanded PACC pilot. The budget for the two supplementary pilots is $20,000. From year three (3) onwards, subject to the verification of preliminary results achieved at Ngimis, the program will then be rolled out to interested growers. It is projected that 3,000 sq. m of taro patch per year will be supported for a period of three (3) years. The main public cost of this support will be assistance in the building of dikes (3' high and 2' wide) and flood and flow gates. The assistance provided will be at three levels:

- **Level 1**: 30 m (100 ft) length of dike supported by a digger and the supply of earth in readily accessible locations (estimated cost $9,600 – annex 1)
- **Level 2**: 30 m length of levy supported by the supply of earth in not so readily accessible locations (estimated cost $6,600 – annex 1)
- **Level 3**: 30 m length of levy supported with on-site manual labour digging assistance in locations only accessible by foot (estimated cost $6,300).

The total annual public cost is estimated at $22,500. A further $2,500 is allowed for in private labour costs to build the dikes and trenches. No allowance is made for labour used to grow the taro since these are active taro patches and the taro would have been grown anyway.

After year 5, it is projected that the cost of building the dikes and gates is assumed to be met entirely by the farmers. By that time, enterprises specialising in this work will have developed and efficiencies will have been gained. Thus the total annual cost associated with building 90 m (300 ft) length of dikes annually will be reduced to $15,000.

No allowance is made for maintenance of dikes. A well constructed earthen dike, on which trees are planted, can be expected to last generations of taro growers.

Support for 10 wetland taro participants in the soil school program is provided for in years 2, 3 and 4. The estimated cost per participant is $500.

The projected costs over the 15-years are summarised in table 12.

Table 12: Projected estimated costs of the sustainable wetland taro program ($)

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Ngimis demonstration/pilot	9,400	12,000													
Two additional demonstration pilots		20,000													
Program roll out			25,000	25,000	25,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000
Partipation in the "soil school" program		5,000	5,000	5,000											
Total cost	**9,400**	**37,000**	**30,000**	**30,000**	**25,000**	**15,000**	**15,000**	**15,000**	**15,000**	**15,000**	**15,000**	**15,000**	**15,000**	**15,000**	**15,000**

Comparing benefits with cost for the scaling up of the wetland taro pilot

The projected benefits and costs of scaling up the wetland taro pilot are compared in table 13. The flow of benefits and cost are calculated in present value terms by discounting at a rate of 4%. This is a relatively low discount rate, justified by the fact that it is a community-orientated long term public investment project and its benefits are expected to flow beyond the current generation.

Table 10: Comparing the wetland taro program benefits with costs.

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Estimated benefits ($)	1,250	2,203	3,742	6,760	9,625	13,245	17,872	23,170	29,695	37,425	50,670	63,804	75,663	87,493	99,303
Estimated costs ($)	9,400	37,000	30,000	30,000	25,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000
B-C	**-8,150**	**-34,798**	**-26,258**	**-23,240**	**-15,375**	**-1,755**	**2,872**	**8,170**	**14,695**	**22,425**	**35,670**	**48,804**	**60,663**	**72,493**	**84,303**
PV benefits (i=4%)	**331,253**														
PV costs (i=4%)	**216,108**	**NPV=**	**115,145**	**B/C=** 1.5		**IRR=** 13%									

The estimated benefit cost ratio for the projected scaling of the wetland taro pilot is 1.53 with an IRR of 12.9%. Thus such a scaling up program is seen to be economically viable based entirely on the market value of the taro produced. Considerable additional benefits accrue from savings in foreign exchanges, improvement in nutrition, savings in health care costs, and safeguarding the Palauan taro patch culture.

Sustainable food production through upland agroforestry

The PACC upland pilot will need to continue for at least another three (3) years before results can be realistically proven and demonstrated to farmers for their adoption. Most of the financial benefits from agroforestry tend to more long term. Accordingly, adoption of the findings of the agroforestry research and demonstration pilot could be expected to be slower in comparison to the taro patch pilot.

However, the value of soil amendments such as liming and composting will soon become apparent to farmers and should be promoted from the outset. So too will the value of adopting soil conservation measures such as the utilisation of vetiver grass in hedgerows. It is expected that there will be opportunities to profitably grow root crops and short term crops such as pineapples by adopting sustainable production methods. The participation of farmers and communities in the 'soil school' program will no doubt accelerate the adoption process.

According to PALARIS 2006, 182.25 sq. km. of land area on Babeldaob remains under primary forest. A major justification for introducingan upland agroforestry program is to reduce the pressure to clear primary forest. The PALARIS survey estimated that a further 50.6 sq. km was no longer under primary forest - the agroforestry pilot project is focussed on the sustainable utilisation of this land area. A reasonable 10-year target would be to have 5% of this land - 2.5 sq. km (620 acres) under various agroforestry regimes. Additional public investment programs could be justified in soil conservation programs such as the vetiver grass hedgerow planting to reduce runoff into Palau's valuable but fragile marine environment.

