Tuvalu Food Futures Program
Food Cubes Comparative Analysis Study

live & learn
ENVIRONMENTAL EDUCATION

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Live & Learn Environmental Education – Tuvalu

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Cover image: Ulufale Vaitusi harvesting Chinese cabbage from FoodCubes on Nukulaelae Island.

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Glossary of Abbreviations

DEP	High Age Dependency Household
DFAT	Australian government Department of Foreign Affairs and Trade
EM4	Effective Micro-organisms 4 (an organic liquid microbial soil additive)
FC	FoodCube
FHH	Female Headed household
FW	FoodWall
HH	Household
INSEC	Household with insecure land tenure (e.g.: rental or lease)
LLEE	Live and Learn Environmental Education
MIG	Migrant
SML	Smallholder
TASMP	Tuvalu Agriculture Strategic Marketing Plan
TFF	Tuvalu Food Futures Food Security program

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1. Executive Summary

Tuvalu is a small island developing state, with a population of 10,645 people[1] that is spread across 10 small atolls and reef islands and a total land area of only 26km^2. Soil quality is generally poor, agricultural production is low and more than 90% of farming households are engaged in subsistence agriculture

As a small island state with an average elevation of 1.83m above sea level Tuvalu is predicted to be one of the first nations to be affected by climate change, with traditional pulaka pit gardens already increasingly subject to saltwater inundation.

In partnership with DFAT and Biofilta, Live & Learn Environmental Education (LLEE) have been implementing since late 2018, the Tuvalu Food Futures program to address the impacts of climate change and sea level rise on food security. A key component of TFF is the use of Biofilta's innovative FoodCubes and FoodWalls self-watering modular garden bed system. The program so far includes 71 households across Funafuti and Nukulaelae Islands using FoodCubes and FoodWalls, as well as larger gardens in institutions on Funafuti and a large community farm on Funafala Island (part of Funafuti).

Live & Learn Environmental Education has commissioned this study into the comparative benefits of the use of Biofilta FoodCubes to address Food Security in its Tuvalu Food Futures program. However as LLEE's approach to Food Security is to both support traditional cultural practices as well as innovative approaches to food production, this comparative study will look for the different benefits of producing food using FoodCubes versus traditional pulaka pit farming, but importantly will also look for complementarities between the two for addressing food security in Tuvalu.

As part of this study, 58 respondents (55 households and 3 institutions) were surveyed in Funafuti and Nukulaelae islands during July and August 2021, including 25 FoodCube households, 25 FoodWall households and 31 households practicing pulaka pit farming.

Survey results and interview data show that LLEE's FoodCube program has increased the number of households growing food at home amongst the sample population from 22%-29% of households (for vegetables and fruit trees respectively) to 84% of households sampled, and increased the amount of food being produced per m^2 for these households compared to traditional pulaka pit farming.

In general, FoodCubes crop yields were 7 times more productive in terms of yield (6.97 kg/m2/yr) than pulaka pits (0.87 kg/m2/yr), which require minimum 2 years and a large area to bring their crop to maturity. Importantly, there is significant complementarity between the two systems, as there is very little cross over of crops grown in each. FoodCubes rank as the 5th most important food source across the sampled households, and the 5th most important source of produce for meeting cultural obligation such as traditional festivals and church events.

In a few cases much higher than average crop yields are reported – indicating that there is still significant potential to increase crop yields across the program for all households. High crop diversity and farmer's level of experience appear to the be the clearest factors affecting high crop yields. Ongoing extension and training, and a focus on crop diversity should be a focus for future programming to maximize crop yields.

[1] Government of Tuvalu (2017) *Population and Housing Mini-Census Preliminary Report*, Central Statistics Division Ministry of Finance, Economic Planning and Industries Funafuti, Tuvalu, p.2.

Figure 1: Fiaiva Tinei growing mixed taro (left) and pulaka (giant swamp taro - right) in FoodCubes, Nukulaelae Island.

Preserving traditional pulaka pit farming is seen as a significant motivation for some households to engage in FoodCube farming, and FoodCubes are also seen as a moderately important means of meeting cultural obligations. These synergies, along with the benefits to FoodCubes of Tuvalu's strong compost making culture should be strengthened to ensure both cultural and food security benefits from the program.

Working on gardens was generally found to be an adult activity, and more often undertaken by men than women. However FoodCubes and FoodWalls show a more equal engagement between men and women compared to pulaka pits. Children are never reported as being involved – a possible area for improvement for nutrition outcomes in future programming.

In order to investigate the relative importance of various aspects of the interaction between climate related shocks/stresses with traditional agriculture and FoodCube crop production, a number of social categories relating to vulnerability have been identified in the sample group. These include: migrants, smallholders, insecure land tenure, female headed households, high age dependency, high income earner dependency and disabled people.

While vulnerability appears to be a barrier or disincentive to spending time working on food production in general, vulnerability does not appear to be defining a factor in households with low crop yields. Furthermore the 20 highest producing FoodCube and FoodWall households have high representation of migrants and smallholders in particular, showing good crop yields are possible in FoodCubes even with lower than average labour inputs.

This indicates that that FoodCubes/Walls are well suited to addressing these households' vulnerabilities related to lack of access to land and labour. However the technology alone is not a

sufficient factor to ensure high crop yields. The most experienced farmers often show the best results, indicating that ongoing training and extension are key to ensuring that all households are able to maximise food production from the small space available in a FoodCube.

Some horticultural practices could be improved with training and extension (composting methods, application rates, managing pests etc). Most important of these is the need to address over watering in order to reduce the risk of negative impacts on household water supply.

Key recommendations include:

- Invest in ongoing training and extension for FoodCube users to build their skills and experience – this is a key determinant of high crop yields.
- Increase crop diversity to improve crop yields and the nutritional value of production
- Investigate training in household production of home made, organic fertilizers (eg: liquid compost, EM4 etc) to increase crop yields
- Increase intensity of crop production through organic horticulture techniques for details (eg: Intensive/high density cropping methods, Rapid succession planting & crop rotation, etc)
- Train program participants in more efficient watering of FoodCubes to reduce drain on household water supply
- Investigate possible over application of compost, particularly for FoodWalls in Funafuti
- Continue household training on high quality compost production to improve soil texture – particularly for FoodWalls in Funafuti. Where possible use existing pulaka pit composting knowledge to increase uptake of training and quality of compost.
- Continue implementation of National Compost Strategy to ensure high quality compost and mulch is available to program participants, particularly in Funafuti.
- Provide pest management training for affected FoodCube participants – home made pesticides, companion planting, crop rotation, etc.
- Engage children in FoodCube gardening for improvement in nutrition outcomes in future programming.
- Continue to engage women as gardeners in future programming to build on existing successes and continue to move towards equal participation of men and women in the programs activities (eg: in networking activities, involement in national events; market displays, seminars etc).
- LLEE may wish to verify survey results showing gender as “other” result and consider inclusion of “other” as a disaggregated gender category in future surveys and programming.
- Engage Smallholders (particularly in Funafuti) and High age dependency households as key vulnerability groups– this will also capture migrants and households with insecure land tenure.
- Research targeting strategies for Female Headed Households regarding definitions, prevalence, food insecurity profile and FoodCube uptake.
- Complete soil pH testing of existing soil samples as a proxy indicator of salinity from salt water intrusion

2. Introduction

2.1. Tuvalu Context

Tuvalu is a small island developing state, located approximately 1000km north of Fiji in the Pacific region. It's population of 10,645 people[2] is spread across 10 small atolls and reef islands, with a total land area of only 26km^2. The population is primarily Polynesian but retains strong cultural and social links with nearby Melanesian Fiji and Micronesian Kiribati.

The fourth smallest economy in the world, Tuvalu is listed as a Least Developed State by the UN, due to the small size of its economy and limited scope for growth. Primary industries include commercial fishing and subsistence agriculture, with a relatively high number of families dependent on remittances from commercial fishing and income from employment in limited civil service jobs in Funafuti.

Immigration from the outer islands to the capital Funafuti has seen population densities 20 times higher there than in the outer islands, putting pressure on land and agricultural resources.[3] Outer islanders living in Funafuti are 80% of the population on the island, but as a group face a particular set of challenges, with limited access to land and high reliance on limited cash income to support themselves.[4]

Agriculture is declining in Tuvalu, particularly on Funafuti as the dependence on the cash economy grows. However, it is still the major form of economic activity in the outer islands, where subsistence agriculture is primarily traditional *pulaka* pit farming and the main cash crop is copra (processed coconut). Soil quality is generally poor, agricultural production is low and more than 90% of farming households are engaged in subsistence agriculture.[5] The Tuvalu Agriculture Strategic Marketing Plan (TASMP) 2016 – 2025 details the Tuvalu government's plan for increasing food security. The overall vision for the TASMP is "to revive the marketing of local food and other local produce to increase the resilience of the Tuvalu people to climate change".

As a small island state with an average elevation of 1.83m above sea level Tuvalu is predicted to be one of the first nations to be affected by climate change, with Traditional gardens already increasingly subject to salt water inundation.

Climate change projections for Tuvalu for the period to 2100 include:[6]

- El Niño and La Niña events will continue to occur in the future (very high confidence), but there is little consensus on whether these events will change in intensity or frequency;
- Annual mean temperatures and extremely high daily temperatures will continue to rise (very high confidence);
- It is not clear whether mean annual rainfall will increase or decrease, the model average indicating little change (low confidence), with more extreme rain events (high confidence);

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[2] Government of Tuvalu (2017) *Population and Housing Mini-Census Preliminary Report*, Central Statistics Division Ministry of Finance, Economic Planning and Industries Funafuti, Tuvalu, p.2.

[3] Government of Tuvalu (2017) *op. cit.*, p.3.

