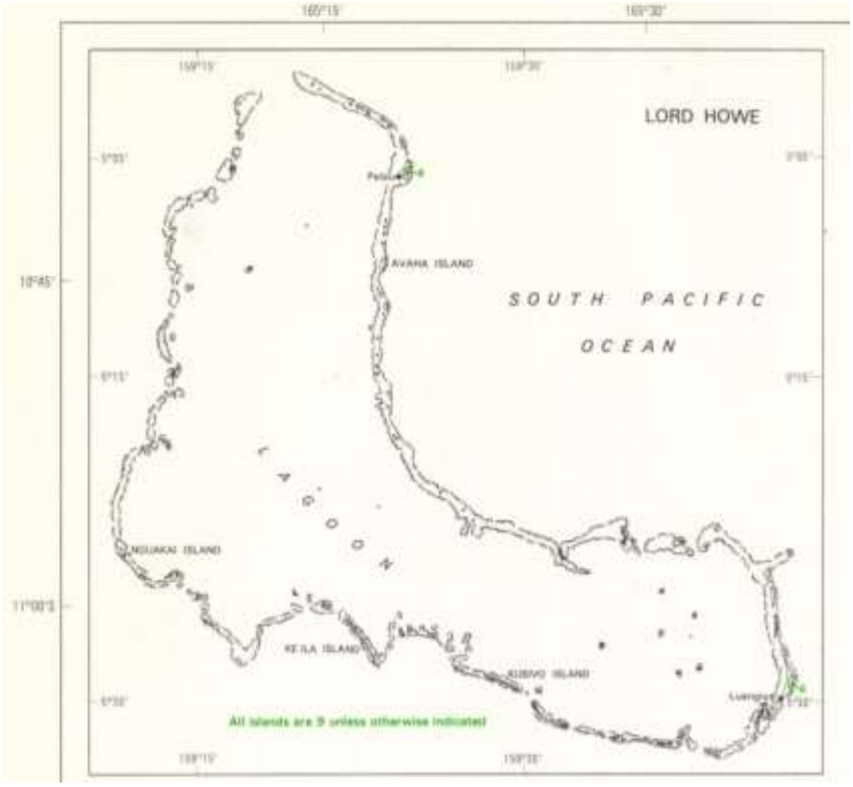
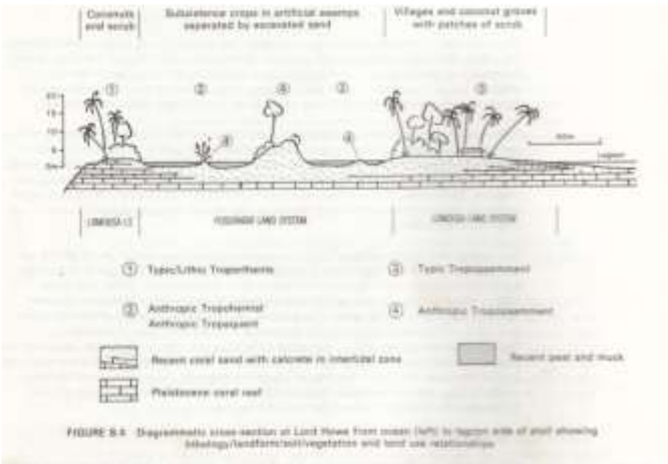
THE SOLOMON ISLANDS PACC ONTONG JAVA PILOT FOOD SECURITYPROJECT: A BENEFIT COST ANALYSIS





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Executive Summary

The densely populated low lying atolls in the Solomon Islands 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 is also expected increase. On Ontong Java, the decline in available subsistence crops is exacerbated by increasing population and a sharp decline in income earning opportunities that enable the purchase of rice and other substitute staples.

While quantitative food production surveys have not been undertaken on Ontong Java since 1986, indications are that food production has declined significantly. The combined impact of declining taro production and increasing population is reflected in that over 60% of available income on Ontong Java is spent on the purchase of imported food. In addition to declining availability of energy food, there are particular low levels of fruit and leafy vegetables availability.

In 2011 the Government imposed a ban on the trade of beche-de-mer, which hitherto accounted for around 95% of total household income. The ban has not only meant a loss of income to purchase food, it has reduced access to food. Without beche-de-mer to purchase and with virtually no copra now produced, there is little incentive for ships to travel to the atoll.

Three broad project options exist for improving food production on Ontong Java:

1. Taking measures to reduce salt water contamination in food production areas
2. Introducing root crop varieties and cultivars that have tolerance to salinity
3. Modifying the soil and food production environment

Option 3 is recommended for the PACC Pilot Project. This option is seen to have the highest probability of success in a reasonably short time frame. The proposed PACC pilot project builds on the current Anglican Church of Melanesia (ACM) food security and water supply project and includes expanding parallel activities from Luangiua to Pelau. The PACC Project can be considered as a phase two of the ACM Project.

The challenge is to take existing scientific knowledge together with food production experience from other atoll situations, and apply this in an effective way on Ontong Java. What is being introduced, while new, is not seen as foreign to Ontong Java residents. The proposed pilot project essentially involves an appropriate modification of the organic environment in which food is grown. This modification involves an integrated combination of measures, including:

- Improved composting techniques that increase the volume and quality of available compost
- Agroforestry techniques that involves the use of nitrogen fixing trees and legumes
- Growing vegetables in raised beds and containers (including appropriate hydroponics) and improved home gardening techniques
- The establishment of small nurseries for high quality vegetable seedling and agro forestry planting material
- The introduction of the 'soils school' extension methodology so people understand their soil and how best to utilise it for sustainable food production

The total cost of the three year project is approximately $SI2.5 million (US$ 350,000). Direct project benefits are measured in terms of the dollar value of increased nutrition arising from project. Using 1986 data as the bench mark, it was estimated that the current annual value of the nutrition lost since that time lies in the range of $440,000-660,000. Taking the average of this range, different scenario of the project's projected success can be modelled.

A range of plausible scenarios include:

Scenario 1: The value of nutrition derived from local food production restored to the 1986 level in three years and then gradually increases for the next decade(seen as possible but unlikely)

Scenario 2: The value of nutrition derived from local food production restored to the 1986 level in three years, where it remains for the next decade (seen as challenging but possible)

Scenario 3:The value of nutrition derived from local food production restored to the 1986 level in five years, where it remains for the next decade (seen as readily achievable for a well implemented project)

Scenario 4: The value of nutrition derived from local food production restored to 50% of the 1986 level in three years, where it remains the same for next decade (would be a disappointing result if the project could not achieve at least this level of outcome)

The benefits and the costs are projected over a 13-year period – a decade beyond the end of the Project. There are ongoing costs beyond the three year life of the project. The flow of benefits and costs are calculated in present value terms by discounting at a rate of 4%. The results are summarised as.

		NPV	B/C	IRR
Scenario 1	$	3,539,246	2.34	28%
Scenario 2	$	2,332,236	1.88	23%
Scenario 3	$	1,836,527	1.70	17%
Scenario 4	$	(152,833)	0.94	3%

It would be a disappointing result if the project could not achieve at least the level of outcome projected in scenario 4. This scenario was found to be slightly economically sub-marginal, with a benefit cost ratio of 0.94. However, when the "without" Project case situation is taken into consideration a positive economic outcome is likely to result. "Without" the Project, food production will continue to fall, rice and other food imports will further increase and the level of nutrition will further deteriorate. A simulation is undertaken to illustrate the impact of not undertaking the project.

There are also significant non direct benefits to the national economy. The absence of a project with a reasonable food production outcome will increase the pressure on people to migrate to Honiara.Accelerating out-migration brings with it costs to urban areas and the national economy. The Solomon Islands are already dealing with unsustainable high rate of urban migration with the attendant urban environmental and social problems of poverty, squatter housing, over-taxed infrastructure, congestion, pollution crime and political instability. To the extent the proposed project reduces the rate of out migration it represents a project benefit.

List of Acronyms

ABM	Australian Bureau of Meteorology
ACIAR	Australian Centre for International Agricultural Research
ACM	Anglican Church of Melanesia
BCR	Benefit cost ratio
CePaCT	SPC Centre for Pacific Crops and Trees
CIP	International Potato Centre in Peru
CIRAD	Centre de coopération internationale en recherche agronomique pour le dévelopement
CSIRO	The Commonwealth Scientific Industrial Research Organization
DSAP	SPC, Development of Sustainable Agriculture in the Pacific Project
ENSO	El Nino Southern Oscillation
FFS	Farmer Field School
FSM	Federated States of Micronesia
HIES	Household Income and Expenditure Survey
IRR	Internal Rate of Return
KSA	Kastom Gaden Association
MAL	Ministry of Agriculture and Livestock
NFTA	Nitrogen Fixing Tree Association
NGO	Non Governmental Organization
NVP	NPV
OMV	Organic Matters foundation
PAAC	SPREP, Pacific Adaptation to Climate Change Project
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
V&A	Vulnerability and Adaptation

Acknowledgements

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Exchange rates

Exchange rates per unit of foreign currency (mid-market rate July 1st 2012)

	SI Dollar
USD	7.08
AUD	7.24

Source: Universal Currency Convertor

The Problem

Climate change and food security on the Solomon Islands densely populated atolls

Climate Change and its impact on the food security of the densely populated low lying atolls in the Solomon Islands is a major concern. These areas 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. This situation is already contributing to declining food production and is occurring at a time when the population has been increasing and income earning opportunities decreasing.

While there is a wide diversity of social and biophysical environments within the low lying atolls, some areas are likely to be particularly sensitive to climate change and extreme climate variability. The Pacific Adaptation to Climate Change (PACC) Project, Vulnerability and Adaptation (V&A) Assessment Report (2011) for Ontong Java identified the following areas as being of greatest importance:

- subsistence agriculture and nutrition
- human health
- coastal environments and systems
- water resources and;
- marine resources

The meaning of food security in the context of Solomon Islands atolls

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 of 2009 identified four pillars of 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. The Solomon Island atoll communities are facing increasing food security stress across all four pillars.

According to the 2011 PACC V&A Assessment Report, food security in the low-lying atolls is strongly linked to the following combination of factors:

- land availability to produce sufficient quantities of nutritional food for the family;
- availability of giant swamp-taro to sustain families during drought periods and disaster seasons;
- accessibility of marine resources to exploit and earn income to buy imported foods to supplement locally available food;
- market access to be able to trade to earn income;
- transport availability to sell goods and access food; and,
- efficient communications to enable contact with to relatives in urban centres for provision of goods and other items.