The benefits from scaling up the sustainable upland agroforestry pilot

Identifying the benefits

The direct primary benefit from the program is the value of food production from areas that are currently producing little or no food. As with the wetland taro program, there would be accompanying flow-on benefits in terms of foreign exchange saved and improved health nutrition when locally grown food is consumed instead of imported processed foods.

There are also a number of indirect benefits, some of which may prove to be more important than the direct benefits. These fall in three broad areas:

- youth employment;
- environmental and amenity benefits from reducing the need to clear Palau's remaining primary forest areas; and,
- environmental and future income generating benefits from reducing soil runoff into Palau's marine environment.

Generating youth employment

High youth unemployment poses major social and economic problems for Palau. Yet, a major constraint to the achievement of relatively modest production targets will be the unwillingness of young people to become involved. There is an overall lack of interest amongst youth to become involved in agriculture. The 'soil school' program is seen as the key to motivating a sufficient number of young people to see agricultural as an interesting and remunerative income earning opportunity. The scale and type of agroforestry program that is envisaged could eventually provide gainful employment for 200 to 300 people. Given the reality of Palau's labour market it is likely significant number of these will be migrant workers. The benefits resulting from the involvement of youth in agriculture are in principle quantifiable – although it is beyond the scope and resources of this study to try do so.

Environmental, economic and amenity benefits from conserving Palau's primary forest

Palau has the largest area remaining under primary forest in Micronesia – with 75% of total land area under primary forest[18]. There are considerable environmental, economic and amenity benefits arising from this situation.

Having a large forested area creates favourable microclimatic conditions and a habitat for a wide range of indigenous and endemic bird species. Most importantly this large forest area minimises the runoff into the marine environment. Palau's marine environment is its most valuable economic resource. World class diving and a pristine marine environment are the main attractions for the estimated 80,000 tourists that visit annually. These visitors are the main source of private income and government revenue. Thus all necessary measures need to be taken to protect the natural resource that brings them to Palau.

In Palau, the traditional approach to dry land farming has been shifting cultivation. Forest areas were cleared and planted with root crops. Once exposed the forest soil quickly loses its fertility and need to be left in prolonged fallow to restore fertility. The saltation of wetland taro land will increase the pressure to utilise primary forest land for food production. The dryland agroforestry pilotintends to demonstrate a viable alternative that makes the use of primary forest land for food production unnecessary. The resulting conservation of the remaining primary forest area will bring with it very substantial economic benefits through the protection of the marine environment.

It recommended that contour planting of vetiver grass be extended beyond projected agroforestry areas utilised for food production. The primary economic benefit from this soil conservation measure is the protection of the marine environment. This is seen a public investment activity that needs to be funded accordingly.

These secondary environment and economic benefits arising from the agroforestry program are likely to be substantial but go well beyond the scope of this study to quantify.

Palau is one of the most urbanised Pacific island country. In a situation of increasing urbanization and congestion people place value on knowing that primary forest exists and and could be visited should they so wish. This value has probably been enhanced by the building of the high quality Babelbaob Compact road. Survey techniques exist for valuingthe amenity provided by forests and open space (Vieth et al. 1995). However, such an evaluation is beyond the scope of this study.

[18] The break-down of the Babelbaob land area is as follows:

	Sq Kilometers	% of total area
Primary forest	182.25	75%
Disturbed reforested	11.36	5%
Disturbed not reforested	39.24	16%
Other	9.72	4%
	242.57	
Sources: PCS, Palau Forestry Office and PALARIS		

Palau is one of the most urbanised Pacific island country. In a situation of increasing urbanization and congestion people place value on knowing that primary forest exists and and could be visited should they so wish. This value has probably been enhanced by the building of the high quality Babelbaob Compact road. Survey techniques exist for valuing the amenity provided by forests and open space (Vieth et al. 1995). However, such an evaluation is beyond the scope of this study.

Quantifying the benefits

The quantification of the wetland taro production involved one product coming from a defined area. Valuing any future increased food production resulting from the upland agroforestry program is more complicated for two (2) reasons.

- The current small upland pilot is only now starting to be implemented – thus there is less confidence in the likely success of the approach being adopted and thus more conservative projections need to be made.
- The upland agroforestry program involves multiple products coming from a broad area – albeit a potentially much larger area for increasing food production.

The potential value to Palau arising from the implementation of sustainable upland agroforestry program is illustrated usingconservative indicative targets. It is hoped that the implementation of successful upland pilot will result in these targets being surpassed.