[4] Asker, S. (2019) *Local Voices of Resilience; A Rapid Assessment of Perceptions in Food Security in Tuvalu*, Live & Learn Environmental Education.

[5] Government of Tuvalu (2017a) *Population and Housing Census*, Central Statistics Division Ministry of Finance, Economic Planning and Industries Funafuti, Tuvalu, p.42.

[6] *Tuvalu, Climate Science Information* (March 2016) Pacific Climate Change Portal website (viewed 28/6/2020) https://www.pacificclimatechange.net/country/tuvalu

- Incidence of drought is projected to decrease slightly (low confidence);
- Ocean acidification is expected to continue (very high confidence);
- The risk of coral bleaching will increase in the future (very high confidence);
- Sea level will continue to rise (very high confidence); and
- December–March wave heights and periods are projected to decrease slightly (low confidence)

In 2016, Biofilta, a Melbourne based environmental engineering consultancy was selected as one of 11 winning applications to DFAT's innovationXchange "LAUNCH food" global challenge, and was provided with initial funding to support a trial of their modular wicking gardening systems – the FoodWall and FoodCube – in a low-lying atoll environment.

In partnership with Biofilta and DFAT, LLEE have been implementing a food security program in Tuvalu using Biofilta's FoodCubes and FoodWalls since late 2018. The program so far includes 71 households across Funafuti and Nukulaelae Islands, as well as larger gardens in institutions on Funafuti and a large community farm on Funafala (an islet of Funafuti).

Figure 2: Funafuti island from the air (source: Funafuti Kaupule)

2.2. *Purpose & Scope of the Comparative Study*

Live & Learn Environmental Education has commissioned a study into the comparative benefits of the use of Biofilta FoodCubes to address Food Security in its Tuvalu Food Futures program.

The purpose of the study as outlined in the Terms of reference is:

- To assess the performance of Foodcubes relative to traditional garden beds in addressing technological barriers to food production. e.g. low soil fertility, lack of/inefficient irrigation, inundation of agricultural land by sea level rise etc.
- To assess the performance of Foodcubes relative to traditional garden beds in addressing social barriers to food production. e.g. lack of access to land, labour, inputs, markets.
- To assess the extent to which Foodcubes are complementary to and valuable in conjunction with traditional agriculture as a value adding technology.

However as LLEE's approach to Food Security is to both support traditional cultural practices as well as innovative approaches to food production, this comparative study will look for the different benefits of producing food using FoodCubes versus traditional pulaka pit farming, but importantly will also look for complementarities between the two for addressing food security in Tuvalu.

This is captured in the principles of the study from the research Terms of Reference (see box below) Note that the study does not compare FoodCubes to other non-traditional forms of raised bed horticulture commonly found on Tuvalu. This is because this is not primarily part of LLEE's programming, whereas both pulaka pit farming and FoodCubes gardening are. Supporting pulaka pit farmers is seen as a key approach to addressing food security through culturally appropriate means. Where relevant, areas for further research regarding other forms of horticultural production will be laid out in the report findings.

Figure 3: Comparative Study Guiding Principles

Comparative Study research Principles

Enabling: The analysis will be integrated into and enabling of the current Project implemented under the Tuvalu Food Futures project supported by DFAT and it will align with strategic priorities of the Tuvalu government including the Tuvalu Agriculture Strategic Marketing Plan (TASMP) 2016 – 2025 and future investments in food security.

Farmer focussed: The study will consider the farmer perspective including perspectives on farming practices and building on local knowledge.

Integration: Where the analysis will test input/output from FoodCubes and traditional farming, it will avoid creating a dual paradigm where one method is pitched against another. Instead it will seek complementarities between approaches in a geographical context heavily influenced by the impacts of climate change.

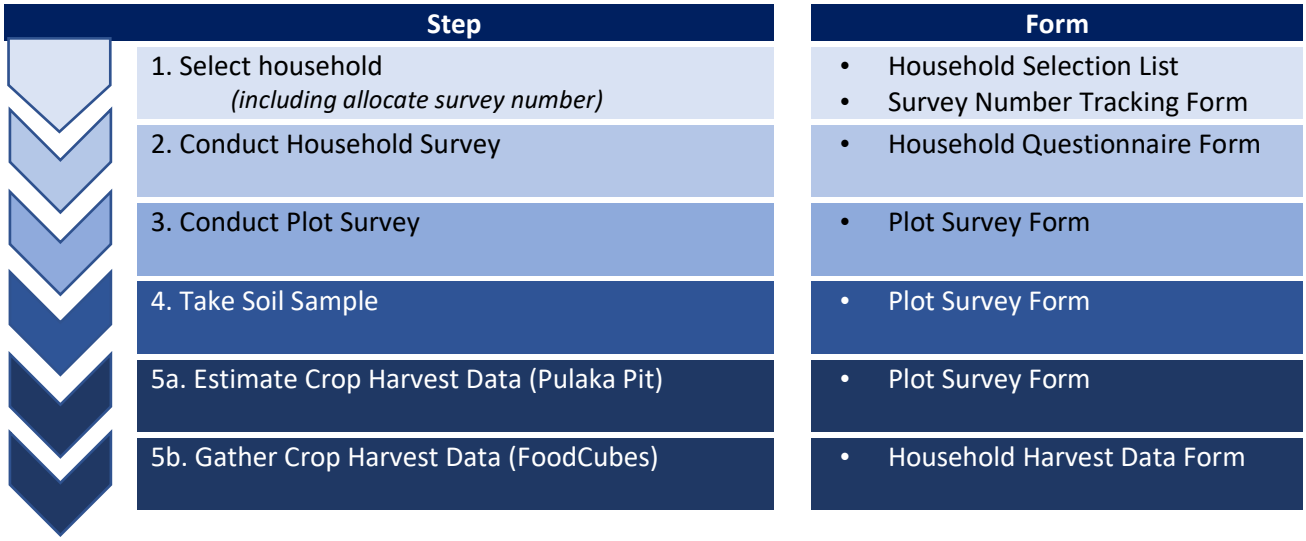
Participatory: The analysis will engage local Live & Learn Tuvalu teams and leverage from good relations with local stakeholders and government departments.

Methodology

2.3. General Methodology

In order to assess the comparative and complimentary nature of FoodCubes/FoodWalls and traditional agriculture in Tuvalu, a mixed approach incorporating household surveys and plot surveys has been used.

Figure 4: Survey Flow Chart - from TFF Comparative Study Household Survey Instruction Manual



58 respondents (55 households and 3 institutions) were surveyed in Funafuti and Nukulaelae islands during July and August 2021. These sites were selected as the location of the existing LLEE Tuvalu FoodCube program, and to provide insights on the differences between Funafuti and the outer islands food security profile. Households were randomly selected by the consultant from LLEE Tuvalu program participants (table 1). Pulaka pit farmers were selected in Nukulaelae from existing survey participants, and in Funafuti the entire population of 9 pulaka pit farming households were surveyed.

Some households practice both FoodCube gardening and traditional pulaka pit farming, bringing the survey numbers up to the target numbers for each production type.

Respondents were primarily the main gardener in the house, or the head of the household if the main gardener was not available. However a target was set for 50-50 gender split amongst respondents to ensure a diversity of responses, particularly regarding the gendered nature of food production, livelihoods, vulnerability and division of roles.

Table 1: Survey Responses by location (n=58)

Island	No.	%
Nukulaelae	25	43%
Funafuti	33	57%

Table 2: Survey target and responses breakdown, by garden bed type and location (n=58)

	Total Program Participants (HH)	Survey Target HH numbers	Final HH Numbers Surveyed
Funafuti FoodWalls	36	25	25
Nukulaelae FoodCubes	35	25	25
Overall FoodCubes/Walls	**71**	**50**	**50**
Funafuti Pulaka Pits	9	9	9
Nukulaelae Pulaka Pits	est. 57	20	22
Overall Pulaka Pits	**66**	**29**	**31**

Key Questions were developed by the consultant and LLEE Tuvalu, in consultation with LLEE and other members of the TFF working group. A list of Key Questions can be found in Appendix 1.

A number of activities were used to gather data within the surveys, including:

- Proportional piling to assess relative importance of food sources for feeding the family, selling for income and meeting cultural obligations
- Harvesting and weighing vegetable crops from FoodCubes/FoodWalls
- Estimating likely harvest yields from pulaka pits
- Taking soil samples for testing texture and pH.

Full description of how each of these activities was undertaken is outlined in the Household Survey Instruction Manual for the survey (to be submitted along with this report as a separate attachment). Details of estimating pulaka likely harvest yields is outlined in section 5.1 regarding crop yields.

Figure 5: Mafuli Pule during a household survey interview, Nukulaelae island.

2.4. The Survey Team - Roles and Responsibilities

The survey was undertaken by a mixed team, including:

- the LLEE Tuvalu Country team:
    - Itaia Lausauveve
    - Kilateli Falenga
- Survey Team (Takaio, Lialia, Pepetua, Neieli, Tracey Auina)
- the lead consultant (Alex McClean, based in Australia)

Team Member	**Role**
LLEE Tuvalu country Team	Manage all work in Tuvalu including: • Manage enumerators and data collection • Manage all logistics • Undertake data entry in mWater app • Translation
LLEE Survey Enumerators	Undertake all data collection in Funafuti and Nukulaelae, including: • Household surveys • Plot surveys • Support households to collect harvest data
Household participants	Collect harvest data
Consultant	Manage the research, including: • Design method and key questions • Design HH survey, plot survey and harvest method • Develop survey manual and train enumerators • Analyze data • Write final report

2.5. Household Vulnerability Categories

In order to investigate the relative importance of various aspects of traditional agriculture and FoodCube crop production, a number of social categories relating to vulnerability have been identified in the sample group (table 3 - next page).