Weaknesses in all six of these areas contribute to a food insecurity situation.

The specific impact of climate on the local availability of food

Low-lying atoll communities depend for their subsistence on root crops, coconuts, breadfruit and marine products. The root crops are mainly giant swamp (*Cyrtosperma merkusii)* locally known as kakake and taro tru (*Colocasiae esculenta)*. The importance of the latter has declined significantly in recent decades due to intolerance to salinity, disease[1] and other factors. The decline in the availability of subsistence crops has coincided with a period of rapidly increasing population growth and a sharp decline in income earning opportunities that enable the purchase of food. The Solomon Islands Smallholder Agriculture Study (2006) classified the atolls of Ontong Java and the Sikiana group as locations of high stress (Vol 2, p. 13). However, they concluded that this stress was modified somewhat by the fact that traditional society and the associated coping mechanism still functioned well. This augers well for the prospects for a food security project.

The changing food security situation on Ontong Java

The situation in 1971 and 1986

The last detailed study of cropping systems and food production on Ontong Java was conducted in 1986 by Bayliss-Smith as part of the AusAID South Pacific Small Holder Project.[2]. The 1986 study was a follow up to intensive field surveys undertaken by Bayliss-Smith in 1970-71. In 1970-71 precise estimates of cultivated production and crop yields were obtained. In 1986 only crop areas were estimated. In the absence of any other information it is assumed that yields in 1986 were the same as in 1970-71. Based on these findings, table 1 presents comparative data for the area cultivated, production and per capita consumption of swamp taro and taro tru. These data show a significant increase in swamp taro production over the 15-year period (31%) and some decline in taro tru production (13%). However, due to rapid population growth over the period, the per capita consumption of both root crop staples fell significantly – 14% for swamp taro and 43% for taro tru. According to Bayliss-Smith, the total population of Ontong Java in 1986 was 1,408 compared with 926 in 1972 (p. 7).

Comment [KM1]: who's project is this; name coordinating agency

Table 1: Cultivation area, production, and consumption for swamp taro and taro tru (1970-1 and 1986)

[1]Bayliss-Smith 1986 makes particular reference to a dry root disease spread in the soil by the nematode *Hirshammiel lamiticausa*. Dr Grahame Jackson confirmed the damaging impact of this disease. And its likely continued presence (per. com. June 2012 http://issuu.com/terracircle/docs/extensionfs). Surprisingly this disease is not mentioned in the long list of taro pest and diseases mentioned in PACC V&A Report. Grahame Jackson is of the view that it unlikely that a number of the serious pest and diseases are indeed present, to quote: "I am slightly amazed that it says all those pests and diseases are present there. Are they sure or have they just taken the pests present elsewhere in the country and said they are there too. For instance, are taro beetles really there; are the taro viruses present, taro leaf blight, and the rest of those pathogens listed. Could be, but the whole section reads as if it has been purloined from some other document "(per com June 2012)

	Swamp taro			Taro tru		
	1970-71	1986	% change	1970-71	1986	%change
Est. cultivated area (ha)	37.42	39.80	6.4%	3.3	3.1	-6.1%
Est. annual production (edible net weight tonnes per annum)*	56	73	30.9%	29	25	-13.0%
Yield (net weight per ha)	1.49	1.49		8.8	8.8	
Edible net weight per capita (kgs per person	60	52	-13.9%	31	18	-42.8%

* estinated at 45% of gross weight for swamp taro and 42% of gross weight for taro tru

As a consequence, there was a large increase in the energy needs that were met from imported food (table 2). The percentage of calories sourced from imported food almost doubled over the period to stand at 51%. All local sources of calories declined over the period – with the decline greatest for taro (falling 6% for swamp taro and 5% for taro tru). Table 3 compares the per capita annual consumption of imported food in 1970-71 and 1986.

The food situation in 2012

As described by the PACC 2011 V&A Report:

> The land is mainly used for coconuts. One village is located at Pelau and another on Luaniua and growing in the backyards at the villages are crops like banana, taro tru, kongkong taro (*Xanthsom*a taro), few cut nuts, slippery cabbage and pumpkin. Pigs can be seen tethered under the coconuts near the villages. The main crop is the swamp taro (*Kakake*). This crop is now the main daily subsistence crop – but fall far short of meeting families' daily caloric needs.

Unfortunately, since 1986, a follow-on comprehensive study of food production and the pattern of food consumption on Ontong Java has not been undertaken. One thing that is known is that population has continued to grow at a rapid rate. The 2009 Population Census put the Ontong Java population at 2,857 – a doubling of the population in the 13 years since 1986.

While quantitative surveys of food production on Ontong Java have not been undertaken since 1986, all indications are that food production has declined significantly under climatic pressures and associated disease together with over exploitation of fragile land resources.

Table 2: A comparison of the source of calories consumed 1970-71 and 1986*

	1970-71 million kilocalories	%	1986 million kilocalories	%
Swamp taro	96	18%	82	12%
Taro tru	58	11%	41	6%
Coconuts	112	21%	102	15%
Other (sweet potato, banana etc.)	21	4%	7	1%
Imports (rice, wheat flour etc.)	143	27%	347	51%
Fish and other marine products	101	19%	102	15%
Total	531	100%	681	100%

*Source: Bayliss-Smith 1986, p. 18.

Table 3: A comparison of the per capita (kg) consumption of imported food, 1970-71 and 1986*

Comment [KM2]: column lines ?

	1970-71	1986	% increase
Flour	10.9	20.0	83%
Rice	17.7	36.6	107%
Sugar	11.7	18.7	60%
Biscuits	3.3	6.5	97%
Tin fish	0.1	1.5	1400%

* source: Bayliss-Smith 1986, p.36

The current subsistence agriculture situation is described in the 2011PACC V&A Report:

> According to the islanders' own observation, recently salt water intrusion has increased, contaminating the swamp taro growing creeks due to sea level rise and occasional sea surges during bad weather. The people reported that swamp taro contamination now occurs at locations where it has never been experienced in the past. In 2008, a Ministerial report described after high swells were experienced that: *"The waves of the high swells have caused much damage to the agriculture of the atoll people. Severe in Luaniua, moderate in Pelau. High waves drives through the coast and into the planting fields that are located very close to the coast. The inner kakake fields were affected by salt water intrusion. Due to the high waters that came with the waves, salt water intrude in to the water table as a result that the kakake fields were flooded with saltwater. As a result of those kakake plants went brackish, wilt then die after. Kakake fields or gardens were flooded from waves and upwelling." (p, 35).*

The PACC Report goes on to describe further specific impacts on the main staple swamp taro:

> About a decade ago in 2000, a new problem had arisen with *kakake* tubers. This time it was noticed that tubers were rotting at their bases. Initially the issue occurred mostly in gardens that

> were located in the areas close to the coast on both islands, but later it also slowly affected the patches in the centre and the southern end of the island.
>
> Plant growth is decreasing further, with plants now about 30 – 60 centimetres at the most and no big trees are standing in there. However, in the patches that are positioned in the centre of the islands with big trees standing, *kakake* plants are growing really healthy with heights of 1 – 5 feet high.
>
> Information gathered from the people on the atoll showed that many of them believed that the rotting of plants is due to increasing sea level rise and salt water intrusion over the years. However, the symptoms can also be attributed to the existence of water bourn fungal diseases. Proper soil salinity measures or maps has to be produced simultaneously with thorough pathology assessments to ensure that the people on the island are certain, well aware and informed of the nature of issues they are dealing with so that they can be able to effectively adapt to coping measure that may be identified by existing projects or future adaptation initiatives (p. 42).

A Ministry of Agriculture and Livestock (MAL) tidal surge assessment visit to Ontong Java in December 2008 found that " 85-90% of swamp taro gardens visited have been indicated yellow leaves and wilting."(Labu Toito'ona 2008)

At the time of the Bayliss-Smith survey, taro tru was still being grown in the taro swamps together with swamp taro. This is now rarely the case. *Colocasia* taro has much lower saline tolerance than *Cytrosperma (*Manner 2011*)*. Taro tru is now mainly grown on dry land, where it faces even greater constraints relating to poor soil fertility and high labour input requirements. The expectation is that decline in taro tru production has even been greater than that of swamp taro which has a degree of salinity tolerance and less disease susceptibility[3]. Bayliss-Smith also suggested that the underlying reason for the decline in taro tru production was the low return to effort in producing dietary energy. While swamp taro yields are lower, it requires far less labour to produce the same amount of energy.[4] People continued to put the effort into growing taro tru because of its cultural role in exchange ceremonies[5]. The PACC V&A Mission observed that such ceremonial uses for taro tru continue today.

The PACC V&A Report identified declining soil fertility as a major issue in Ontong Java:

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[3]It is the view of plant pathologist Grahamee Jackson, with vast Solomon Island experience that *Cyrtosperma* is probably not affected by any pest or disease in Ontong Java, but Colocasia taro certainly is (per. com, June 2012).

[4]Bayliss-Smith makes the following comparison (p. 24):

	Colocasia	Cytrosperma
Annual work input (hours)	51,300	26,000
Food output	40 tonnes of corms	69 tonnes of corms
Energy gained (MJ)	246,690	404,183
Productivity (MJ/hr)	4.81	15.55

[55]Bayliss-Smith notes that in 1986 marriage ceremonies involved the exchange of calico (from the bridegroom's side) and taro (from the brides side). The exchange rate at the time was 50 corms of taro for per fathom of cloth (p, 24)

> The soil composition of the two land systems in Ontong Java, Lomousa and Pusaraghi, do not provide favourable conditions for productive agricultural activities, especially due to increased loss of top soil humus. This increases the risk of food insecurity which can impact adversely on the people's ability to engage in agricultural activities and production of vegetables, fruits, and other crops for subsistence consumption and sale to other people on the island. The low-lying nature of agricultural land- just barely 15 metres from shoreline poses high soil contamination risks due to salt water intrusion which is currently causing harm to the swamp taro crop, an important staple ingredient in the islanders' livelihood" (p, 24)..

The Report further notes that declining land productivity is also in part due to the land repeatedly being used over generations to make gardens.