The projections start with a small base of 1.5 acres at the Ksid 'ridge' pilot in the first year. The area covered by the programs is projected to double every year to reach 760 acres (approximately 5% of the deforested land) in year 10 and from then on the area covered increases by 20% per year for the next five (5) years.

Table 14: The projected direct benefits from the program for upland agroforestry development

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Area covered upland agroforestry program (acres)	1.5	3	6	12	24	48	96	190	380	760	912	1,094	1,313	1,576	1,891
Root crop production (lbs)	-	900	1,800	3,600	7,200	14,400	28,800	57,600	114,000	228,000	456,000	547,200	656,640	787,968	945,562
Root crop value ($)		1,800	3,600	7,200	14,400	28,800	57,600	115,200	228,000	456,000	912,000	1,094,400	1,313,280	1,575,936	1,891,123
Fruit production (lbs)	-	300	600	1,200	2,400	4,800	9,600	19,200	38,000	76,000	152,000	182,400	218,880	262,656	315,187
Fruit value ($)	-	300	600	1,200	2,400	4,800	9,600	19,200	38,000	76,000	152,000	182,400	218,880	262,656	315,187
Total value of the production	**-**	**2,100**	**4,200**	**8,400**	**16,800**	**33,600**	**67,200**	**134,400**	**266,000**	**532,000**	**1,064,000**	**1,276,800**	**1,532,160**	**1,838,592**	**2,206,310**

The indicative food crops grown in this area are root crops (*Colocasia* taro, *Xanthosoma* taro, cassava and sweet potato) and fruit (mainly pineapples because of its favourable fruit fly status). The assumed root crop yield is 600 lbs per acre. This is lagged by one year to allow a sufficient build up in soil fertility. The assumed yield for fruit is 200 lbs per acre - also lagged by one year. The assumed retail prices are $2/lb for root crops and $1/lb for fruit[19]. The total annual value of the resulting production increases from a meagre $2,100 in the first year to $2.2 million in year 15.

The proposed agroforestry areas currently have little to no agricultural production – thus production without the program is assumed to be zero. This contrasts with the wetland

[19]Indicative prices are provided P-T Farmers Association. Calendar of Activities W/Strategic Plan for 2012.

taro situation where there would still be taro production without the program – albeit declining over time.

There are also flow-on benefits in terms of foreign exchange saved and improved nutrition. These are the same as those identified for wetland taro. However, because of the larger area involved the order of magnitude of these benefits is potentially considerably greater.

The cost of expanding the agroforestry pilot

In its first six months of the operation the Ksid 'ridge' spent around $12,000. A further expenditure of around $34,000 is estimated to be required over the next two and half years to enable the proper implementation of the pilot. At the beginning of 2013 it proposed that two parallel pilot demonstrations also be initiated. No budget has been prepared for these additional pilots. It is thus assumed that each will cost about the same as that estimated Ksid 'ridge' ($46,000), spent over three years. By the end of four years the three pilots will cover 12 acres, with all the costs will be met by public funds. From year 5 onwards it is expected that there will be both public and private funding contributions. By year 10 it is projected that approximately 380 acres will be part of the agroforestry program, increasing to around 1,900 acres by year 15. The main cost elements are summarised below.

- *Soil amendments*: The Palau USDA Soil Survey recommends that on many acid soils, between 1 and 2 tonnes of lime per acre are required to raise the soil pH to an acceptable level. It is assumed that an average of the equivalent of one tonne of crushed rock island sand will be applied per acre. The estimated cost based on discussion in annex 2 is $60 per acre. A further $20 per tonne is allowed for the purchase of other soil amendments.
- *Planting material*: The agroforestry forestry program is built around the planting of soil enhancing and nitrogen fixing trees, fruit trees and suitable timber species. At any particular location these trees will be planted in the first two years. An allowance of $400 per acre is allowed for the acquisition of such trees. A further $50 per acre is provided for the acquisition annual crop (eg. root crops and pineapples) and soil conservation material (such as vetiver grass).
- *Equipment to facilitate composting:* The main capital item is expected to be shredders to break down vegetative material such as tree branches and coconut husks. The cost of a mobile unit is estimated at $7, 000, with a further $3,000 allowed materials and ancillary equipment. Two such units are allowed for in the Ksid 'ridge' and the two parallel pilots. It is projected that a further ten units will be acquired over the 15 year period to support the overall program.
- *Farmer participation in the 'soil school' program:* This is seen as critical for success of the upland sustainable agriculture program. Soil schools are programed for years 2, 3 and 4. There will be 20-upland farmer participants in each of these courses at a cost of $500 each.

- *Labor input for land preparation and maintenance:* Requirements have been budgeted for the first three (3) years of the Ksid 'ridge' pilot and the two parallel pilots. Beyond year four (4), an average annual labour requirement of 25 person days per acre covered by the program is budgeted for at a daily rate of $30. The main labour input can is expected in the first two establishment years in any location.