The rationale for this analysis is based on the assumption that all these vulnerability groups will be more exposed to or less able to cope with shocks and pressures associated with climate change and disasters than the broader population. Therefore investigating the results of their use of FoodCubes and traditional agriculture can indicate whether FoodCubes can help address their climate and/or social vulnerability.

Table 3: Definition and rationale for household vulnerability categories

Category	Definition	Rationale
Migrants	Inter-island migrants within Tuvalu, not international. (Self identified in survey)	Often migrants (particularly in Funafuti) are assumed to experience food insecurity through lack of access to land, and inability to practice traditional agriculture.
Smallholders	No access to land beyond house plot for growing food or any other purposes	Smallholders are assumed to experience food insecurity through lack of access to land, and inability to practice traditional agriculture. Closely correlates to migrants and insecure land tenure group.
Insecure Land Tenure	Smallholders who are renting or leasing their house plot	Households with insecure land tenure are assumed to experience food insecurity and inability to practice traditional agriculture, through disincentive to invest in land based livelihoods activities. Closely correlates to migrants and smallholder groups.
Female Headed Households	Female respondents who identified as single, widower or divorced	Female headed households are assumed to less often engage in agricultural livelihoods activities, through lack of access to labour.
High Dependency	Age dependency ratio above 100 (ie: greater than 1:1 ratio of non-working age to working age household members)	These households are assumed to experience food insecurity through lack of access to labour relative to number of dependents in the household.
High Income Earner Dependency	Income earner dependency ratio above 1:6.5 (ie: higher than the national average household size depending on one income earner)	These households are assumed to experience food insecurity through lack of access to income relative to number of dependents on the household.
Disabled	Self identified in survey	Not included as no respondents identified as disabled.

3. Findings – Sample Population Data

3.1. Sample Household Location

43% of respondents were located in 9 villages across Nukulaelae Island (in the southern island group) while 53% of respondents were located in 6 villages across Funafuti (central island group, and the capital of Tuvalu).

Table 4: Survey Responses by location (n=58)

Island	No.	%	Villages covered
Nukulaelae	25	43%	9
Funafuti	33	57%	6

60% of household respondents identified as inter island migrants (n=55). However this figure is much higher amongst Funafuti respondents (74% n=31) compared to Nukulaelae respondents (42%, n=24), reflecting the general trend of migration from outer islands to Funafuti.

Table 5: Number of self identified migrant households (n=55)

Self identified migrant households	No.	%
Yes	33	60%
No	22	40%

Table 6: Types of migrant/indigenous status (n=55)

Migrant Status	No.	%	Comment
Migrant, Funafuti	23	74%	% of Funafuti respondents (n=31)
Indigenous, Funafuti	8	26%	
Migrant Nukulaelae	10	42%	% of Nukulaelae respondents (n=24)
Indigenous, Nukulaelae	14	58%	

3.2. Respondent Profile

3.2.1. Age (please circle)

66% of respondents were of working age (between 15-59yrs)[7] and 92% are aged between 25-74 years, reflecting the survey's approach of asking to speak to the head of household wherever possible.

Table 7: Respondent age brackets (n=53)

Respondent Age Bracket	No.	%
15-24	1	2%
25-39	10	19%
40-59	24	45%
60-74	15	28%
75+	3	6%

[7] Age range chosen to align with Tuvalu national census data.

3.2.2. Gender

Equal numbers of men and women were interviewed in the survey (49% of each), reflecting the study's methodology regarding collection of disaggregated gender data. One surveyor responded "other". While it is outside of the scope of this study to investigate further, LLEE may wish to verify this result and consider inclusion of "other" as a disaggregated gender categorify in future surveys and programming.

Table 8: Respondent Gender results (n=55)

Gender	No.	%
Male	27	49%
Female	27	49%
Other	1	2%

3.2.3. Marital Status & Female Headed Households

The vast majority of respondents (84%) identify as currently married.

Table 9: Respondent Marital Status (n=55)

Marital Status	No.	%
Married	46	84%
Single	4	7%
Divorced	1	2%
Widow/widower	4	7%
Female Headed Households	3	5%

To identify female headed households (FHHs), all respondents identifying as female, and either widowed, divorced, or single are categorised as an FHH. This is much lower than the national average of 25.7% of households reported as FHH in the 2007 Tuvalu Demographic Health Survey.[8] While no definition of "Female Headed Households" could be found in that study, it is quite likely a different method of identifying FHH was used, including self identification.

Given the size of this group in national data, FHHs should be further investigated by LLEE to improve targeting of programs.

3.2.4. Disability

No respondents identified as having a disability.

Table 10: Respondent disability status (n=54)

Disability Status	No.	%
Yes	0	0%
No	54	100%

[8] *Tuvalu Demographic and Health Survey 2007* (2009) Central Statistics Division, the Secretariat of the Pacific Community, Noumea, New Caledonia.

3.3. Household Vulnerability Results

As outlined in section 3 above, a number of social categories relating to vulnerability have been identified in the sample group, in order to investigate the relative importance of various aspects of traditional agriculture and FoodCube crop production. Of these, migrants (60% of households) and small holders (47% of households) are the most commonly represented vulnerability groups. However this does not necessarily mean these are the most important vulnerability groups in terms of the impact of vulnerability on their livelihoods or food security, nor the impact of FoodWalls and FoodCubes on their vulnerability type. This will be investigated throughout the rest if the report.

Table 11: Frequency of vulnerability types among sample households (n=55)

Category	Freq HH	%	National Average
Migrants	33	60%	39.8[9]
Smallholders	26	47%	-
Insecure Land Tenure	13	24%	-
Female Headed Households	3	5%	25.7[10]
High Dependency	19	35%	-
High Income Earner Dependency	7	13%	-

34% of households experience 3 or 4 types of vulnerability. No households experience more than 4 (out of a 6 possible). Amongst this group the most frequent combination is for a migrant household, living in Funafuti, renting a house only (ie: small holder with land tenure insecurity) and often with a high number of dependents.

Table 12: Frequency of household vulnerability per household (n=55)

Number of Categories per HH	Freq HH	%
0	8	15%
1	17	33%
2	9	17%
3	11	21%
4	7	13%
Average per HH	1.7	

"Our family have been eating from these FoodCubes since harvesting. Even our family members are depending on our FoodCubes harvests. These FoodCubes are very important especially to us in outer islands and as a woman itself…We are eating healthy from our FoodCubes"

Semolina Tavita, Nukulaelae Island

[9] *Tuvalu Population & Housing Mini-Census* (2017) Central Statistics Division Ministry of Finance, Economic Planning and Industries Funafuti, Tuvalu

[10] *Tuvalu Demographic and Health Survey 2007* (2009) Central Statistics Division, the Secretariat of the Pacific Community, Noumea, New Caledonia.

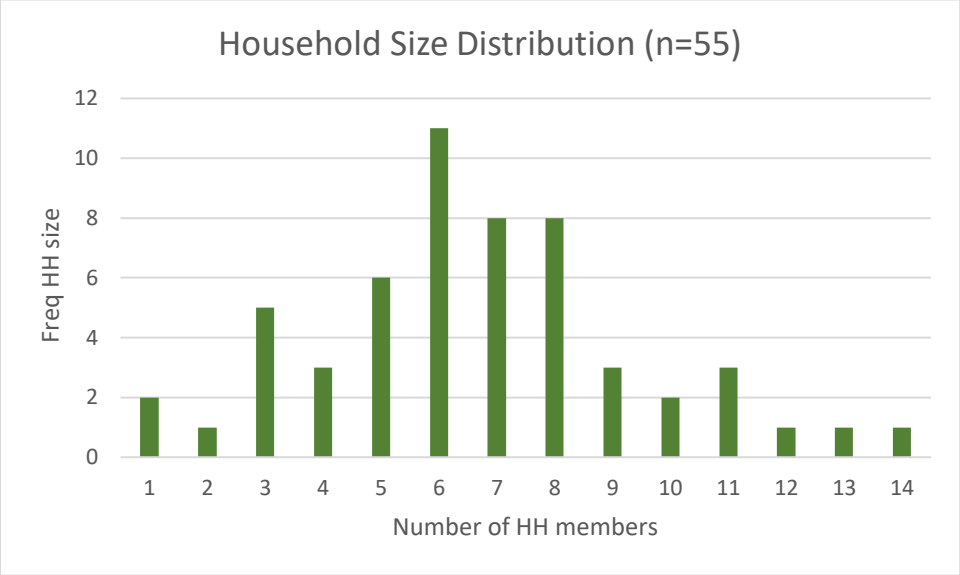
4. Findings – Livelihoods Data

4.1. Household Size

Respondent households ranged in size from 1-14 people. Average household size is 6.63ppl/hh (n=58), marginally higher than the national average of 6.5ppl/hh.

61% of households have 5-8 members.

Figure 6: Respondent Household Size distribution (n=55)



4.2. Dependency

Household dependency measures the ratio of non-working age people (below 14 or above 60 yrs) to working age people (15-59ys) to living in the house. A result of over 100 means more non workers than workers.

Tuvalu has no officially recorded age dependency ratio. Using national census data, it can be estimated at approximately 70.9[11] placing it in the top third of nations recorded by the World Bank, alongside Timor-Leste, Zimbabwe and Iraq.[12]

The sample population has an age dependency ratio of 87.2, significantly higher than the national dependency ratio.

Table 13: Age Dependency Ratio (n=55)

Age Brackets	No.	%
Total working age	195	53%
Total non-working age	170	47%
Age Dependency Ratio	87.2	

[11] *Tuvalu Population & Housing Mini-Census* (2017) Central Statistics Division Ministry of Finance, Economic Planning and Industries Funafuti, Tuvalu

[12] https://data.worldbank.org/indicator/SP.POP.DPND?locations=TV&most_recent_value_desc=false

Of the households surveyed, 19 HH (35%, n=55) were found to have a very high dependency ratio (ie: greater than 1:1 ratio of non-working age to working age household members).