> Gardening had been going on since the time the islands were inhabited. An elder on Luaniua recalled that the gardens are on the same areas since their fore fathers inhabited the islands many years ago adding that soil in the past was very dark and the water in the swamp was good to drink. Today the soil has lost its colour; water is brackish in most areas and the soil mostly sandy. The elder relates that the loss of soil fertility was due to loss of traditional knowledge by the younger generations. This reflects a long history of poor land use practice; which is related to over and unsustainable usage of available land and in some instances use of inorganic fertilizers to boost agricultural production (p, 46).

The combined impact of declining taro production and increasing population is reflected in that 63% of available income on Ontong Java is spent on the purchase of imported food (HIES Survey 2011).

In addition to declining availability of food energy, the PACC Report highlights the particular low level of availability of "protective" foods such as fruit and leafy vegetables:

> As far as the diet of the people is concerned, much of the food intake is energy foods and protein foods. Protective foods are almost absent. According to the HIES there are incidences of high blood pressure, diabetes, diarrhoea, TB, and yaws. Protective foods are not grown in the islands because of poor soil conditions. (p. 50).

Medium term climate projections

Impact of climate change and ENSO induced climatic extremes on Ontong Java

Sea level rise and extreme tides

Pacific Climate Change Science Program (PCCSP) report that the sea level rise near the Solomon Islands, measured by satellite altimeters since 1993, is mostly over 8mm per year (ABM and CSIRO 2011 p, 206). This is larger than the global average of 3.2 ±0.4 mm. In any one year sea levels are strongly influenced by the ENSO cycle – with sea levels higher by 0.1 m during La Niña sessions and lower by a similar amount during the El Niño session.

The combination of rising average sea level and extreme ENSO events have contaminated the fresh water lens that feeds the patches where taro is grown. This has happened in Ontong Java and other Pacific island atolls. Reported examples include Mortlock Island atoll east of

Bougainville (Bourke and Betitis2003) Tuvalu (McGregor and McGregor 1999), Kiribati (Tuioti 2011) and Palau (McGregor 2011 and Tuioti2011).

It can be expected that the problem of salt water contamination will be further exacerbated in the future with ENSO induced tidal fluctuations around an ever increasing (albeit gradual) average sea level. The associated loss of land through erosion and soil salinization has serious implications for subsistence food production in locations that are already seriously stressed - such as Ontong Java.

Rainfall

For the Solomon Islands as whole the PCCSP predicts, with a high degree of confidence, that the intensity and frequency of days of extreme rainfall will increase over the 21st Century (ABM and CSIRO 2011 p, 209).

What is less clear for the Pacific islands, is the association of extreme drought conditions with ENSO events. For much of the region there is an evident correlation between severe drought and El Niño events[6]. 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[7]. 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 to Kiribati and Tuvalu. Ontong Java can expect repeated extreme drought events mainly driven by the ENSO cycle. As noted by Brian Dawson, SPC's Senior Climate Change Advisor:

> Undoubtedly, climatic variability over the short to medium term will be dominated by what stage of ENSO we are in, hence the biggest effect on crops. ENSO is also the biggest effect on the frequency and intensity of drought and storm activity over the short term. The big question is whether El Nino or La Nina stages of ENSO will be more frequent and intense. The scientific evidence is mixed and, at present, it is not possible to project how ENSO will behave with climate change. In the past (over the multi-million year record), there has been a correlation between global mean temperature and intensity of El Nino – La Nina. In general in a warmer world, there is evidence that El Nino becomes more pronounced as the average state (not good for the western Pacific). However, that does not mean that will occur again. There is also some evidence that the El Nino intensity has been higher in the last 20 years than the last 100-year average. Also, La Nina events have been rare but the latest has been unusually strong (pers. comm. April 2011).

[6]Benson(1997) reports that the severe Fiji droughts of1987and 1992were associated with ENSO episodes. An even more severe El Niño-induced drought was experienced in Fiji and across western Melanesia in 1997-98. For Papua New Guinea, Allen (1997), observing data, dating from 1888 reports that severe drought with accompanying frost and forest fires occurred in1902, 1914, 1941, 1972, 1987, and 1997. He concluded that, "the statistical association between measures of ENSO severity and the physical impact of these in terms of drought and frost is reasonable, but by no means perfect.

[7]This is explained by Neville Koop, Pacific island meteorological expert as follows: "La Nina will lead to drought in Kiribati because the South Pacific Convergence Zone (SPCZ) moves south and the warm water pushes west towards PNG and the Solomon Islands with cooler than normal water along the equator from South America to the date line. The upward branch of the Walker Circulation shifts westwards and, as a result, less rain falls along the equatorial Pacific Ocean. Nauru is similarly affected."

For the Solomon Islands as whole PCCSP predicts, with a moderate degree of confidence, that the incidence of drought will decrease during 21st Century (ABM and CSIRO 2011 p, 209). However, PCCSP expects the frequency of moderate and severe drought to remain approximately stable.

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

Water and air temperature around the Solomon Islands have risen gradually since the 1950s. Since the 1970s the warming rate for sea surface temperature has been approximately 0.12°C per decade (ABM and CSIRO 2011 p, 206). 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 (ABM and CSIRO 2011 p, 209).

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°C, combined with a night air temperature of24°C (p.132).Significantly, Bourke and Harwood (2009) report that tuber production in PNG is reduced significantly at temperatures above 34°C. Bourke and Harwood indicate the possibility of increased incidence of some diseases with increasing temperature, particularly those influenced by rainfall and humidity (2009, p.79). 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).

Impact of demographic changes

According to the 2009 Population Census, the population of Ontong Java stood at 2,857 – a doubling of the population in the 13 years since 1986. With a land area of 12sq. km, the atoll now has a population density of around 250 persons/sq. km. This is way beyond the carrying capacity of Ontong Java projected as by Bayliss-Smith. He forecast that the population of Ontong Java would probably reach 1830 by 1996 and to support this population at current consumption levels would require a combination of one or more of the following:

- the full use of subsistence resources;
- an intensification of copra making; and/or
- further exploitation of beche-de-mer (1986, p.39)

Two and a half decades on, none of these requirements have been met. Subsistence production has declined significantly. Less than 5 tonnes of copra were produced in 2011, providing an income of only $13,333 from 60 sampled households (HIES 2011) (around $30 per head). In 1974, Ontong Java produced 458 tonnes of copra (Wall and Hansell, p. 46).

In 2011 the Government imposed a ban on beche-de-mer trade ,. Prior to the ban, beche-de-mer accounted for around 95% of total household income (table 4). Nothing has come close to replacing it.

Table 4: The annual 2011 income earned by a sample of 60 Ontong Java households*

Source of income	Value($)	% of income	Number of households involved	% of households involved
Beche-de-mer	12,160,00	95.4	60	100
Trochus	480,000	3.7	60	100
Shark fin	60,000	0.47	60	100
Copra	13,333	0.1	4	7
Pigs	16,000	0.13	2	3.3
Wages and salaries	12,000	0.09	1	1.3
Remittances	1,000	0.008	1	1.3
Total	12,742,333		600	

Under the current prevailing circumstances it is difficult to see how the population growth of the last decade could be maintained without massive consequences to the health and wellbeing of the Ontong Java community. If the status quo remains it could be expected that in the next few years a tipping point will be reached, where the population will rapidly decline. Improving the subsistence production is one policy element to address this dire situation.

Other factors contributing to food insecurity on Ontong Java

Throughout the Pacific islands remittances have proven an important economic lifeline for outer-island communities. Thus it is surprising that in 2011 remittances were only an insignificant fraction of Ontong Java income (table 4). In fact, when the beche-de-mer trade was in place remittances flowed in the other direction – with part of the beche-de-mer income going to support the Ontong Java community living in Honiara. It is not known if this has changed since the ban on beche-de-mer sales.

The ban on beche-de-mer sales has meant both a loss of income to purchase food, as well as a loss of access to food. Without beche-de-mer to purchase and with virtually no copra, there is little incentive for ships to travel to the atoll. Prior to the ban, there were two to three ships per month travelling to the atoll to collect produce and to drop off trade store goods. Since the ban, there is only one ship every three to four months. As a result, there has been a sharp decline in the availability of imported food to purchase. This situation has been further compounded by the drying up of trade store credit, without beche-de-mer to offer as collateral. Finally there is exceptionally poor telecommunications between the atoll and Honiara –relying entirely on two way radio connections.

Measuring the value of the decline in per capita food production on Ontong Java

Measuring the value of root crop production in 1986

It is known that the atoll's population has increased by over 50% since 1986, while total food production has declined. However, in the absence of any systematic surveys since 1986, it is not known by how much food production has declined. It is assumed that the production of giant swamp taro has declined by at least 10% and taro tru has declined by at least 50%. The much higher rate of decline assumed for taro tru production is based on *Colocasia* taro*'s* much lower salinity tolerance than *Cytrospema* taro. This difference in salt tolerance is discussed on page 15.

In 1986, it is known that 73 tonnes of swamp taro and 25 tonnes of taro tru were consumed (table 1). The nutritional value of this production can be estimated using the information in table 5. From this data, the rice equivalent that would have been imported to provide the same amount of dietary energy can be calculated (table 6). The root crop production can be valued in terms of the retail value of the imported price on Ontong Java at the time ($1.25/kg according to Bayliss-Smith, p. 37). Thus it is calculated that the value of root crops grown on Ontong Java in 1986 was approximately $70,000. At 2012 prices, these same root crops would be valued at $783,000 (at an Ontong Java retail rice price of $14/kg).

Table 5: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: Manner 2011 p, 12. derived from the SPC. 2006. Taro. Pacific Food Leaflet No. 5. Healthy Pacific Lifestyles.

Table 6: The value of taro produced in 1986 in terms of rice import equivalents saved

	1986 production (tonnes)	1986 total nutritional energy value (Kcal)	1986 per capita annual nutritional value (Kcal)	Rice equivalent of 1986 production (tonnes)		1986 dollar value of rice equiv
Swamp taro	73	52,560,000	37,330	30.35	$	37,937
Taro tru	25	47,880,000	31,500	25.61	$	32,012
Total	98	100,440,000	68,830	55.96	$	69,949

This value estimate is based on the food energy contribution of the root crops grown. As shown in Table 7, swamp taro is particularly rich in dietary fibre (3 times that of white rice), calcium (over 40 times that of white rice), iron (nearly twice that of rice) and zinc (three times that of rice). Taro tru does not perform as well nutrition wise as swamp taro, but is far superior to white rice. White rice contains no β-carotene or vitamin C. Both types of taro contain able quantities of these elements that are important for human health – with swamp taro being particularly rich in β-carotene. Ontong Java villagers have very limited alternative sources of dietary fibre and essential minerals and vitamins. It is not possible to quantify the replacement value of these non-energy nutritional elements if taro was not produced. However, it would be reasonable to assume that this value is at least equal to the value of the food energy lost – particularly in the light of scarcity of other dietary fibre, minerals and vitamins other than from marine products and coconuts.