A summary of projected costs is presented in table 15. These increase from a mere $12,000 in year 1 (the start-up Ksid 'ridge' pilot), to around $1.7 million by year 15.

Table 15: Projected estimated costs of the sustainable upland agroforestry program ($)

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Ksid "ridge" pilot	12,000	17,000	17,000												
Two parallel pilots		31,000	31,000	31,000											
Soil amendments					1,920	3,840	7,680	15,200	30,400	60,800	73,000	87,500	105,000	126,000	150,000
Planting material					5,400	10,800	21,600	42,300	85,500	171,000	68,400	82,080	98,550	118,195	141,750
Composting equipment					10,000		20,000			20,000				40,000	
Labour					18,000	36,000	72,000	142,500	285,000	570,000	684,000	820,800	984,960	1,181,952	1,418,342
Soil Schools		10,000	10,000	10,000	10,000										
Total costs	**12,000**	**58,000**	**58,000**	**41,000**	**45,320**	**50,640**	**121,280**	**200,000**	**400,900**	**821,800**	**825,400**	**990,380**	**1,188,510**	**1,466,147**	**1,710,092**

Comparing benefits with costs

The projected benefits and costs for the upland agro forestry program are presented in table 16. The flow of benefits and cost are calculated in present value terms by discounting at a rate of 4%. The estimated benefit cost ratio for the projected scaling of the wetland taro pilot is 1.12 with an IRR of 18%. Thus it is expected that an appropriate and well implemented upland agroforestry program will be economically viable based entirely on the market value of the resulting food and timber products. Considerable additional benefits accrue from savings in foreign exchanges, improvement in nutrition, health care cost savings, youth employment, amenity from maintaining primary forest areas and the protection of the marine environment from soil runoff.

Table 16: Comparing the upland agroforestry program benefits with costs

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Estimated benefits ($)	-	2,100	4,200	8,400	16,800	33,600	67,200	134,400	266,000	533,500	1,067,000	1,282,800	1,544,160	1,862,592	2,254,310
Estimated costs ($)	12,000	48,000	32,700	31,000	35,320	50,640	121,280	200,000	400,900	821,800	825,400	990,380	1,188,510	1,466,147	1,710,092
B-C	**-12,000**	**-45,900**	**-28,500**	**-22,600**	**-18,520**	**-17,040**	**-54,080**	**-65,600**	**-134,900**	**-288,300**	**241,600**	**292,420**	**355,650**	**396,445**	**544,218**
PV benefits (i=4%)	**$5,498,849**														
PV costs (i=4%)	**$4,920,443**	**NPV=**	**$578,406**	**B/C=**	**1.12**	**IRR=**	**18%**								

A benefit cost analysis a consolidated sustainable food security development program

In table 17 the wetland taro and upland agroforestry programs are combined and aggregated benefits and costs compared. The BCA results are summarised in table 18. The sustainable agriculture food security program was found be economically viable when benefits and cost are projected over a 15 year period. The estimated benefit cost ratio for the wetland taro program is 1.53 with an IRR of 12.9%. The significantly larger upland agroforestry program generates a lower but still positive B/C of 1.12 – but yields a higher IRR of 18%. The only benefits that have been quantified in obtaining these results are the estimated market value of the resulting production. Thus this national food security program would be a worthwhile investment of public funds based entirely on value of the resulting increased production food and forest products.

No attempt has been made to quantify and to take into account:

- The foreign exchange saved from the food now not imported as a result of the program.
- The nutritional and public health benefits from consuming more nutritious locally grow food (particularly taro) and less processed food imports (particularly white rice).
- The potential future benefits wetland taro growers in other Pacific island countries arising from the identification of salt tolerant varieties in Palau.
- The social benefits for generating productive youth employment.
- The environmental and amenity benefits from conserving Palau's remaining primary forest.
- The environmental and future income generating benefits from reducing the runoff into Palau's important but fragile marine environment.

Some of these benefits are likely to be considerable. The incorporation of their value into the benefit stream would result is a substantially higher benefit cost ratios.