There is an above average correlation between high age-dependency households and being located in Funafuti (68%), or being a migrant (58%).

4.3. Income Earner Dependency

Income earner dependency measures the ratio between the number of non-income earners to income earners in a household.

The average number of non-income earners to income earners in the sample population is 3.8 per household (n=55).

Of the households surveyed, 6 HH (11%, n=55) were found to have a very high income dependency ratio (ie: Income earner dependency ratio higher than the national average household size 6.5ppl depending on one income earner).

There is low correlation between this group and other forms of vulnerability. These households are evenly spread between Funafuti and Nukulaelae.

4.4. Land Access and Tenure

Issues of land access and land tenure security are seen as potentially critical barriers to improved food security in Tuvalu. As a nation made up of coral atolls and islands, overall land mass is extremely limited – the average island size is 2.8km^2, with surveyed islands of Funafuti (2.4km^2) and Nukulaelae (1.8km^2) being below average in size. This is further limited by high population and insecure land tenure in Funafuti, as well as traditional agriculture only being able to be undertaken in Pulaka pits, that require a lot of work to establish and so are only limited to certain locations.

FoodCubes are thought to be able to address these issues through their small size, mobility and high productivity. This will be investigated throughout the report, particularly in sections 5.5, 6.1 and 6.2.

This section outlines the nature of land access and tenure in general before examining it's impact on livelihoods and FoodCube results.

The majority of households (75%, n=55) hold customary land title over their house, either family land ownership (*manafa-kaitasi* land 20%) or individual land ownership (*manafa-totino* land 55%) – both very stable and secure forms of land tenure within Tuvalu's cultural context. Both are less common in Funafuti however, where 40% of households rent or sub-lease their house (compared to only 8% in Nukulaelae).

Households which rent or sublease their house land **and** have no access to other land for growing food are classified as having insecure land tenure in the study's vulnerability analysis, and make up 30% of all households (n=55). This group correlates very strongly with both being migrants (100%) and being located in Funafuti (83%).

Table 14: Land Tenure - house (n=55)

How do you own your house land?	All HH		Nukulaelae HH		Funafuti HH	
	No.	%	No.	%	No.	%
Family (*manafa-kaitasi* land)	11	20%	6	24%	5	17%
Individual land owner (*manafa-totino* land)	30	55%	17	68%	13	43%
Private Title (from the government)	0	0%	0	0%	0	0%
Sub-leasing (from government)	7	13%	0	0%	7	23%
Rent (from landlord)	7	13%	2	8%	5	17%
Community land (*manafa-fakangamua* land)	0	0%	0	0%	0	0%
Other	0	0%	0	0%	0	0%
Total	**55**		**25**		**30**	

Table 15: Land Tenure - Food growing (n=55)

How do you own your food growing land (including other *manafa*/land)?	All HH		Nukulaelae HH		Funafuti HH	
	No.	%	No.	%	No.	%
Family (*manafa-kaitasi* land)	20	36%	10	40%	10	32%
Individual land owner (*manafa-totino* land)	24	43%	15	60%	9	29%
Private Title (from the government)	0	0%	0	0%	0	0%
Sub-leasing (from government)	7	13%	0	0%	7	23%
Rent (from landlord)	8	14%	2	8%	6	19%
Community land (*manafa-fakangamua* land)	0	0%	0	0%	0	0%
Other	0	0%	0	0%	0	0%
Total	**56**		**25**		**31**	

Overall access to land is restricted among the sample group, with 93% of the population using less than half a hectare to grow food. This is not unexpected in a coral atoll nation like Tuvalu, where land is extremely limited. Even those households with access to land for growing food being the house predominantly have access to well less than a hectare.

Smallholders households (HH's with only restricted house plot and no access to land beyond the house plot for growing food or any other purposes) make up 55% of the sample population (n=55), rising to 78% in Funafuti (n=30) where population densities are much higher than in Nukulaelae and other outer islands.

Table 16: Land Access - food growing (n=55)

How much land do you have to grow food on? (including *pulaka* and other *manafa*/land)	All HH		Nukulaelae HH		Funafuti HH	
	No.	%	19	76%	11	37%
Only the house plus 3m	30	55%	7	28%	23	77%
$100m^2$ (10x10m) or less	0	0%	0	0%	0	0%
Less than half a hectare (50x50m)	21	38%	16	64%	5	17%
Between half to one hectare (100x100m)	4	7%	2	8%	2	7%
Total	**55**		**25**		**30**	

4.5. *Food Sources*

Surveyors were asked where they source their food from, to assess availability of food, and for cross referencing with various vulnerability types. The sample population averages 5.98 food sources per household and is quite homogenous regarding diversity of food sources (see tables 18 & 19). Across all households, buying from the local store, raising pigs, and using FoodCubes were the most common food sources.[13] All vulnerability groups have a below average uptake of FoodCubes (table 18), indicating targeting of these groups could better address vulnerability amongst the broader population.

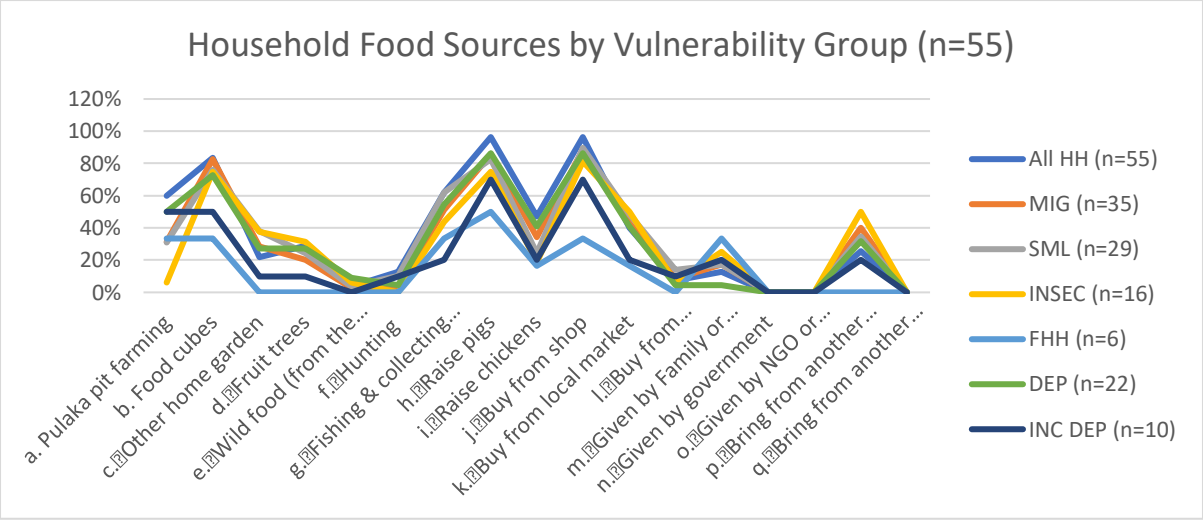
Female headed households and households with high dependency rates per income earner have the least diverse range of food sources (5.00 and 5.43 food sources per household respectively), although are both very small sample sizes so results are not strong (see table 18). These groups also currently have low uptake of FoodCubes, indicating the program could further target them in the future to address vulnerability.

Households with insecure land tenure appear to have the most diverse range of food sources (6.23 per household), and a mid-rage level of FoodCube uptake. This indicates a willingness to engage in a range of food producing activities, but room for further targeting in the program.

Table 17: Average number of food sources per household, by vulnerability category (n=55)

Category	Average Food Sources per HH	% HH using FoodCubes/Walls
All Households	5.98	84%
Migrants	5.88	83%
Smallholders	6.19	76%
Insecure Land Tenure	6.23	75%
Female Headed Households	5.00	33%
High Dependency Households	6.26	73%
High Income Earner Dependency Households	5.43	50%

Table 18: Frequency of household food sources among all vulnerability categories (n=55)



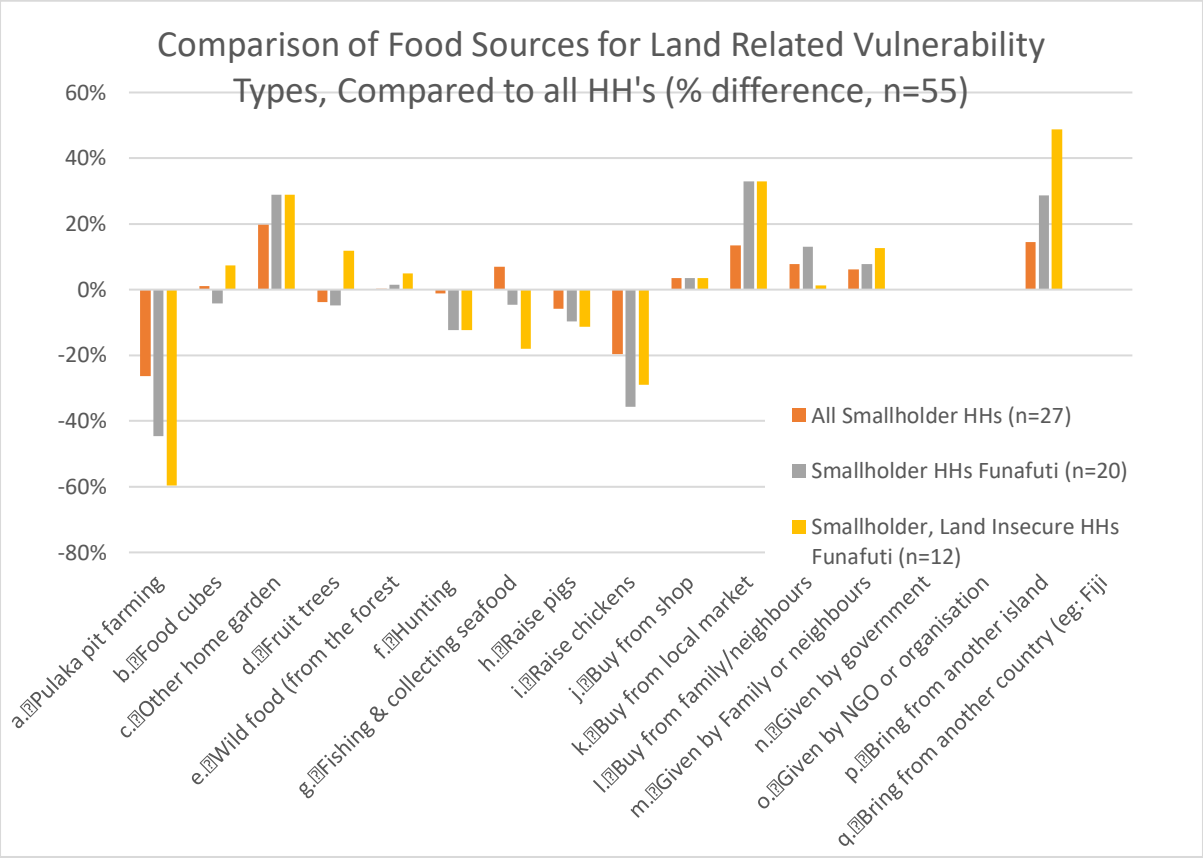
[13] High FoodCube usage is to be expected as the sample population was primarily focused on program participants, who are already using FoodCubes and FoodWalls.