Thus it is estimated that the 100 tonnes of taro (both types) that was consumed in 1986 is valued at $140,000 (at 1986 prices) and at $1.6 million (at 2012 prices). This estimate measures the value of food that would have to be imported to provide the equivalent level of nutrition.

Table 7: A comparison of the non- food energy contribution of white rice with swamp taro and taro tru(per 100 gm edible portion)

Comment [KM3]: if you have the time, be good to show all tables this way

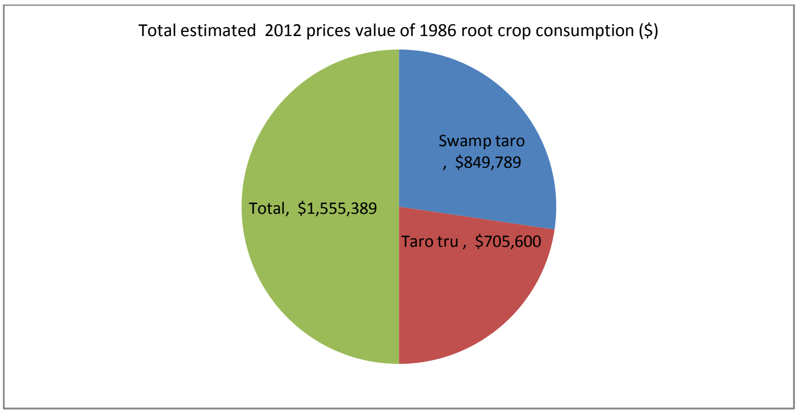
	white rice	swamp taro	% difference compared with rice	taro tru (white)	% difference compared with rice
fibre (gms)	0.8	2.5	213%	0.8	0.0
calcium (mg)	4	165.0	4025%	34.0	7.5
iron (mg)	0.3	0.5	67%	1.0	2.3
zinc (mg)	0.6	1.9	217%	0.8	0.3
β-carotene (μg)	0	27.0	∞	38.0	∞
Thiamin (mg)	0.03	0.0	-33%	0.1	1.7
vitamin C (mg)	0	7.9	∞	5.0	∞

Measuring the value of the decline in root crop production since 1986

It is believed that swamp taro consumption has declined by least 10% since 1986 and taro tru production by at least 50%. Based on the methodology presented above, table 8 estimates the annual value of lost root crop consumption (at 2012 prices) for different consumption decline scenarios - based on a 10%, 15% and 20% fall in swamp taro production and a 50%, 60% and 70% fall in taro tru production. On this basis, it is estimated that the annual value the decrease in root crop production since 1986 is in the range of $440,000 to $660,000 (average $550,000).These estimates provide a basis for calculating the expected benefits from any food security project for Ontong Java that has the restoration of food production as its objective.

Comment [KM4]: whats this belief based on again?

Table 8: The estimated annual value current root crop production compared with 1986 with different production scenarios



Value of decrease swamp taro (2012 prices)			Value of decreases taro tru (2012 prices)			Total value of decreased production (2012 prices)	
10% consumption fall compared with 1986	$	84,979	50% consumption fall compared with 1986	$	352,800	$	437,779
15% consumption fall	$	127,468	60% consumption fall	$	423,360	$	550,828
20% consumption fall	$	169,958	70% consumption fall	$	493,920	$	663,878

The proposed PACC Ontong Java food security pilot project

A pilot project for Ontong Java could be designed for any of the pillars of 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. However, this particular PACC food security pilot project will focus on households being able to grow their own food. This decision is based on the PACC V&A Report that concluded that the best prospects for enhancing food security on Ontong Java in the short to medium term lie with improving domestic food production.

Project aim

The aim of the proposed food security project is to reverse the decline in food production on Ontong Java. The project has as its medium term objective the return of nutrition derived from terrestrial food production to 1986 levels (the time of the last comprehensive food production survey).

Considerations in designing the pilot food security project

There were two important considerations in designing a food security production project for Ontong Java:

- The existing food security project already in place under the auspices of the Anglican Church of Melanesia (ACM)

- The advances in scientific knowledge of improved organic and biological production systems for the tropics that could be applied on Ontong Java in combination with traditional knowledge.

The ACM food security project

Since January 2011 the ACM has been implementing a two-year Food and Water Security pilot on Ontong Java. The project, with around USD 100,000 in funding from the United States Episcopal Church, is scheduled to end in December 2012. This small project has worked entirely on the island of Luangiua and has included:

- Introducing breadfruit varieties from Santa Cruz. Breadfruit is a common traditional food security crop grown by atoll communities in the Pacific. However, surprisingly little breadfruit grown on Ontong Java. Through varietal selection there is scope to increase breadfruit production and to extend the fruiting season. Breadfruit's large leaves have an important composting and mulching contribution to make.
- Introducing root crop varieties from Santa Cruz. This has involved dry land *Colocasia* taro (Santa Cruz is said to be free from damaging taro viruses and taro leaf blight), stem taro (*Alocasia*) and kongkong (*Xanthosoma*) taro.
- Introducing fruit trees – including three banana varieties, Polynesian chestnut(*Inocarpus fagifer**)*** and *Spondius dulcis.*
- Introducing organic and biological production systems involving composting, mulching and alley cropping using the legume tree *leucaena leucocephala.*

The ACM project is coordinated for Honiara but has a local supervisor who works with four lead 'farmers'. There is now good scope for working with and building on the ACM project, which would include expanding the activities to Pelau. There are major advantages in having an implementing entity already in place that has learnt from experience and is accepted by the community and the Area Council. An expanded ACM Food Security Project would seem well placed to lever inputs from other entities such as MAL, KGA and individual expertise.

The advances in scientific knowledge of improved organic and biological production practices and systems for tropical environments

There have been considerable advances in scientific knowledge of soil health and improved organic systems for tropical environments. When these are combined with traditional knowledge on sustainable food production, this knowledge offers opportunities to increase food production and nutrition from harsh atoll environments. Cultivation techniques such as mulched raised beds and agroforestry offer the prospect of significant improvements within a reasonably short time frame. Advances in extension techniques have also occurred that effectively convey to farmers the need and requirements for soil health to sustainably increase food production.

Pilot project options

Three broad project options exist for improving food production on Ontong Java:

1. Taking measures to reduce salt water contamination in food production areas. This engineering approach would involve the constructing seawater retaining walls and the draining of taro swamps.
2. Introducing salinity tolerant root crop varieties and cultivars.
3. Modifying the soil environment for producing. This organic systems/soil health approach involves agroforestry, composting, mulching, raised beds, quality seedling production etc. It could also include simple hydroponics[8].

Each of these options is discussed briefly below.

Taking measures to reduce the degree of salt water contamination

The decline in food production on Ontong Java can, in part, be attributed to salination, particularly of the taro swamps. Thus If salt contamination could be reduced this would, in part, provide a solution to the problem. Reducing the salinity of the swamps would likely require the building of retaining walls and the draining of the existing salt contaminated swamps. Such measures have been recommended in other atoll locations such as Angaur in Palau and in FSM (McGregor and Bishop 2011). However, there is no information available on the success or otherwise of such measures. Before such a project could proceed it would be necessary to undertake substantial and expensive hydrological and engineering studies. If, based on these studies, a decision was made to proceed the capital cost would be substantial and way beyond the resources available to the current PACC project. Given Ontong Java's large population such a project could eventually be justified. However, there are too many unknowns for this option to be included as a part of the present benefit cost analysis for the PACC Project.

The introducing of root crop varieties and cultivars that have greater tolerance to salinity

Much is said about the availability of "climate ready"/salt tolerant root crop varieties. The PACC V&A Report places emphasis on this option, which is seen as overly optimistic.

As part of this benefit cost analysis, 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.

[8] It should be noted that hydroponics were invented on atolls to feed the US army, with fuel drums cut vertically in half to produce to long containers full with coconut husks you can grow lots of vegetables

The consensus is that there is a long way to go in breeding significant salt tolerance into root crops. Dr Taylor suggests, however, that potential gains could be made from introducing *Cytrosperma* taro suckers from FSM where over 50 swamp taro varieties have been identified.

A first step would be to actually measure the salinity that currently existing in Ontong Java soils. The salinity of Ontong Java soils has not been tested since work of Wall and Hansell in the 1970s. *Cytrosperma* taro is the most salt tolerant of all root crop types[9] and it is possible that the rotting problems could be due the influence of other factors such as disease and a decline in mulching in the taro pits[10].

SOPAC have the equipment to accurately measure soil salinity and have undertaken this work in Tuvalu. This could be more simply done with refractometer/conductivity meter (Webb 2007). Comprehensive soil testing has been included at a start-up activity for the pilot PACC Project.

Cytrosperma is a relatively minor aroid for which there are no known breeding program*s*. Even if there was breeding for salt tolerance it would be very long process with an uncertain outcome. SPC CePaCT has 9 accessions of Cytrosperma that have been sourced from Fiji, Kiribati, Samoa and Tokelau. These have not been selected for their salt tolerance. For taro the breeding priority has been for *colocasia*, with the emphasis on resistance to taro leaf blight. It took over 15 years for the Samoan program breeding program to achieve the desired results (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.

Efficient breeding 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". He expects that the best varieties will come from somewhere else with similar conditions in the Solomon Islands. Mary Taylor notes that PNG has reported varieties of sweet potatoes that perform "well" on atolls – although the meaning of "well" needs to be quantified.

The case for climate ready/salt tolerant sweet potato has been greatly overstated and in the view of Grahame Jackson it is "extremely unlikely that you would find anything that will perform well in atolls conditions".