Table 17: Comparing the overall sustainable agriculture food security program benefits with costs

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Benefits ($)															
Wetland taro	1,250	2,203	3,742	6,760	9,625	13,245	17,872	23,170	29,695	37,425	50,670	63,804	75,663	87,493	99,303
Upland agroforestry	-	2,100	4,200	8,400	16,800	33,600	67,200	134,400	266,000	533,500	1,067,000	1,282,800	1,544,160	1,862,592	2,254,310
Sub-total	1,250	4,303	7,942	15,160	26,425	46,845	85,072	157,570	295,695	570,925	1,117,670	1,346,604	1,619,823	1,950,085	2,353,613
Costs ($)															
Wetland taro	9,400	37,000	30,000	30,000	25,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000
Upland agroforestry	12,000	58,000	58,000	41,000	45,320	50,640	121,280	200,000	400,900	821,800	825,400	990,380	1,188,510	1,466,147	1,710,092
Sub-total	21,400	95,000	88,000	71,000	70,320	65,640	136,280	215,000	415,900	836,800	840,400	1,005,380	1,203,510	1,481,147	1,725,092
B-C	-20,150	-90,698	-80,058	-55,840	-43,895	-18,795	-51,208	-57,430	-120,205	-265,875	277,270	341,224	416,313	468,938	628,521
PV benefits (i=4%)	**$5,830,102**														
PV costs (i=4%)	**$5,185,055**	**NPV=**	**$645,047**	**B/C=**	**1.12**	**IRR=**	**15%**								

Table 18: A summary of the BCA results for the Palau sustainable agriculture food security program

	NPV	B/C	IRR
Wetland taro program	$ 115,145	1.53	12.9%
Upland agroforestry program	$ 529,902	1.11	15.5%
Combined sustainable agriculture food security program	$ 645,047	1.12	14.8%

Overall conclusions

The overall conclusionsfrom thestudy are:

- The expansion of two terrestrial PACC pilot food security projects is justified and necessary.
- The expectation is, subject to the verification of the expanded pilots, that it will be worthwhile investing private (farmer) and public (government and donor) funds in the scaling up of the pilots into a national sustainable food security program.

Annex 1: Budgets for assistance in the construction of earth dikes

Table 11: Budget for assistance in the construction of 100'x3'x4' earth dike – providing materials and heavy equipment.

Activity	Description	Budget details	$
Purchase of overburden soil	overburden soil for construction of the dike. Type of soil recommended because of its compactionand stability capability	Overburden soil @ $20/yrd x 25 yrds	500
Equipment rental	Dump truck for the delivery of the overburden soil	@ $45/delivery x 12 deliveries	540
Equipment rental	Dump truck for the delivery of course rock to stabilise the dike	@ $45/deliver x 5 deliveries	225
Equipment rental	Back hoe/loader for construction of dike	@ $100/hr x 8hrs	800
Purchase of materials for the construction of flood gates	Metal sheeting, cement, sand and gravel 5-16" rebar	metal sheets @ $200, cement @ $15/sack X 5, sand and gravel @ $ 135, rebar @ $20x5	510
Assistance in levy contruction and stabilisation	Hired labour	$40/day x 7 x 8 days	2,240
Purchase of hand tools and equipment to be used on all projects	Heavy wheel barrow, chain saws (16 inch) shovels, long spade, garden rakes, machete, hatchet, and green marchine	Wheelbarrow $ 250X4; chainsaw $500x2; shovel $25x4; machete $20x4; hatchet $15x4; green machine $500x2	3,320
Fuel and oil	for implementation and monitoring	$50 per trip x 10	500
Repair and maintenance	for tools and equipment parts		500
Supplies and materials for training	paper, folders etc		500
			9,635

Annex 2: Background information on Palau's potential sources of lime[20]

The waste from lime manufactured for use with betel nut chewing. Waste from making lime for betelnut chewing kesmad improves acidic soils, adds calcium, and increases the availability of many plant foods. Available from lime makers in small amounts at $8-12 for ¾ filled cement bag. There are lime makers in Kayangel, Anguar and Peleliu.

Coral (crushed rock island) silt. This waste product is yellow in color adds calcium, improves the availability of magnesium and apparently provides other plant foods. Large amounts available as it is a by-product of materials used for construction and road building. Coral silt is available from Hawaiian Belau Rock Corp. $3 for a 40 lb. bag (delivered at the rate of $35-75 load depending on location). Used frequently for all crops as it produces a positive response.

Crushed rock island (washed mechanized) sand. This material is yellow in color adds calcium slowly, improves the availability of magnesium and apparently provides other plant foods. Crushed rock island sand is available from Hawaiian Belau Rock Corp. $49 at per cubic yard. Delivery charges are $35-75 per load depending on location. Large amounts available as it is a material used for construction and road building.

Coral sand. This product is grey in color and improves acidic soils, adds calcium and magnesium and improves drainage. Coral sand is available in some mangrove areas and areas adjacent to mangroves and some quarries. Large amounts also available as it is a material used for construction and road building.

Coral cobble bertakl. This is grey in color, improves acidic soils, adds calcium and magnesium and improves drainage. Coral gravel/cobble is available from dredge operations and old dredge sites and storage areas and quarries. Large amounts available as it is a material used for construction and road building $15 -18 per cubic yard. Delivery varies depending on the supplier.