A particularly critical combination of vulnerabilities occurs when looking at smallholders in Funafuti with insecure land title (ie: renting or leasing). By examining the combination of these vulnerability types on access to food sources we can see the following:

- Compared to all smallholders (n=27), those in Funafuti (n=20) are less engaged in pulaka pit farming, hunting, fishing, raising pigs and raising chickens – many of the most common food source types reported in the survey.
- Funafuti based small holders are also more likely to source food from local markets, buy from neighbors and bring food from outer islands – all of which are positive strategies for sourcing fresh culturally appropriate food, but which come with low reliability as a food source.
- These same Funafuti smallholder families are however much more likely than the average smallholder to be engaged in other vegetable gardening, and have slightly lower than average uptake of FoodCubes so far. This make them a key target group for future programming.
- Funafuti based smallholder families with insecure land tenure are similar in many ways to those who own their own house plot, but are much less likely to be involved in pulaka pit farming or fishing and are more likely to bring food from outer islands. This is unsurprising as this group is predominantly made up of migrants from the outer islands.

In regards to the diversity and reliability of food sources then, it can be concluded that while outer island migrants living in Funafuti with limited access to land are a particularly vulnerable sub group, in fact the broader group of Funafuti based smallholders share many of the same vulnerabilities. Targeting this broader group will improve the uptake of FoodCubes and also capture the migrant sub-group.

Table 19: Comparison of Food Sources for Land Related Vulnerability Types, Compared to all HH's (% difference, n=55)



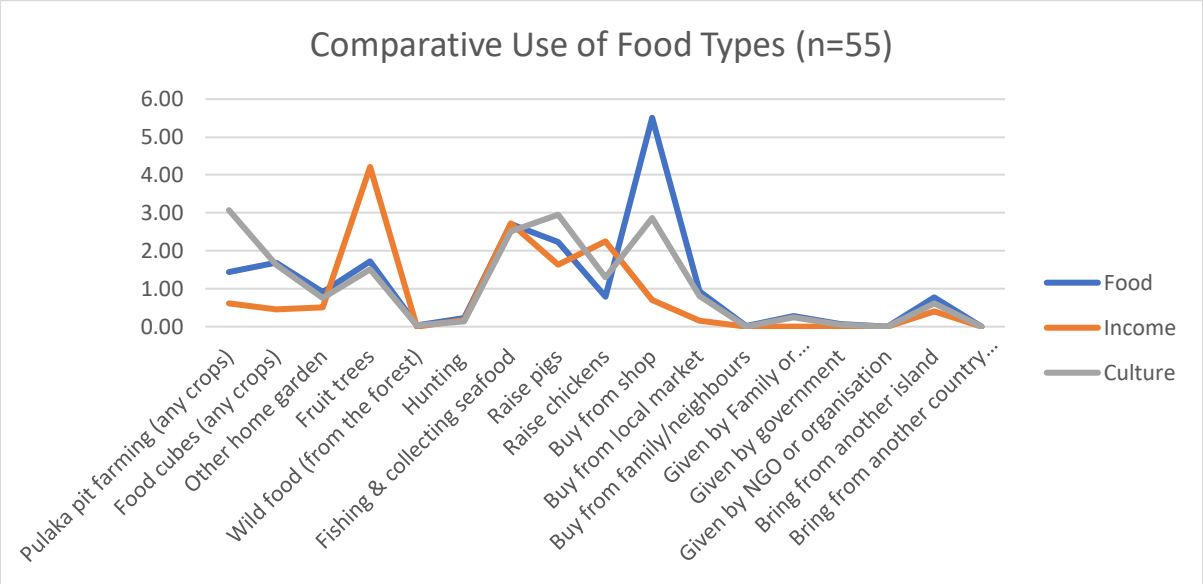
4.6. *Ranking Importance of Food Sources*

Survey participants were asked to rank the various food sources (including FoodCubes and pulaka pits) shown above in terms of their importance for feeding their family, for selling for income, and for meeting cultural obligations (such as traditional festivals or church events).

Ranking was done using a proportional piling system, whereby each participant was given 20 pebbles representing their entire food sources. They were then asked to place these on each food source listed to represent their relative importance as a proportion of all the food sources they make use of.

Results displayed are therefore an average score out of 20 provided by respondents. However the importance of food sources in relation to each other should be considered to be more important than the actual score provided, which is simply a quantitative representation of respondents qualitative responses.

Table 20: Comparative Ranking of Food Sources as a Proportion of All Food Sources Used for Feeding the Family (n=55), Income Generation (n=33) and Meeting Cultural Obligations (n=55)



"These FoodCubes are very useful as we can rely on them for our daily nutritious meals. I have harvested cabbages 4 times and 5 times with cucumbers. With these harvests, our other family members are using these as well for their meals. Not only our daily use, but we can use them for island feasts and others."

Faauila Auega, Nukulaelae Island

Table 21: Food Sources Ranked by Average Importance for Feeding the Family (n=55), Selling as Income (n=33) and Meeting Cultural Obligations (n=55)

Rank	Food Type	Score	Produce Sold Type	Score	Cultural Produce Type	Score
1	Buy from shop	5.51	Fruit trees	4.21	Pulaka pit farming	3.07
2	Fishing & seafood	2.71	Fishing & seafood	2.73	Raise pigs	2.95
3	Raise pigs	2.24	Raise chickens	2.24	Buy from shop	2.87
4	Fruit trees[14]	1.73	Raise pigs	1.64	Fishing & seafood	2.51
5	FoodCubes	1.69	Buy from shop	0.70	FoodCubes	1.64
6	Pulaka pit farming	1.44	Pulaka pit farming	0.61	Fruit trees	1.51
7	Buy from local market	0.93	Other home garden	0.52	Raise chickens	1.29
8	Other home garden	0.91	FoodCubes	0.45	Buy from local market	0.80
9	Raise chickens	0.78	Bring from outer island	0.39	Other home garden	0.75
10	Bring from outer island	0.76	Hunting	0.18	Bring from outer island	0.62

4.6.1. Food Sources to Feed the Family

The shop is by a long way the most important food source for all respondents. Surprisingly this is even more the case in Nukulaelae than Funafuti.

FoodCubes already rank as the 5th most important food source across the sampled households, and are already ranked higher as a food source in Nukulaelae than in Funafuti – perhaps as a result of fewer food sources available and higher reliance on the store in the outer islands. FoodCubes also rank higher than existing gardens a source of food, but not higher than existing fruit trees. On average they also rank higher than pulaka pits as a source of food, but only because they rank so low in Funafuti compared to Nukulaelae, where pulaka is still slightly more important than FoodCubes as a source for food.

4.6.2. Selling Food Sources for Income.

While all respondents completed this section for food and cultural obligations, only 60% responded regarding the use of food sources as an income source. This perhaps reflects that selling produce is anecdotally not common in Tuvalu, particularly in the outer islands where reciprocity and sharing is seen as a cultural virtue.

Raising pigs is the most common food source sold for income (64% of HHs, n=33), but sale of produce from fruit trees ranks as proportionally more important on average as a source of income compared to other produce types.

FoodCubes only rank as the eighth most important source of produce for selling, slightly below both other (7th) home gardens and pulaka pits (6th).

4.6.3. Food Sources to Meet Cultural Obligations.

Pulaka pit farming, raising pigs and fishing are the most important food sources used to meet cultural obligations. However interestingly buying from the shop is also important here (anecdotally this is often sugar four and rice used as ingredients in recipes for festival food), perhaps reflecting

[14] Including coconut trees

the prestige associated with buying food, and/or that this category of “cultural obligations” includes not only traditional festivals but also church events and other cultural activities more broadly.

FoodCubes rank 5th as a food source here, even though only two households reported growing pulaka in their FoodCubes. This reflects that while pulaka is a highly culturally significant crop in Tuvaluan culture, it is not the only crop being grown and used to meet cultural obligations. This indicates that there may be further scope to increase the relevance of FoodCubes to Tuvaluan food culture through a range of crops. This will require further investigation, but may well provide both a means to further support the preservation of traditional Tuvaluan agriculture, and increase the effectiveness of the LLEE’s food security program through linking FoodCubes to traditional cultural farming practices through a range of crops.