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[9] Webb (2007) provides a guide to the range of salinity tolerance for swamp taro from Tuvalu

Conductance (μ/cm)	Conditions of *pulaka* (swamp taro)
≤1,000	Ideal growing conditions
1,000-2,000	Tolerable growing conditions
≥3,000	Crop decline and failure

Laboratory testing undertaken by SPC CePaCT showed that swamp taro can tolerate up to 1.5% NaCl (15 ppt salinity), but this needs verification in the field (per.com. Valerie Tuia June 2012)

[10] Grahame Jackson reports from FSM that the level of the soil in the swamps and pits has gone down and this was the main cause of the damage that was seen and not saltation. The reason was that people were no longer adding mulch to the swamps. In Palau there are a heap of trees grown specifically to add to swamps, and they are found everywhere

It is not recommended that a major focus of the pilot project be on the introduction of salt tolerant planting material. The results of such an effort are seen as highly speculative and likely to fall well below expectations. This doesn't mean there would not be low cost opportunities to introduce root crop varieties that might be promising for a variety of reasons from other locations (provided it meet quarantine requirements with respect to pest and diseases). The Church of Melanesia has been bringing in small volumes root crop cultivars from Santa Cruz. The people can then decide what cultivars they wish adopt based on such things as yield and their taste preferences. The same could apply to some of the SPC material[11]. However, what is being suggested is that there should not be a major funding allocation for a larger scale germplasm introduction activity as a part of the PACC food security project.

Modifying the environment through improved organic systems

Food production on atolls has been traditionally based on organic systems. Wall and Hansell 1976 describe the system for the outlying Polynesian atolls of Ontong Java, Tikopia, Anuta and Sikaiana:

> Initially, they were lagoonal depressions lying at or slightly above sea level now deepened and extended laterally for the cultivation of swamp taro. The system of cultivation includes the frequent addition of leafy organic matter as a mulch, which was gradually built up into thick surface layers of peat resting on coral sand sub soil.........From the sample profile on Ontong Java the peat is seen to be soft, dark brown and rather sandy, basic in reaction with high carbonate and conductivity and a high CEC saturated with calcium, sodium and magnesium cations........ The peat has a wide C:N ratio and is, poorly decomposed. Reserve and available phosphorus levels are high in the peat dropping predictably in the inorganic subsoil (p, 30).

As noted by Dalla Rosa, Program Director for the Pacific, the Nitrogen Fixing Tree Association (NFTA) Agro Forestry Information Service:

> Atoll farmers have always practiced mulching and composting to some degree. Most consider regular organic additions integral to any agricultural activity. Organic matter management--more on atolls than anywhere-is crucial to sustained food production. Organic matter holds nutrient ions, retains precious soil moisture, and buffers soil pH. In all soils, it builds and maintains good soil structure and provides essential plant nutrients. In atoll soil, it must also take the place of the missing clay component in providing nutrient cation exchange sites that are crucial to nutrient cycling processes.
>
> Although composting has always been part of the farming/gardening routine on atolls, one key ingredient is in very scarce supply-Fresh/green organic matter**.** As a result, mulch and compost are often spread too thinly to yield significant benefits. Compost formation is slowed drastically in piles with too high a dry: green (carbon:nitrogen) ratio of organic material (p, 1).

The challenge is to take existing scientific knowledge on sustainable organic production systems, together with the gained experience in food production in other atoll situations,[12] and to apply this in an effective way to Ontong Java. While what is being proposed is new, it is not seen as

[11] For example if PNG recommends varieties for atoll production and they are available in the SPC CePaCT collection they could be introduced at the same time as other initiatives are implemented

[12] See for example Thaman, R.R and Chase.R (1990); Iqbal, M. (1992); and, Iqbal, M and Seluka, S. (1992). F

foreign to the people of Ontong Java. The proposed pilot project essentially involves an appropriate modification of the organic environment in which food is grown through an integrated combination of measures, including:

- Improved composting techniques that increase the volume and quality of available compost.
- Agroforestry that involves the use of nitrogen fixing trees and legumes.
- Growing vegetables in raised beds and containers (including appropriate hydroponics) and improved home gardening techniques.
- The establishment of small nurseries for high quality vegetable seedlings and agro forestry planting material.
- The introduction of the 'soils school' extension methodology so people understand their soil and how best to utilise it for sustainable food production.

A pilot project involving modifying the environment through improved organic systems

The proposed pilot project has seven interdependent components:

Component 1: Baseline information on soil status and food production

Component 2: Improved composting techniques

Component 3: Agroforestry

Component 4: Home gardening

Component 5: Nursery production of high quality seedling and agroforestry planting material

Component 6: Training – soil schools and farm to farmer exchanges focus

Component 7: Project management

Component 1: Baseline data on soil status and food production

There have been no soil tests or salinity measures undertaken since the work of Wall and Hansell in the 1970s. This base line information is needed before the commencement of the pilot project. It is required so the measures to be taken are appropriately focussed and their results measured[13]. Expertise to do this soil testing is available locally, although the sample would have to be sent overseas for analysis[14]. It is particularly important to know what the particular salinity levels are throughout the atoll. This is needed to separate out the impact of salinity and other factors on swamp taro production. This will determine if, and where, the salinity levels are such that the production of swamp taro is no longer viable. SOPAC have equipment to do detailed salinity testing and analysis and have undertaken this work in Tuvalu. SOPAC assistance should be requested.

[13]It is most fortunate that a copy of the Wall and Hansell Land Use Report have been sourced from the archives in the UK and is now with MAL. These reports contain invaluable base line data for the pilot project.

[14]Soil scientist and organic farmer Dr Shane Tutua would to be a very appropriate person to do this work.

It is proposed that the Australian Organic Matters Foundation (OMF) implement the "soil schools" program on Ontong Java. A representative of OMF should be involved in an initial soil testing inception mission. This involvement is seen critical for the specific design of the targeted "soil school" program.

It is recommended that a food production and consumption survey be conducted as part of the inception mission. There has been no such survey for Ontong Java undertaken since the work of Bayliss-Smith in 1986. These data is essential if the proposed PACC Food Security is to be effectively monitored and evaluated. Such a survey should be based on the same methodology as the Balyliss-Smith 1986 Survey and could be conducted by appropriately trained staff from MAL or KGA.

Component 2: Improved composting techniques

Composting has always been part of atoll cropping systems and it is the key element in expanding food production. The challenge is to have sufficient volumes of quality compost to meet the requirements for expanded food production. The key to meeting this challenge is the better utilisation of the available biomass and where ever possible increase the supply of biomass through agroforestry systems. The ACM's food security is already working on trying to address this constraint.

The most readily available source of biomass would seem to lie with coconuts. Bayliss-Smith reports the consumption of 585 coconuts per head in 1986 (p. 20). This compares with only 84 coconuts per head for the whole of the Solomon Islands at the time. Even if this exceptionally high per capita coconut consumption has fallen significantly since 1986, there would still remain a large volume of coconut husks available for systematic composting after allowing for those coconut husks used for fuel.[15] One of the intended outcomes of the agroforestry component is increase the availability of fuel wood and thereby releasing more coconuts for composting. While surplus piles of coconut husks do eventually degrade into compost this process is not efficient and much of the benefit of this resource is wasted. On Santo in Vanuatu great success is achieved with burying coconut husks in trenches for 18 months to two years. After this period the nuts can be readily shredded into a fine cocopeat that is used as a high quality potting mix. An appropriately modified version of this approach could be trialled on Ontong Java. On Ontong Java seaweed is reported at to be abundant at times and would make an ideal complement to a coconut husk based compost. The use of organic additives such as biochar could be used until such time sufficient biomass is available locally (Saran Sohi et.al 2009)[16]. SPC DSAP Project has undertaken work on the use of charcoal on atolls.

[15] If per capita consumption is now 300 coconuts per year the total quantity of coconuts available for systematic composting would be 900,000. To this would have to be added the accumulated piles of coconut husks from previous years.

[16]Lex Thomson noted"I really think Biochar would be the best soil amendment for atolls and make a tremendous different to, for example production of vegetables. The main problem is source of biomass – possibly coconut husks and purpose grown woody biomass (such as leucaena and acacia ampliceps and local species such as Vitex trifoliata, Casuarina equsetifolia and of course any unwanted woody weeds). Leafy material would be better composted. It wouldn't be nice but possibly you could add human waste

The success of the composting component will be fundamental to the success of the other components of the Pilot Project and in particular for the home garden, nursery and soil school components.

Component 3: Agroforestry

The ACM's project has initiated a program of alley cropping – with rows of the nitrogen the nitrogen fixing legume *Leucaena leucocephala* between 60sq meter garden blocks. Coralline soils are extremely nutrient deficient and highly alkaline. They are especially lacking in iron, potassium, and nitrogen. Nitrogen-fixing trees are able to "fix" or take up atmospheric nitrogen. They do this through a symbiotic relationship with certain bacteria that form nodules in their roots. When the leaves and branches of these trees drop off or are harvested and placed on the ground, this nitrogen becomes available to other plants.

Most nitrogen fixing trees are "pioneers" and readily establish on poor or degraded sites. These tenacious trees also grow rapidly, and can produce large amounts of nitrogen-rich green foliage in harsh environments.

Good mulch/compost producing nitrogen fixing trees atoll environments have the following characteristics as described by Rosa (1993)

- high leaf nitrogen concentration;
- tolerance to excessive soil alkalinity;
- tolerance to excessive soil salinity;
- relatively high leaf tannin content;[17].
- repeated and vigorous resprouting/regrowth after pruning; and,
- multi-purpose/multi - produce firewood/charcoal, pig fodder, and timber or poles for construction.

Leucaena measures up well against most of these criteria. However, it does have the problem of weediness unless well managed. Other nitrogen fixing trees, such as the readily available *Gliricidia sepium*[18], could also be trialled on Ontong Java. The experience in Vanuatu using *Gliricidia* for alley cropping in home gardens has been particularly encouraging (Kaoh 2009).

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into the mix which would then make a better quality char (and might stop groundwater contamination)" (per com June 2012).

[17]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.

[18] Rosa lists the desirable characteristics of *Gliricidia*as:

- A small branching tree to 10 m
- Tolerates droughts to 8 months
- Tolerates saline soils
- Coppices and re-sprouts vigorously
- Used for fodder, nurse tree, live-fencing, windbreaks
- Leafless sticks root easily
- No seed treatment necessary

*Flueggea flexuosa (*Poumuli*)*[19]is an other agroforestry tree that would be worth trialing on Ontong Java. Flueggea is traditionally an important source of durable, round timber throughout its natural range which includes Samoa, Solomons, Vanuatu, Tonga and Fiji. A major attraction for re-planting is its production of naturally durable logs on short rotations - e.g., 6–7 years for fence posts and 12–15 years for construction poles. Honiara based SPC forester, Basil Gau, is of the view that *Flueggea* would perform satisfactory on Ontong Java, given its performance in comparable locations elsewhere in the region. He also suggested trialing *Cordia Subcordata* on Ontong Java. This high value timber is prized for wood carving and is found in a number of atoll locations(Fosberg 1948).