Crushed rock island 3/8 gravel. This product is yellow in color, adds calcium slowly, improves drainage and helps plants 'anchor' in windy locations and` 'weak' soils. Crushed rock island gravel is available from Hawaiian Belau Rock Corp. $49 at per cubic yard. Delivery charges are $35-75 depending on location. Large amounts available as it is a material used for construction and road building.

'Overburden'. This is a mixture of crushed rock island materials used usually as a base for roads. It would need to sifted to be used as a soil amendment. It has a tendency to cement if used in a layer. Overburden is available from Hawaiian Belau Rock Corp. at $9 per cubic yard. Delivery charges are $35-75 depending on location. Large amounts available as it is a material used for construction and road building.

[20]The information for this annex was provided by Bob Bishop President of the of the Palau Organic Growers Association

Sand chelechol. This slowly improves acidic soils, slowly adds calcium and improves drainage. Sand is available from quarries e.g. BNQ for $49 per cubic yard. Delivery charges for $20 within Koror for a dump truck and $45 for a boom truck. The material can be place in a sling for an additional $59 charge. Large amounts available as it is a material used for construction and road building.

It is recommended that the utilization of lime materials that are by products and waste materials for road works or from existing quarry operations be the main focus of the upland agro-forestry pilot activities. This due to the substantial volume of liming material that is potentially available at low cost. These do not require the initiation of new quarrying and mining operations with their associated environmental downside.

Annex 3: Gross Margins for Small Scale Wetland Taro Production

Bob Bishop supplied current gross margins for two taro patch (bluu) in Airai and Ngatpang States. One uses entirely hired labour, while the other uses a combination of hired and family labour. The Airai case the grower sells the area to the buyer – which means a lower return per volume of taro grown. In this case yields are also significantly lower because only hired labour is used and there is no supervision. The gross margin is still a worthwhile $30 for a small 50 m2 area. This same grower could control some 10 to 20 bluu. The second case is a community plot which is more typical and the returns are significantly higher. The taro is sold by the lb. and family labor is utilised resulting in higher yields. The 27 m2 plot yields a gross margin of over $140 and return of $18 per hour of family effort.

Gross margin for a taro 'bluu' (50 m^2) hiring labour		
Airai State (2012)		
Production	**17**	**kgs**
Gross Income	**$57.80**	
Sold	15	kgs
Subsistence/custom	2	kgs
Unit value	3.4	$/kg
Variable costs	**$27.50**	
transportation (fuel)	2.5	$
Hired labor	25	
1/2 day planting @$25/day		
1/2 day harvesting		
Gross margin	**$30.30**	
Gross margin for a taro 'bluu' (27 m^2) hiring labour and using family labour		
Ngatoang State		
Production	**50**	**kgs**
Gross Income	**$170.00**	
Sold	45	kgs
Subsistence/custom	5	kgs
Unit value	3.4	$/kg
Variable costs	**$27.50**	
transportation (fuel)	2.5	$
Hired labor	25	
1/2 day planting @$25/day		
1/2 day harvesting		
Family labour	8	hour
Gross margin	**$142.50**	
Gross margin per hour of family labor effort	**$18**	

Bibliography

Ali Kamiloand SalesiKaitu'u (2009). DSAP Tonga Trialling the mucuna bean - farmer-led extension. Case Studies Lessons from the field the DSAP Experience SPC 2009.

Allwood Allan, EnglebergerKonrad, Armstrong John W and Sengebau Fred (1999)Feasibility Study on Eradication of Fruit Flies Attracted to Methyl Eugenol (Bactroceradorsalis and Bactroceraumbrosa) in Palau. Project on the Regional Management of Fruit Flies: RAS/97/3331

Asian Development Bank (2011). Asian Development Bank and Palau Fact Sheet. December 31st 2010

Australian Bureau of Meteorology and CSIRO, 2011. Climate Change in the Pacific: Scientific Assessment and New Research. Volume 2: Country Reports.

Basilius Leonard (2007). The vulnerability assessment of taro patches in the Republic of Palau. A presentation to Republic of Palau Second National Communication to the UNFCCC, Sept 2007.

Bishop Robert V (1998). A Preliminary Report on Damage Assessment to Taro Patches. Report prepared for the National emergency Management Office, Dec 1998.

Bishop Robert (2003). Taro Production and Value adding in Palau.Third Taro Symposium in 2003 at SPC-Fiji.

Bishop Robert V (2001). Draft Strategy For National Agricultural Development :Horizon 2010, World Food Summit Follow-up. Republic of Palau Oct 2001

Bishop, Robert V. and Wichman, V (2005). Food Security in Palau: A Situation Analysis,' Palau Household Food Security Task Force, Palau Community Action Agency and the South Pacific Commission, Koror, Palau, June 1995.