5. Findings – Crop Production Data

5.1. Crop yields

A wide range of crop yield results between different FoodCubes and FoodWalls were recorded. Interestingly, some outlying data from FoodWalls that was initially excluded in the preliminary

Figure 7: Lyn Pule and daughter harvesting Chinese cabbage from FoodCubes in Nukulaelae Island.

findings report as being unreliably high has since been verified and is now included. These farmers appear to be the more experienced, capable of producing higher yields, particularly for heavy crops such as pumpkin and cucumber.

In general, FoodCubes were 3.5 times more productive in terms of yield per year (kg/m^2/yr) than pulaka pits, which require minimum 2 years and a large area to bring their crop to maturity. FoodWalls are even more productive, almost twice as productive per m^2 as FoodCubes and 7 times as productive as pulaka pits. The averages are slightly lower than comparable crop yields seen in FoodCubes in Australia, indicating improvements are still possible.[15]

Table 22: Crop Yield results - FoodCubes (n=49)

Result	Average	Units	High	Low
Yield per FoodCube	6.97	Kg/FoodCube/yr	25.38	2.04
Plot area	1	m^2		
Yield per m2 per year	6.97	Kg/m^2/year	25.38	2.04

Table 23: Crop Yield Results - FoodWalls (n=42)

Result	Average	Units	High	Low
Yield per FoodWall	6.98	Kg/FoodWall/yr	23.64	0.625
Plot area	0.5	m^2		
Yield per m2 per year	13.96	Kg/ m^2/year	47.28	1.25

Table 24: Crop Yield Estimates – Pulaka Pits (n=34)

Result	Average	Units	High	Low
Pulaka/plot	2.50	Pulaka counted per plot	8	1
Plot area	6.56	m^2	10	1
Pulaka growing area	2.62	m^2/pulaka	10	0.5
Est corm weight	4.02	Kg/corm at 24 months	6	2
Est Harvest per plot	10.06	Kg/plot/harvest	24	4
Est Harvest per plot/year	3.83	Kg/plot/year	12	2
Est harvest/m2/yr	1.92	Kg/ m^2/year	2	0.2

When crops yields were compared at the household level with vulnerability types, no clear patterns can be discerned for those households who remain low producing households. Both households with several vulnerability types and those with none were represented in this group. Their vulnerability does not appear to be a factor in their low yields.

Furthermore the 20 highest producing FoodCube and FoodWall households have high representation of migrants and smallholders.

This indicates that that FoodCubes/Walls are well suited to addressing their vulnerability, and that LLEE's program already targets this population well. However it is not the only factor, with training and extension being key to ensure that all households are able to maximise food production from the small space available in a FoodCube.

[15] Dean, G. *pers comm* December 2021

Figure 8: Ulufale Vaitusi weighing harvests for the plot survey, Nukulaelae Island.

5.2. <u>Crop diversity</u>

FoodWalls also produce a slightly greater variety of crops than FoodCubes, both of which are much more diverse in output that pulaka pits which were only recorded as growing pulaka (even though other crops can potentially be grown in pulaka pits). This perhaps reflects the fact that FoodWalls have been in use for much longer within the program than FoodCubes, so their gardeners are more

experienced and confident in growing a variety of crops. It also indicates the highly complimentary nature of FoodCubes/walls and pulaka pits, which produce very different crops – almost no overlap.

Table 25: Average number of crops grown per household by garden bed type

Garden Bed Type	Average Crops/HH
FoodCubes	1.65 (n=49)
FoodWalls	1.78 (n=40)
Pulaka Pits	1 (n=34)

Overall crop diversity is low with 56% of households (n=58) reporting growing 3 crop types or less. In general five crops are most common, with cabbage being very common amongst more than half of all FoodCubes/walls surveyed.

Table 26: Crops grown per Household (n=58)

Crops	HHs	%
No answer	9	16%
1	8	14%
2	12	21%
3	12	21%
4	11	19%
5	4	7%
6	1	2%
7	1	2%
Total	**58**	**100%**

Table 27: Most Common Crops grown in FoodCubes & FoodWalls (n=89)

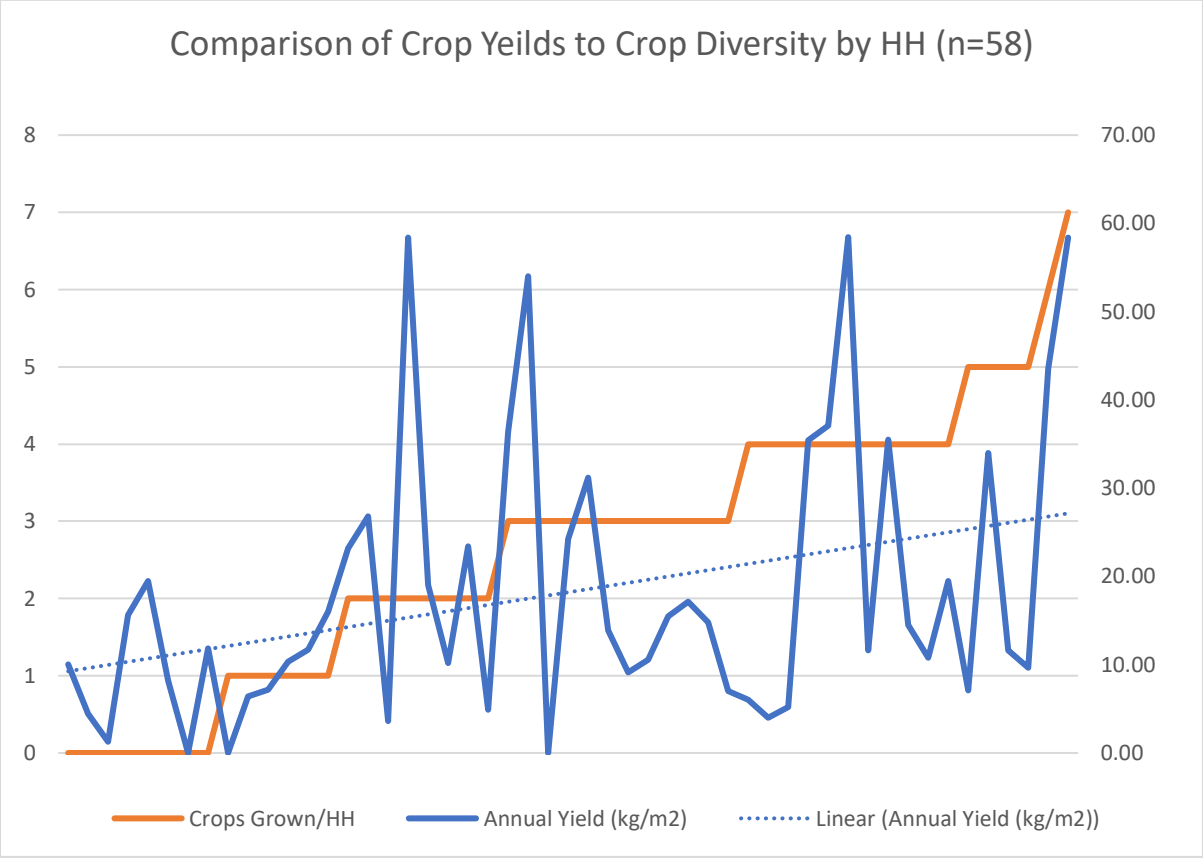
Crop	HH	%
Cabbage	57	64%
Taro	23	26%
Cucumber	22	25%
Pepper	12	13%
Tomato	10	11%
Spinach	8	9%
Pumpkin	5	6%
Chilli	3	3%
Pulaka	2	2%
Sweet Potato	2	2%

Only 2 households have trialled growing pulaka pits in FoodCubes, yet interview data shows this is a significant motivation for some households. This indicates that more trials could be undertaken here. But this also points to the possible need for a change in design of the FoodCube if they are to be used to grow pulaka (more depth, and possible larger area also).

There is a visible correlation between crop diversity and overall yield per m^2. Crop yields increase from average 10kg/m^2/yr for single crop households to an average of 30kg/m^2/yr for gardeners growing 6 and 7 crops, although the trend is not strong.[16] Furthermore, all the high producing households are growing 3 or more crops. This is more visible at household level than at individual garden bed level indicating the trend is unlikely a causal effect of greater diversity within a single bed leading to greater crop yields, and is more likely the indirect effect of more confident farmers growing a greater range as well as a greater volume of crops.

LLEE should seek to increase the diversity of production as a strategy for increasing overall harvest yields. This will also increase the nutritional benefits of the food available at household level through increased diversity of food types.

Table 28: Comparison of Crop Yields to Crops Diversity per household (n=58)



"We can make use of them [FoodCubes] by growing our vegetables and traditional food crops. I have planted cabbages at first and harvest two times then I plant them with cassava and taro.

Malia Silitine, Nukulaelae Island

[16] Note - some zero values included to account for: households who collected no harvest data due to crops not being ready yet; households who collected harvest data, but failed to answer separate questions relating to number of crops present in the garden bed.

Figure 9: Options for Intensive vegetable Production

Intensive Vegetable Production Options

FoodCubes are designed as an intensive vegetable production technology. In order to maximise the food produced by these FoodCubes in the TFF program, LLEE could consider the following common approaches to intensive vegetable gardening:

- Ongoing extension and farmer engagement, including training, accompaniment, field schools and on site problem solving
    - Intensive cropping methods (eg: square foot gardening, biointensive gardening)
    - Rapid succession planting & crop rotation
    - Companion planting for diverse crops and pest management
    - Vertical planting and climbers (corn, beans, choko, bitter melon, cherry tomatoes)
    - Vine crops allowed to ramble outside the FoodCube (eg: pumpkin, cucumber, melons, kang-kong etc)
    - Multi harvest plants that produce more than one food type, eg:
        - Pumpkin (ripe fruit, green fruit, young leaves)
        - Cassava (roots and young leaves)
        - Sweet potato (roots and young leaves)
        - Papaya (ripe fruit, green fruit, young leaves and flowers)*
        - Banana (fruit and flowers)*
    - Planting of high nutrient food to increase the nutritional value per m^2 (eg: amaranth, purslane, sweet potato, etc)
    - Non-chemical fertilisers (home made liquid compost, EM4, earthworms in FoodCubes)
    - Non-chemical pest management (home made pesticides, companion plantings)

* These crops may need investigation for suitability – both are top heavy and potentially not appropriate for shallow FoodCubes.