Dr Lex Thomson, Pacific Island agroforestry specialist, recommends a number of other trees for testing and demonstration on Ontong Java. These include *Acacia ampliceps* from north-western Australia. He notes "Acacia ampliceps would probably be an excellent large shrub for atolls – tolerant of very high pH, brackish soils (around saline seeps), and moisture extremes" (pers comm June 2012)[20].

Success is being had in other Pacific islands with the use of the legume mucuna bean or velvet bean (*Mucuna pruriens*) in restoring or building soil organic matter in a short time period (Ali and Kaitu'u 2009). Mucuna is a vigorous annual climbing legume. It has been traditionally used as a fallow crop to restore soil fertility (adding nitrogen, potassium and phosphorous) and to suppress weeds[21]. The crop is shade tolerant and has very vigourous growth, high biomass production and low labour requirements for establishment. It is non-invasive because it is an annual that has to be propagated from stored seed.

Most of the experience with mucuna beans in the Pacific islands has been with acid or pH neutral soils, although Nat Tuivavalagi reports mucuna in Tonga being effective in soils with a pH or around 6.5. SPC's Dr Siosiua Halavatau reports mucuna bean has been tried by people on calcareous soils but may be not as poor as atoll soils. He report that we "tried in Tanaea in Kiribati but it did not do so well" (per. com May 2011). Dr Halavatau believes that it would be worthwhile trialling mucuna on atolls with compost to the planting holes before sowing (per. com June 2012).

It can also be manufactured in rat bait

[19]Detailed information on poumuli can be found in Thomson (2006).

[20]He further notes "In 1984 I discovered a fully prostrate form of *Acacia ampliceps* in the bottom of Wolfe Creek Crater but when I returned several years later it was gone. This form would transform life on the atolls by keeping down dust and providing excellent compost. Aborigines grind and eat the seed (but Pacific Islanders would not do this) and cattle love eating the phyllodes (leaves). The pH at this site must be one of the highest on the planet – it went right off the CSIRO colour chart ...perhaps more than 11 if that is possible in nature!"

[21]A literature search by Taveuni Agriculture Officer Rohit Lal undertaken for his USP Master of Agriculture Thesis found:

> A sole crop of mucuna bean adds about 155-200 kg/ha of nitrogen to the soil (Buckles et.al 1998). Jiri et.al (2004) confirmed that the velvet bean "complex" accumulated large quantities of calcium (140kg/ha, potassium (100 kg/ha) and phosphorous (15-20 kg/ha)

The ACM agro forestry work has also involved the introduction of breadfruit and some other fruit and nut trees (including *Terminalia catappa* and *Spondius dulcis)*. This should continue with the expanded pilot project. Breadfruit is seen as particular priority – both for its direct food value and for a source of biomas for composting via its leaves. There will be opportunities to access breadfruit varieties suited to atoll conditions from the SPC CePaCT collection to increase breadfruit production and to extend the season[22]. The availability of planting material from the existing Ontong Java breadfruit trees could increased by applying the marcotting techniques developed by the ACIAR Pacific Breadfruit Project in Fiji. Marcotted trees have the advantage of coming into production within two years. There would be value in promote cooking recipes to encourage greater utilisation of breadfruit when it is available.

Component 4: Home gardening

It is anticipated that a high percentage of the increased food production will be grown around houses. This will involves the introducing techniques such as alley cropping (described above), raised beds, growing vegetables in containers, and the introduction of appropriate hydroponics[23]. Planting in raised beds and growing vegetables in containers, such as large plastic polybags or fuel drums cut vertically, are proven production systems for harsh environments. Their success will depend on having a good supply of quality compost.

Component 5: A nursery for high quality seedlings

The production of healthy vegetables on Ontong Java will also depend on availability of quality seedlings and high quality compost. The establishment of two small seedling nurseries for this purpose is proposed – one located on Luaniua and one on Pelau. These nurseries would also used for the propagation of agro forestry trees.

Clear plastic would be required to protect the seedlings from heavy rainfall. A watering system (water tank and watering cans) is needed for dry periods. A critical component for the nursery would be simple soil sterilisation units (drums, mesh wire and pipes). pH and refractometers for soil testing is also required together with rain, temperature and solar gauges

Component 6: Training – soil schools and farm to farmer exchanges focus

Training and garnering the enthusiasm of households, particularly youth, will be critical to success of the pilot program. There is a need for the food producers to understand the biological systems in which they operate. They need to be able to identify and understand soil health problems and the solutions for their amelioration. Based on the a farmer field school (FFF) methodology the Organic Matters Foundation (OMF) have designed a program of "Soil Schools" for Pacific Island farmers (***www.organicmatters.org.au***). OMF in partnership with Pacific islands groups delivers soils training programs that directly address local needs and changes. These partnerships aim at creating culturally appropriate learning experiences that transfer biological farming practices, soil health education and sustainable farming to the farmers themselves. Farmers are trained to do their own soil tests and to evaluate the results and to design

[22] SPC CePaCT has big leaved bread fruit varieties from the Marshalls and Kiribati in their field plot. One variety produces fruit all year round in Kiribati (per.com. Valerie Tuia June 2011)
[23] The SPC DSAP Project promoted hydroponic vegetable growing on Futuna Island Wallis and Futuna (Ferraton 2009).

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. It all starts with the farmers and a change of mindset.

Typically a class involves around 30 participants and runs intermittedly over a two year period involving both introductory and advanced courses. The aim would be to training around 200 farmers and 20 champions. "Soil Schools" have been run in Fiji, Samoa, Tonga and the Cook Islands. The most substantial program has been in Taveuni Fiji – where it was a partnership between OMF and the Marist Tutu Rural Training Centre and the NGO Teitei Taveuni (http://www.spc.int/lrd/index.php?option=com_docman&task=cat_view&gid=313&Itemid=130). This training was introduced in response to rapidly declining yields experienced amongst commercial taro farmers.

It is proposed that OMF be part of Project inception mission to Ontong Java. It is at this stage that specific design details would be finalized and bench mark soil and salinity tests be undertaken. The inception visit would provide the trainer with a snapshot of conditions and issues for which the "Soil School" would be specifically tailored to meet farmer needs. Whilst the core principals of "Soil School" remain the same for all locations there are always inherent differences from one situation to the next.

As the people of Ontong Java try to deal with their increasing dire food security situation they no doubt fell isolated. There are other Pacific island communities facing similar problems and trying to adapt in their own way. Some have derived innovative solutions such as the composting being undertaken on Kwaio under the auspices of KGA and MAL. In such situations appropriate farmer to farmer exchanges are seen as an important extension tool and a way of reducing the negative impact of isolation. In the first year of the pilot project it is proposed that a number of Ontong Java's lead farmers will visit selected farmers from similar environments who successfully adopted organic farming techniques[24]. By year three it is hoped that Ontong Java will be model of achievement in sustainable atoll food production and farmers from other similar locations will visit Ontong Java as part of a farmer to farmer exchange program.

Component 7: Project Management

The key factor in the success of any project is management. Ontong Java isolation and poor communications (both with shipping and telecommunications) will present major management challenges. It is fortunately that the Anglican Church of Melanesia has been operating a small food security pilot project on Luangiua. The philosophy and direction that the ACM project is fully consistent with has been proposed for the PACC Project. The PACC Project looks to build on the current ACM Project, including extending parallel activities to the Pelau. The PACC Project should be considered as a phase two of the ACM project.

It is proposed that the current Coordinator of the ACM project become the PACC Project Manager. The logistical reality means that he will be again based be in Honiara but with funding provision to travel to Ontong Java at least twice a year. A major function of manager will be

[24] It would be very useful to organic farmer and soil scientist Dr Shane Tutua as a resource person in these farmer to farm exchanges.

coordinating technical inputs in support of the project. These will be such areas as soil science and organic production, agro forestry and nursery management. With exception of the operation of the "soil schools" all of this expertise is available within the Solomons Islands. Expertise will be drawn from MAL, KGA and from other individuals. A major challenge for the coordinator will be to program and consolidate technical inputs that takes best advantage of the limited and expensive shipping.

The ACM project has created a strong links with a lead farmer on Luangiua, who is a former forestry officer who has considerable nursery experience. It is proposed that this person will provide on-site oversight for the PACC project. The emphasis of the project will be on developing other lead farmers and champions.

To improve the links between the Honiara based Coordinator and the people operating in field an investment is required in high frequency two way radio system. However, it is hoped that over the life of the project that other agencies or donors will fund internet access to help overcome the tyranny of isolation for these remote islands.

Estimated Project costs

The estimated cost for each of the project components is presented in table 9. The cost details of each component line item presented in annex 1. The total cost of the three year project is approximately $2.5 million (US$ 350,000). This includes a 15% contingency provision.

Projected Project Benefits

Direct project benefits are measured in term of the dollar value of increased nutrition arising from project. Using 1986 data as the benchmark, it was estimated that the current annual value of the nutrition lost since that time lies in the range of $440,000 to $660,000. Taking the average of this range, different scenario of the project's projected success can be modelled. A range of plausible such scenarios are presented below:

- **Scenario 1**: The value of nutrition derived from local food production restored to the 1986 level in three years and then gradually increases for the next decade(**seen as possible but unlikely**)
- **Scenario 2**: The value of nutrition derived from local food production restored to the 1986 level in three years, where it remains for the next decade (**seen as challenging but possible**)
- **Scenario 3**:The value of nutrition derived from local food production restored to the 1986 level in five years, where it remains for the next decade (**seen as readily achievable for a well implemented project**)
- **Scenario 4:** The value of nutrition derived from local food production restored to 50% of the 1986 level in three years, where it remains the same for next decade (**would be a disappointing result if the project could not achieve at least this level of outcome**)

In all four scenarios it is assumed that there would be no further reduction in taro production over the next decade if the pilot project did proceed. This is a conservative assumption with further falls in taro production could be expected "without" the project. An allowance for further declines in taro production is made in the "without" project simulation presented in table 13.