Bourke, R.M. and Betitis, T., 2003.*Sustainability of Agriculture in Bougainville Province, Papua New Guinea*, Land Management Group, Australian National University.http://rspas.anu.edu.au/papers/lmg/SustainAg_Bvill_text.pdf

Bourke, R.M. and Harwood, Tracy, eds, 2009.*Food and Agriculture in Papua New Guinea*.The Australian National University E Press. Canberra, Australia.

Canfield Joan (1980). Palau: Diversity and Status of the Native Vegetation of a Unique Pacific Island Ecosystem. Department of Botany University of Hawaii.

Donnegan Joseph, Sarah L. Butler, Olaf Kuegler, Brent J. Stroud, Bruce A. Hiserote, and KahgarRengulbai (2007) Palau's Forest Resources 2003. United States Department of Agriculture, Forest Service/Pacific North West Forest Service. Research Bulletin PNW-RB-252 January 2007.

Clarke G and Wright Duncan (2005).On the Periphery?Archaeological Investigations at Ngelong, Angaur Island, Palau. Micronesia 38 (1): 67-91, 2005.

Colin Patrick L (2009) Marine Environments of Palau: Indo-Pacific Press for Coral Reef Research Foundation : Mutual Pub., LLC, 2009. Koror, Palau ; Honolulu

Evans, Dale (editor) (2008). Taro Mauka to Malai: A Taro Production and Business Guide for Hawai'I Growers. College of Tropical Agriculture and Human Resources, University of Hawaii

Government of Palau and the Secretariat of the Pacific Community (2009). Joint Country Strategy 2009–2013

Grove, R. H, (1998).Global impact of the 1789–93 El Niño. Nature 393: 318–319.

Holm Tarita (2011).'An Assessment of Food Security and Sustainable Livelihoods in Palau'National Program Coordination Support, FAO and the National Program Steering Committee of the Palau Food Security and Sustainable Livelihoods Program (FSSLP)June 2011

James R. Rarick (1997). An Update of the Situation Analysis On Food Security In The Republic Of Palau', South Pacific Commission, 1997

KitalongAnn (2011).Palau Adaptation to Climate Change: Gap Analysis. Palau Bureau of Agriculture.

Kitalong Ann Hillmann. Forest Resources of Palau: A long-perspective (2008) .Micronesica 40(1/2): 9-31, 2008

Lebot, Vincent, 2009. Tropical Roots and Tuber Crops: Cassava, Sweet Potato, Yams and Aroid, CAB International , UK.

Mad P. Kempis (1999). Palaun, English Common, and Scientific Names of Trees and Shrubs of Palau, August 1999 Palau Association of Libraries.

McGregor, A. 2000. A feasibility study of eradication of Oriental fruit fly (B. dorsalis) and breadfruit fly (B. umbrosa) from the Republic of Palau. RMFFP publication. 45pp.

McGregor, A., R. M. Bourke, M. Manley, S. Tubuna, and R. Deo. (2009). Pacific Island Food Security: Situation, Challenges and Opportunities. Pacific Economic Bulletin 24(2): 24–42.

McGregor, Andrew M. and McGregor, Ian K.L., 1999.*Disasters and Agriculture in the Pacific islands*. South Pacific Disaster Reduction Programme (RAS/92/360).

McGregor Andrew with Peter Kaoh, LaiseneTuioti Mariner, Padma NarseyLal and Mary Taylor (2011).Assessing the social and economic value of germplasm and crop improvement as a climate change adaptation strategy: Samoa and Vanuatu case studies. International Union for the Conservation of Nature, Suva.

McGregor Andrew with Robert Bishop (2011) A technical assessment of the current agricultural conditions of Angaur Island Palau: with recommendations for the sustainable use of the island's natural resources. A report prepared for GIZ.

Norman David and HeikoBammann (2000) An Assessment of the Informal Employment and Sustainable Livelihoods Project (IESL). Republic of Palau (TPP/97/002)

Otto Judy (2000).Nutrition and Food Security in the Republic of Palau, Report prepared for FAO

Palau Pacific Adaptation to Climate Change (PACC) Project (2012). Climate Change Impacts on Food Security and Health in the Republic of Palau: A Socioeconomic Assessment Report. June 2012

Palau Bureau of Public Health (2000).Nutritional Improvement in the Republic of Palau: Strategic Policy Framework

Palau Community College (2012). Palau PACC Project: Evaluation of Taro Varieties for Salt Tolerance. Pacific Adaptation to Climate Change Project. Palau Community College , Second Quarterly Report, July 2012.

Palau National Committee on Population and Children/United Nations(1997)

Sustainable Human Development: Progressing from the Past.