5.3. Perceived difference in taste

No trials for food preference were undertaken during the study due to logistical issues preventing sourcing a single crop (taro) from both Nukulaelae and Funafuti, from both FoodCubes and pulaka pits to compare in a taste trial. This should be investigated at a later date if possible, with a particular focus on taro and pulaka as crops most commonly grown across both FoodCubes and pulaka pits.

5.4. Soil Test Results

Soil samples were taken from 78 garden beds and plots across the 58 respondents and 125 plots covered in the survey. Soil texture tests were undertaken and pH tests started, although not completed within the study period due to logistical limitations (see below).

Each sample was made up of 2-5 small samples taken from across each plot, follows:

a. FoodWalls: 2 samples
b. FoodCubes: 3 samples
c. Small Pulaka Plot: 3 samples (from inside *titi* basket)
d. Large Pulaka Plot: 5 samples (from inside *titi* basket)

Samples were also taken from outside the titi baskets in each Pulaka pit as a reference.

5.4.1. Texture

Soil texture was assessed on 78 plots by LLEE staff using a simple soil particle separation test to measure the relative volume of sand, silt and clay particles in each soil sample. Based on these results, soil samples were classified according to soil texture classification method in ACIAR's *Guidelines For Sustainable Management Of Tropical Upland Soils*.[17]

Overall, soil texture in FoodCubes and FoodWalls was found to be less consistent than in pulaka pits, where methods are well established and soil texture has been built up over a longer period of time as either a silty or sandy loam.

81% of FoodCubes and 66% of FoodWalls showed results in the most desirable categories for a wicking bed system: Sandy loam; Silty loam; or Loam. This indicates good results from the program so far in terms of quality of compost being produced for FoodCubes and FoodWalls by participants. However there is not a strong correlation between soil texture and crop yields. This means that while better results are possible from improving the quality soil mix in FoodCubes/walls, it is not the most important factor in creating high yields.

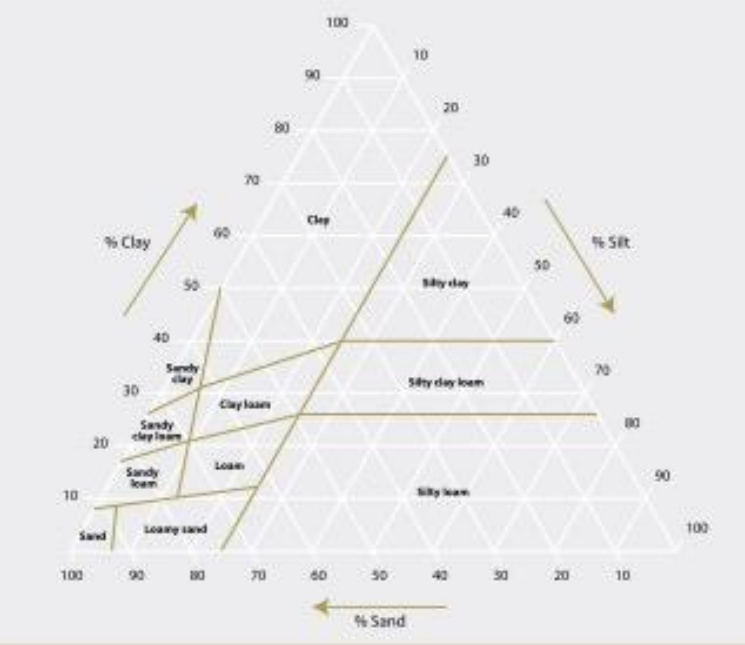


Figure 10: Soil Texture chart, McDonald et al 1990 from Moody et al 2008.

Table 29: Soil Texture Tests (n=78)

Soil Texture	FoodCubes (n=22)	FoodWalls (n=27)	Pulaka Pits (n=29)	All (n=78)	Average Yield – FCs FWs (kg/m²/yr)
Sand	0%	4%	0%	1%	38.2
Loamy sand	0%	0%	3%	1%	0
Sandy loam	18%	37%	28%	28%	14.5
Silty loam	36%	7%	66%	37%	6.3
Loam	27%	22%	3%	17%	9.4
Sandy clay loam	0%	4%	0%	1%	6.0
Silty clay loam	5%	15%	0%	6%	5.9
Clay loam	14%	11%	0%	8%	11.7

[17] McDonald et al (1990) citied in Moody, P.W. and Cong, P.T. 2008. Soil Constraints and Management Package (SCAMP): guidelines for sustainable management of tropical upland soils. ACIAR Monograph No. 130, 86pp.

5.4.2.Soil pH Testing

Soil pH tests were included in the survey as an important proxy indicator of soil salinity and salt water intrusion into Pulaka pits and FoodCube compost supplies.

Soil pH tests were undertaken by the Department of Agriculture staff using a field pH test kit. Due to limitations in ingredients required for testing, and inability to source replacement supplies, only 19 soil samples were tested (all FoodCubes from Nukulaelae).

This small sample is presented below. However further testing should be undertaken to verify conclusions drawn.

Table 30: pH Test Results, FoodCubes, Nukulaelae (n=19)

pH Test Result	No.	%
5	0	0%
6	1	7%
7	7	50%
8	5	36%
9	1	7%

Overall, most FoodCubes tested as having either neutral or slightly alkaline soil pH (7 or 8) – acceptable levels for growing vegetable crops. Limited data means no strict comparison can be drawn, however 2010 surveys of ground water salinity in pulaka pits in Tuvalu show Funafuti and Nukulaelae to be the two most impacted by high ground water salinity.[18]

Given that supporting Tuvaluan program participants to address the negative impacts on food security of climate change related salt water intrusion into ground water, further soil testing of FoodCubes/walls, pulaka pits and standard horticulture should be a priority for further research by LLEE.

Figure 11: Sauni Auega with a crop of cucumber, Nukulaelae Island

[18] Rao S (2011) Salinity Tolerance of Giant Swamp Taro (*Cyrtosperma merkusii*); *In vitro* and *In vivo,* Masters Thesis USP.

6. Findings – Horticultural Practices Data

6.1. Distribution of Production Types

125 out of a possible 257 plots across 58 respondents were surveyed to assess the horticultural practices being used in both FoodCube and pulaka pit food production.

Of all the gardens surveyed, 91% of all gardens owned by respondents are in use (n=58).

More FoodCubes are active in Nukulaelae than FoodWalls in Funafuti, perhaps reflecting the some of the challenges Funafuti residents have faced accessing compost.

More pulaka pits are also active in Nukulaelae than FoodWalls in Funafuti. The reasons for this are not well known, however likely causes include both the impacts of salt water intrusion and social change on traditional agriculture in Funafuti, where only 9 pulaka pit farmers could be found; and the long distances needed to travel from home to Pulaka pits in Funafuti (sometimes up to 50 minutes). It is well established that traditional pulaka pit farming is under much more pressure in Funafuti than in the outer islands, like Nukulaelae.

Table 31: Garden type, location and usage (n=58)

Garden Type	HH Surveyed	Total Gardens	Total Active Gardens	Average gardens owned	Average gardens active	% active
Funafuti FoodWalls	25	79	68	3.16	2.72	86%
Nukulaelae FoodCubes	25	50	50	2.00	2.00	100%
Overall FoodCubes/Walls	**50**	**129**	**118**	**2.58**	**2.36**	**91%**
Funafuti Pulaka Pits	9	19	16	2.11	1.78	84%
Nukulaelae Pulaka Pits	22	109	101	4.95	4.59	93%
Overall Pulaka Pits	**31**	**128**	**117**	**4.13**	**3.77**	**91%**

Table 32: Average distance from Home to Plot, minutes walking (n=58)

Garden Type	Average distance to plot	Max	Min
Funafuti FoodWalls	2.3	15	1
Nukulaelae FoodCubes	2.1	5	1
Funafuti Pulaka Pits	29.9	50	8
Nukulaelae Pulaka Pits	12.4	25	5

"These FoodCubes are very easy to work with as they are easy to move around. It is also near to our houses so it doesn't take long to walk and work on the FoodCubes."

Mafuli Pule, Nukulaelae Island

6.2. Labour

More labour is spent on FoodCubes each week than pulaka pits, both per household and per garden bed. However the overall labour burden is low at 2.62hrs spent gardening on all plot types per week (table 34), and the disparity may reflect that FoodCubes are closer to home and more available to be worked on, (see table 33 above) and the weeds are less common in pulaka pits as they are underwater (see tables 42 & 43).

As pulaka pits are replenished with compost more regularly than FoodCubes (see table 37), FoodCube labour is being spent on other tasks, particularly watering (section 6.4), but also weeding and pest management.

Table 33: Labour by garden bed type (n=58)

Garden Type	Hrs/HH/week	Hrs/Garden Bed/week
FoodCube	2	1
FoodWall	2.04	1.205
Pulaka Pits	1.65	0.62
All HH's (including all garden types)	2.62	0.92

Working on gardens is generally an adult activity, and more often undertaken by men than women. However this is more pronounced when work in pulaka pits is concerned. FoodCubes and FoodWalls show a more equal split between men and women.