Table 9: Estimated cost of the proposed PACC Ontong Java food security

	Year 1	Year 2	Year 3	Total (SI $)	Total US$
Baseline information	183,000	-	-	183,000	26,169
Composting and soil improvement	21,000	3,000	3,000	27,000	3,861
Agroforestry	57,000	30,000	30,000	117,000	16,731
Planting material acquisition	5,000	5,000	5,000	15,000	2,145
Home gardening	26,500	3,000	3,000	32,500	4,648
Seedling and agroforestry nursey	122,400	41,000	11,000	174,400	24,939
Training	299,000	234,000	334,000	867,000	123,981
Project management, local travel and logistical support	339,000	191,000	191,000	721,000	103,103
Total cost	**1,052,900**	**507,000**	**577,000**	**2,136,900**	**305,577**
Contingency (15%)	157,935	76,050	86,550	320,535	45,837
Grand total	**1,210,835**	**583,050**	**663,550**	**2,457,435**	**351,413**

The projected benefits for the realisation of these four outcome scenarios are presented in table 10

Table 10: Projected benefits for alternative achievement scenarios ($)

Year	1	2	3	4	5	6	7	8	9	10
Scenario 1	183,000	367,000	550,000	580,000	610,000	640,000	672,000	705,000	740,000	777,000
Scenario 2	183,000	367,000	550,000	550,000	550,000	550,000	550,000	550,000	550,000	550,000
Scenario 3	110,000	220,000	330,000	440,000	550,000	550,000	550,000	550,000	550,000	550,000
Scenario 4	90,000	185,000	275,000	275,000	275,000	275,000	275,000	275,000	275,000	275,000

Comparing benefits with costs

The projected benefits for the four scenarios are compared with the costs in table 11.

The benefits and the costs are projected over a 13 year period – a decade beyond the end of the Project. There are ongoing costs beyond the three year life of the project. The farmers will need to continue to spend money on repair and maintenance and the purchase of seed etc. A notional amount of $50,000 is allowed for this after the completion of the project.

The flow of benefits and cost are calculated in present value terms by discounting at a rate of 4% (the rateused in all PACC Project CBAs). 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. The difference between the present value of the benefits and cost provides the estimate of the net present value (NPV) for the project under the alternative outcome scenarios. The ratio of the two provides the benefit cost ratio (B/C) for the particular scenario. The internal rate of return (IRR)[25] is also calculated. The results are summarised in table 12.

[25] The IRR is the interest rate that brings the NPV of the investment to zero, or the B/C to 1.

Table 12: The economic benefits for various outcome scenarios the proposed Ontong Java food security project

		NPV	B/C	IRR
Scenario 1	$	3,539,246	2.34	28%
Scenario 2	$	2,332,236	1.88	23%
Scenario 3	$	1,836,527	1.70	17%
Scenario 4	$	(152,833)	0.94	3%

The result ranged from highly economically viable for scenario 1 (NPV of $3.5 million, B/C of 2.3; and of IRR of 28%) to slightly economically sub-marginal for scenario 4 (NPV = - $153,000, B/C = 0.94, and IRR = 3%).

The "without" Project case situation

It would be a disappointing result if the project could not achieve at least the level of outcome projected in scenario 4. This scenario was found to be slightly economically sub-marginal with a benefit cost ratio of 0.94. However, when the "without" Project case situation is taken into consideration a positive economic outcome could be expected. "Without" the Project food production will continue to fall, rice and other food imports will further increase and the level of nutrition will further deteriorate. If this further decline is averted because of the Project it can be considered as a project benefit. These benefits are captured in a simulation presented in table 13. If the value of a continuing decline in food production is taken into account "without" the project then even scenario 4 was found to be economically viable (NPV= $1.7million; B/C=1.7 and IRR=16%) for the particular simulation undertaken.

In these simulations taro is taken as an overall proxy for food production. It is assumed that by the end of the projected period without the project it will no longer possible to taro tru on Ontong Java and barely possible to grow swamp taro (assumes that production has fallen to 50% of the 1986 level). The calculation of the estimated valuation of this decline in taro production is presented in annex 2.

There are also significant non direct benefits to the national economy. The absence of a project with a reasonable food production outcome will increase the pressure on people to migrate to Honiara.Accelerating out-migration brings with it costs to urban areas and the national economy. The Solomon Islands are already dealing with unsustainably high rates of urban migration with the attendant urban environmental and social problems of poverty, squatter housing, over-taxed infrastructure, congestion, pollution crime and political instability. To the extent the proposed project reduces the rate of out migration it represents a project benefit. While such a benefit is expected to be substantial, it is not possible to quantify.

Table 11: Comparing project costs for alternative benefit scenarios for the proposed Ontong Java food security project

Year	1	2	3	4	5	6	7	8	9	10	11	12	13
Scenario 1													
Benefits	183,000	367,000	550,000	580,000	610,000	640,000	672,000	705,000	740,000	777,000	816,000	856,000	890,000
Costs	1,205,085	577,300	657,800	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000
B-C	(1,022,085)	(210,300)	(107,800)	530,000	560,000	590,000	622,000	655,000	690,000	727,000	766,000	806,000	840,000
PV Benefits (i=4%)		**6,177,038**											
PV Costs (i=4%)		**2,637,792**											
NPV		**3,539,246**	B/C =	**2.34**	IRR =	**28%**							
Scenario 2													
Benefits	183,000	367,000	550,000	550,000	550,000	550,000	550,000	550,000	550,000	550,000	550,000	550,000	550,000
Costs	1,205,085	577,300	657,800	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000
B-C	(1,022,085)	(210,300)	(107,800)	500,000	500,000	500,000	500,000	500,000	500,000	500,000	500,000	500,000	500,000
PV Benefits (i=4%)		**4,970,028**											
PV Costs (i=4%)		**2,637,792**											
NPV		**2,332,236**	B/C =	**1.88**	IRR =	**23%**							
Scenario 3													
Benefits	110,000	220,000	330,000	440,000	550,000	550,000	550,000	550,000	550,000	550,000	550,000	550,000	550,000
Costs	1,205,085	577,300	657,800	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000
B-C	(1,095,085)	(357,300)	(327,800)	390,000	500,000	500,000	500,000	500,000	500,000	500,000	500,000	500,000	500,000
PV Benefits (i=4%)		**4,474,318**											
PV Costs (i=4%)		**2,637,792**											
NPV		**1,836,527**	B/C =	**1.70**	IRR =	**17%**							
Scenario 4													
Benefits	90,000	185,000	275,000	275,000	275,000	275,000	275,000	275,000	275,000	275,000	275,000	275,000	275,000
Costs	1,205,085	577,300	657,800	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000
B-C	(1,115,085)	(392,300)	(382,800)	225,000	225,000	225,000	225,000	225,000	225,000	225,000	225,000	225,000	225,000
PV Benefits (i=4%)		**2,484,958**											
PV Costs (i=4%)		**2,637,792**											
NPV		**(152,833)**	B/C =	**0.94**	IRR =	**3%**							

Table 13: Comparing benefits and costs for alternative scenarios for the proposed food security project allowing for a continuing decline in food production "without" the project

Year	1	2	3	4	5	6	7	8	9	10	11	12	13
Scenario 1													
Benefits													
value of increased food production from the project	183,000	367,000	550,000	580,000	610,000	640,000	672,000	705,000	740,000	777,000	816,000	856,000	890,000
value of food production lost "without" the project	29,260	58,520	87,780	117,040	146,300	175,560	204,820	234,080	263,340	292,600	321,860	351,120	380,380
total benefits	212,260	425,520	637,780	697,040	756,300	815,560	876,820	939,080	1,003,340	1,069,600	1,137,860	1,207,120	1,270,380
Costs	1,205,085	577,300	657,800	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000
B-C	(992,825)	(151,780)	(20,020)	647,040	706,300	765,560	826,820	889,080	953,340	1,019,600	1,087,860	1,157,120	1,220,380
PV Benefits (i=4%)	**8,062,560**												
PV Costs (i=4%)	**2,637,792**	**NPV =**	**5,424,769**	**B/C = 3.1**		**IRR = 36%**							
Scenario 2													
Benefits													
value of increased food production from the project	183,000	367,000	550,000	550,000	550,000	550,000	550,000	550,000	550,000	550,000	550,000	550,000	550,000
value of food production lost "without" the project	29,260	58,520	87,780	117,040	146,300	175,560	204,820	234,080	263,340	292,600	321,860	351,120	380,380
total benefits	212,260	425,520	637,780	667,040	696,300	725,560	754,820	784,080	813,340	842,600	871,860	901,120	930,380
Costs	1,205,085	577,300	657,800	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000
B-C	(992,825)	(151,780)	(20,020)	617,040	646,300	675,560	704,820	734,080	763,340	792,600	821,860	851,120	880,380
PV Benefits (i=4%)	**6,855,550**												
PV Costs (i=4%)	**2,637,792**	**NPV=**	**4,217,759**	**B/C= 2.6**		**IRR= 33%**							
Scenario 3													
Benefits													
value of increased food production from the project	110,000	220,000	330,000	440,000	550,000	550,000	550,000	550,000	550,000	550,000	550,000	550,000	550,000
value of food production lost "without" the project	29,260	58,520	87,780	117,040	146,300	175,560	204,820	234,080	263,340	292,600	321,860	351,120	380,380
total benefits	139,260	278,520	417,780	557,040	696,300	725,560	754,820	784,080	813,340	842,600	871,860	901,120	930,380
Costs	1,205,085	577,300	657,800	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000
B-C	(1,065,825)	(298,780)	(240,020)	507,040	646,300	675,560	704,820	734,080	763,340	792,600	821,860	851,120	880,380
PV Benefits (i=4%)	**6,359,840**												
PV Costs (i=4%)	**2,637,792**	**NPV=**	**3,722,049**	**B/C= 2.4**		**IRR= 26%**							
Scenario 4													
Benefits													
value of increased food production from the project	90,000	185,000	275,000	275,000	275,000	275,000	275,000	275,000	275,000	275,000	275,000	275,000	275,000
value of food production lost "without" the project	29,260	58,520	87,780	117,040	146,300	175,560	204,820	234,080	263,340	292,600	321,860	351,120	380,380
total benefits	119,260	243,520	362,780	392,040	421,300	450,560	479,820	509,080	538,340	567,600	596,860	626,120	655,380
Costs	1,205,085	577,300	657,800	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000
B-C	(1,085,825)	(333,780)	(295,020)	342,040	371,300	400,560	429,820	459,080	488,340	517,600	546,860	576,120	605,380
PV Benefits (i=4%)	**4,370,481**												
PV Costs (i=4%)	**2,637,792**	**NPV=**	**1,732,689**	**B/C= 1.7**		**IRR= 16%**							

Bibliography

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

Allen, B., 1997. *An Assessment of the Impact of Drought and Frost in Papua New Guinea*, PLEC News and Views, No.9.