Palau Office of Planning and Statistics and UNDP Pacific Centre (2006). Analysis of the 2006 Household Income and Expenditure Survey: Final report on the estimation of basic needs poverty lines, and the incidence and characteristics of povertyin Palau. UNDP Pacific Centre Suva, Fiji 11 July 2008.

Palau Office of the Palau Automated Lands and Resources Information System (PALARIS) (2012). Palau PACC Project, Farm Survey Report. Ministry of Public Infrastructure, Industries and Commerce Republic of Palau

Rosa Dalla (1993) Nitrogen Fixing Trees as Atoll Soil BuildersAgroforestry for the Pacific Technologies A publication of the Agroforestry Information Service April 1993, Number 4

Secretariat of the Pacific Community. 2006. Taro. Pacific Food Leaflet No. 5. Healthy Pacific Lifestyle Section.

Sohi S,.Loez-Capel E, Krull E, Bol R., 2009. Biochar's roles in soil and climatechange: A review of research needs. CSIRO Land and Water Science Report 05/09, 64 pp..

Thomson Lex (2006) Flueggeaflexuosa(poumuli) Species Profiles for Pacific Island Agroforestry www.traditionaltree.org. April 2006.

Webb, A. 2007. Assessment of salinity of groundwater in swamp taro (*Cyrtospermachamissonis*) 'pulaka' pits in Tuvalu. EU EDF8-SOPAC Project Report 75. Reducing Vulnerability of Pacific ACP States.SOPAC, Suva, Fiji.

Ryan, Tony (2008). Agricultural Sector Report: Working Paper. TA 4929-PAL Facility for Economic & Infrastructure Management Project. Report prepared for Gov. Palau and the Asian Development Bank.

Salinger, M. J., Allan, R., Bindoff., N., Hannah, J., Lavery, B., Lin, Z., Lindesay, J., Nicholls, N.,Plummer, N., and Torok, S. (1996), 'Observed variability and change in climate and sea-level in Oceania', in Bouma, W. J., Pearman, G. I., and Manning, M. (eds.), Greenhouse: Coping with Climate Change, CSIRO, Melbourne, pp. 100–126.

Seniloli, M et al, 2002. 'Gender issues in environmental sustainability and poverty reduction in the community: social and community issues', Development Bulletin, no. 58, pp. 96-98.

Space James C., Barbara M. Waterhouse, Joel E. Miles, Joseph Tiobech and KashgarRengulbai (2003) Report to the Republic of Palau on Invasive Plant Species ofEnvironmentalConcern**.**USDA Forest Service, Pacific Southwest Research Station, Institute of Pacific Islands Forestry, Honolulu Hawaii, 5th May 2003.

SPC (1997) A Report of a Participative Rural Appraisal of Angaur Island Palau, Economic and Rural Development, 2-5 April 1997.

Solomon, Amy and Anthony Newman (2012). *Reconciling disparate twentieth-century Indo-Pacific ocean temperature trends in the instrumental record.* Nature Climate Change, September 2012.

Teariki F. Mateariki et.al. (1998) Sustainable Food Production Development: Angaur State – The Republic of Palau. February 1998. SPC/PCC-CRE/PCAA-RWG-IESL Project

United States Department of Agriculture, Natural Resources Conservation Service Republic of Palau (2000). Draft soil assessment of Angaur. Sept, 2000.

UNDP, (1997) Project of the Pacific Island Sub-Regional Programme, TTP/97/002, Informal Employment and Sustainable Livelihood in the Republic of Palau. Project Document. Suva: UNDP.

USDA, Soil Conservation Service (1983) Soil Survey of the Islands of Palau Republic of Palau.

VanderWerf, E. 2007.2005 Bird Surveys in the Republic of Palau.Final report for US Fish & Wildlife Service and Palau Conservation Society, 88pp.

United States Department of Agriculture, Natural Resources Conservation Service.2009.Soil survey of the Islands of Palau, Republic of Palau. Accessible online at:http://soils.usda.gov/survey/printed_surveys

Wentworth Chester K, Mason Chester K., Davis Dan A.Salt-Water Encroachment as Induced by Sea – Level Excavation on Angaur Island (1955). Economic Geology, 50, pp. 669-680.

Vieth Gary, Linda J. Cox, and Carol Ferguson (1995) What Is Oahu's Open Space Worth? Cooperative Extension Service CTAHR Fact Economic Fact Sheet no. 21 Department of

Agriculture and Resource Economics. College of Tropical Agriculture and Human Resources.University of Hawaii.

Vessel A.J and Simonson Roy W. Soils and Agriculture of the Palau Islands (1958) Pacific Science, Vol. XII, October, 1958

VisiaAlonz (2007) 2006 Republic of Palau HIES. Ministry of Finance Bureau of Budget and Planning Office of Planning & Statistics