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

Bayliss-Smith, Tim (1974). Ecosystem and economic system of Ontong Java Atoll, Solomon Islands. Cambridge University PhD Thesis

Bayliss- Smith (1986). Ontong Java Atoll: Population, Economy and Society, 1970-1986. South Pacific Small Holder Project. Occasional Paper 9.University of New Englandand Dodo Creek Research Station.

Benson, C., 1997. *The Economic Impact of Natural Disasters in Fiji,* Overseas Development Institute. London.

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.

Ferraton Nicolas (2009) Promoting hydroponics and vegetable farming - Futuna Island DSAP Wallis and Futuna.Case Studies Lessons from the field the DSAP Experience SPC 2009.

Pacific Adaptation to Climate Change Project (PACC): Solomon Islands (2011). Vulnerability and Adaptation Assessment Report for Low Lying Atolls – Ontong Java.

Iqbal, M. (1992). Recommendations for food crop production on the atolls. Tarawa, Kiribati : University of the South Pacific. Report from Pacific Regional Agriculture Program 1A: Sustainable Systems of Food Crop Production for the Atolls.

Iqbal, M. and Seluka, S. (1992). Fruit crop research in the atolls of the Central Pacific. Journal of South Pacific Agriculture 1 (3) , pp. 49-54.

Jansen T, BF Mullen, AA Pollard, RK Maemouri, C Watoto and E Iramu (2006). Solomon Islands Smallholder Agriculture Study.Volume2 Subsistence Production, Livestock and Social Analysis (2006) AusAID.http://www.ausaid.gov.au/publications/pubout.cfm?ID=4088_5412_1071_6193_2813

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

Labu Toito'ona (2008) Agriculture Sector Assessment Report – An assessemt of Ontong Java Atoll Tidal Surge Dec 2008.

Manner, H.I. 2011.Farm and Forestry Production and Marketing Profile for Giant Swamp Taro (*Cyrtosperma chamissonis*). In: Elevitch, C.R. (ed.). Specialty Crops for Pacific Island Agroforestry. Permanent Agriculture Resources (PAR), Holualoa, Hawai'i. http://agroforestry.net/scps

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.

Rasmussen Kield, Wilhelm May, Thomas Birk, Melchior Mataki, Ole Mertz & Douglas Yee (2009). Climate change on three Polynesian outliers in the Solomon Islands: Impacts, vulnerability and adaptation. *Geografisk Tidsskrift – Danish Journal of Geography 109(1):1-13, 2009*

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 climate change: A review of research needs. CSIRO Land and Water Science Report 05/09, 64 pp..

Thaman,R.R and Chase.R (1990). Atoll agricultural research problems and prospects: proceedings of the international conference on developing agricultural research programs for atolls, Pacific Harbour, Fiji, November 1990. Alfua, Western Samoa : ISBN 982-175-018-4Holdings: MALHQ 306/01 ATO

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

Wall J.R.D and Hansell J R F (1976). The Land Resources Study. The Land Resources of the Solomon Islands: Volume 8: Outer Islands. Ministry of Overseas Development. Land Resources Division. 1976

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

Other references cited in the V&A Assessment Report

Solomon Islands National Food Security, Food Safety, and Nutrition Policy 2010-2015

Solomon Islands Red Cross, The adaptive capacity of Pileni Island community, Viakau Ward, Temotu Province, Solomon Islands

Solomon Islands National Disaster Management Office, Action Plan for Ontong Java

Malaita Provincial Government, Agriculture Sector Assessment Report: Tidal Surge on Ontong Java Atolls

Malaita Provincial Government, Water Sector Assessment Report: Tidal Surge on Ontong Java Atolls

Malaita Provincial Government, Medical Sector Assessment Report: Tidal Surge on Ontong Java Atolls

Malaita Provincial Government, Humanitarian Requirement Report: Lord Howe Atolls Assessment

Solomon Islands Ministry of Environment Conservation and Meteorology (Climate Change Division), Trip Report: Ontong Java Multi-sector team assessing the Beche de Mer ban

Solomon Islands Ministry of Environment Conservation and Meteorology (Climate Change Division), Climate Change Assessment Report on Luaniua and Pelau Islands.

Solomon Islands Ministry of Environment Conservation and Meteorology (Climate Change Division), Ontong Java Brief Assessment Report: Climate Change Perspective

Episcopal Relief & Development, Food Security: An Assessment and Plan of Action for Ontong Java

Annex 1: Project cost estimate details

	Year 1	Year 2	Year 3	Total (SI $)	Total USD
Baseline information					
SOPAC salinity tests	70,000			70,000	
Soil scientist (local)	50,000			50,000	
Food production survey	50,000			50,000	
Soil Testing Equipments (pH Meters)/Refractor Meter	3,000			3,000	
Laboratory fees	10,000			10,000	
Sub-total	183,000	0	0	183,000	26,169
Composting and soil improvement					
Mechanical shredder	15,000			15,000	
Legume seeds	2,000	1,000	1,000	4,000	
Materials	2,000	2,000	2,000	6,000	
Garden tools	2,000			2,000	
Sub-total	21,000	3,000	3,000	27,000	3,861
Agroforestry					
Planting material acquisition	5,000	5,000	5,000	15,000	
Tools	2,000			2,000	
Specialist agro forestry expertise	50,000	25,000	25,000	100,000	-
Sub-total	57,000	30,000	30,000	117,000	16,731
Home gardening					
Garden tools	3,000			3,000	
Water catchment tanks (4X 300 ltr)	12,000			12,000	
Roofing iron, guttering and pipes	3,500			3,500	
Watering cans (10)	4,000			4,000	
Containers (used drum/large polybags)	4,000	3,000	3,000	10,000	
Sub-total	26,500	3,000	3,000	32,500	4,648
Seedling and agroforestry nursey					
Shade clothes (2.6 x 50 m 30% shade)	7,500			7,500	
UV resistent clear plastic	10,000			10,000	
Soil sterilisation equipment (drum, wire, pi	10,000			10,000	
Wooden posts (20) –for nursery	5,000			5,000	
Wooden posts (8) –for tanks	2,000			2,000	
Concrete blocks and wire mesh for nursery	10,000			10,000	
Water catchment tanks (2X 300 ltr)	6,000			6,000	
Roofing iron, guttering and pipes	1,750			1,750	
Watering cans (6)	2,400			2,400	
Guages (ran, temp and sunshine)	7,750			7,750	
Vegetable seeds	10,000	5,000	5,000	20,000	
Seedling trays	5,000	3,000	3,000	11,000	
Polybags (various sizes)	5,000	3,000	3,000	11,000	
Specialist nursery expertise	40,000	30,000		70,000	
Sub-total	122,400	41,000	11,000	174,400	24,939

Training					
Soil Schools (x 6)					
Resouce Person fees	50,000	50,000	50,000	150,000	
Course material and training kits	44,000	44,000	44,000	132,000	
International travel	40,000	25,000	25,000	90,000	
Soil tests	65,000	65,000	65,000	195,000	
	199,000	184,000	184,000	567,000	
Farmer to farmer exchanges	50,000		100,000	150,000	
MAL and Kastom Gaden training fees and expenses	50,000	50,000	50,000	150,000	
Sub-total	299,000	234,000	334,000	867,000	123,981
Project management, local travel and logistical support					
Personnel					
Project manager/coordinator (Honiara based)	25,000	25,000	25,000	75,000	
Coordinator field subsistance (@$100/day)	5,000	5,000	5,000	15,000	
Ontong Java based project supervisor/led farmer (Luangiua)	10,000	10,000	10,000	30,000	
Ontong Java based assistant project supervisor/led farmer (Pelau))	5,000	5,000	5,000	15,000	
MAL Officer DSA ($100/day)	5,000	5,000	5,000	15,000	
	50,000	50,000	50,000	150,000	21,450
Travel					
Co-financing vessel fuel (2 trips/year@60,0	120,000	120,000	120,000	360,000	
Onsite Boat hirings/$500/day	4,000	4,000	4,000	12,000	
Fuel Purchase for local boats ($200/Ltrs)	4,000	4,000	4,000	12,000	
Freight charges/materials/equipments	6,000	6,000	6,000	18,000	
Boat fares for personne ($400/Trip)	6,000	4,000	4,000	14,000	
	140,000	138,000	138,000	416,000	59,488
Communication equipment					
HV two way radio (2 sets)	144,000			144,000	
Office equipment and materials	5,000	3,000	3,000	11,000	
Sub-total	339,000	191,000	191,000	721,000	103,103
Total cost	1,047,900	502,000	572,000	2,121,900	303,432
Contingency (15%)	157,185	75,300	85,800	318,285	
Grand total	**1,205,085**	**577,300**	**657,800**	**2,440,185**	**348,946**

Annex 2: The estimated valuation of the forecast future decline in taro production "without" the proposed pilot Project

	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
est. taro-tru production "without" project (tonnes)	13	12	11	10	9	8	7	6	5	4	3	2	1
taro-tru loss "without" the project (tonnes)		1	2	3	4	5	6	7	8	9	10	11	12
rice energy equiv (tonnes)		1.0	2.1	3.1	4.2	5.2	6.2	7.3	8.3	9.4	10.4	11.4	12.5
est. swamp taro production "without" (tonnes)	66	63.5	61	58.5	56	53.5	51	48.5	46	43.5	41	38.5	36
swamp taro loss "without" the project (tonnes)		2.5	5	7.5	10	12.5	15	17.5	20	22.5	25	27.5	30
rice energy equiv (tonnes)		1.1	2.1	3.2	4.2	5.3	6.3	7.4	8.4	9.5	10.5	11.6	12.6
total taro rice energy equiv (tonnes).		2.1	4.2	6.3	8.4	10.5	12.5	14.6	16.7	18.8	20.9	23.0	25.1
estimated value of lost production in 2012 prices ($14,000 per tonne)		29,260	58,520	87,780	117,040	146,300	175,560	204,820	234,080	263,340	292,600	321,860	351,120