Children are never reported as being involved – a possible area for improvement for nutrition outcomes in future programming.

Table 34: Labour on plot types, by Gender/Age (n=58)

Gender/Age category	Av Hrs/wk Pulaka	Av Hrs/wk FoodCubes	Av Hrs/week All Plots
Labour - Adult Males	1.26	1.06	1.59
Labour - Adult Females	0.16	0.76	0.74
Labour - Elderly Males (60yrs+)	0.23	0.16	0.26
Labour - Elderly Females (60yrs+)	0.00	0.04	0.03
Labour - Child male (0-14ys)	0.00	0.00	0.00
Labour - Child female (0-14ys	0.00	0.00	0.00

In general, most vulnerability groups spend less than average hours per week gardening, except female headed households (although the sample group is too small to be statistically significant).

This increases further when the households spending above average time per week on gardening is analysed (3 hrs per week or more), indicating that experiencing these types of vulnerability creates either a barrier or disincentive to spending time on food production (table 36).

However as was seen in section 5.1 above, this is not necessarily a barrier to actual production of food using FoodCubes, with many of the highest producing families also being migrants and smallholders.

Table 35: Labour by vulnerability category (n=55)

Vulnerability Type	Number HHs	average Hrs/wk labour (FCs)	Prevalence (whole sample)	Prevalence (HH's working 3+hrs/wk)	change
Migrant	33	1.73	60%	43%	-17%
Smallholder	30	1.90	55%	39%	-15%
INSEC	13	2.00	24%	17%	-6%
FHH	3	1.67	5%	4%	-1%
Dep	19	1.63	35%	35%	0%
Income Dep	7	1.14	13%	13%	0%

6.3. Compost & Fertiliser Usage

All garden types are most commonly replenished with compost every month. However there is a greater diversity of approaches amongst pulaka pit farmers, resulting in the average compost application for pulaka pits being 1.5-2 times more often per month than FoodWalls and FoodCubes (every 8 days as opposed to every 12 or 17 days for FoodWalls and FoodCubes).

Current FoodWall data indicates they are being replenished with very large volumes of compost. This is probably an indication of inaccuracies inherent in a recall style question used to assess volumes of compost applied each refill. However it is consistently higher amongst Funafuti based FoodWall users, perhaps as a result of the following:

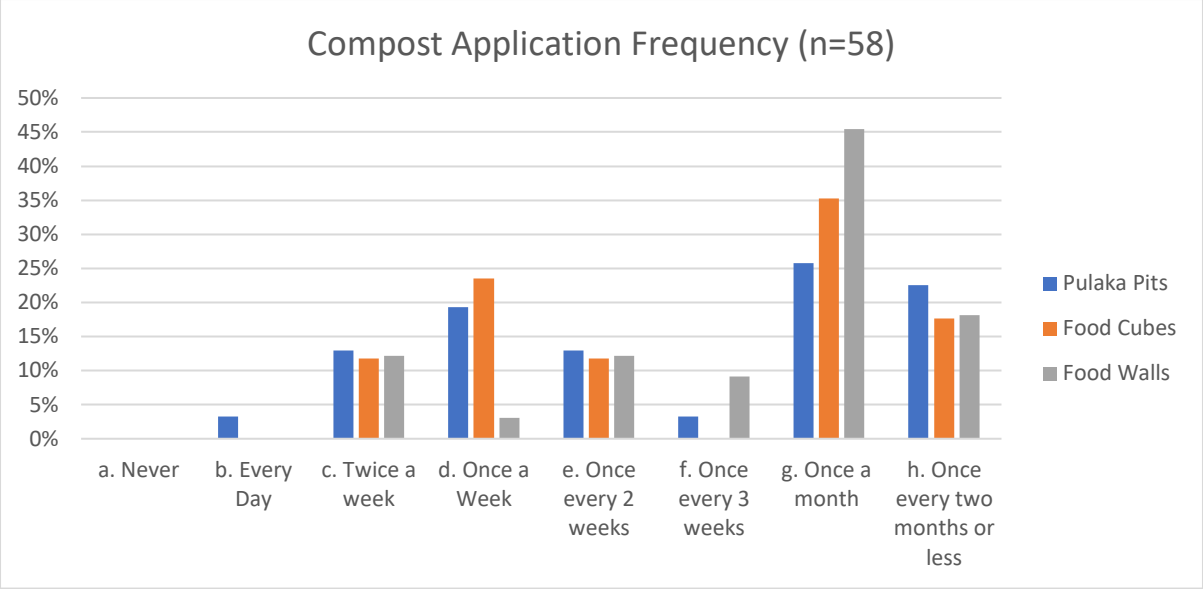
- they are more experienced gardeners, who are reporting applying more compost to with the intention of achieving the higher harvests seen in FoodWalls
- their gardens have been established for longer, meaning they now require more replenishment than would have been the case early on
- FoodWalls are smaller volume than FoodCubes (100L vs 300L), meaning any inaccuracies in the data will be exacerbated.

Table 36: Compost application comparisons by garden bed type (n=58)

	Refill Interval (days)	Average L/month	Garden Size (L)	Refill (months)
FoodCubes	17.0	70.7	300	4.24
FoodWalls	12.6	91.4	100	1.09
Pulaka Pits	8.24	206.1	NA	NA

Figure 12: Applying compost to a pulaka, Funafuti Island

Figure 13: Compost Application Frequency for all garden types (n=58)



Live & Learn's 2020 Compost Feasibility Study data from Funafuti and Nukulaelae indicates compost is being sourced primarily from traditional compost made at home (72% of respondents), with some of FoodWall farmers on Funafuti also accessing compost purchased from Department of Waste. Most common ingredients are dry leaves, pig manure, coconut husks, fresh leaves and soil – leading to the sandy/silty loams seen in soil texture tests in section 6.

Table 37: Most Common Compost Ingredients, (n=39) LLEE 2020 Compost Feasibility Study.

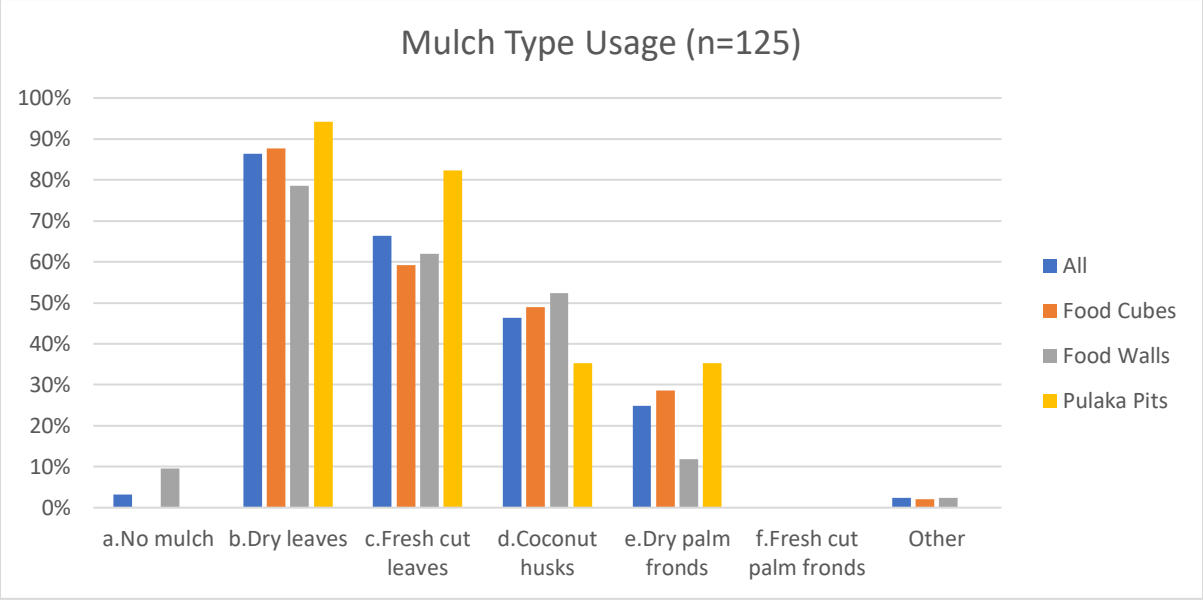
Compost Ingredient	Frequency of Use
Dry leaves	59%
Pig manure	46%
Coconut husks	44%
Fresh leaves	36%
Soil	26%

No farmers reported using fertiliser on pulaka pits or FoodCubes/walls. Chemical fertilisers are discouraged in Tuvalu to protect the freshwater lens. However use of home made organic fertilisers in the program could increase crop yields (eg: liquid compost, EM4 etc).

There appears to be no strong correlation between high crop yields and either high or low compost application, nor types of mulch used. This indicates that while important, these are not the primary determinants of increased crop yields.

"We can use these FoodCubes as a means of adapting ourselves to the impacts of climate change in terms of food security. We know that these are new technologies, yet they are very useful for people like us in the islands who are affected by natural disasters from time to time. With these FoodCubes, we are no longer worried as we are confident that we can still grow our traditional crops in them."

Faiva Namoliki, Nukulaelae Island



6.4. Water Usage

FoodCubes are watered much more frequently than pulaka pits, which are either never watered (rainfed or ground water fed) or are only watered during a drought (13% of pulaka pit farmers).

FoodCubes and FoodWalls are most commonly watered anywhere between every day to twice a week, sourcing water from home rainwater tanks (which is also the household drinking water supply). Most common methods are using buckets and watering cans, indicating top watering onto the plants/soil rather than filling the FoodCube's reservoir (which would reduce evaporation losses, and promote deep rooted plants)

Total water used is between 31-37L/week per household (for FoodWalls and FoodCubes respectively), representing 34-56% refill rate of the FoodCube/wall per week. This effectively means on current usage, FoodWalls can last at least 2 weeks before needing refill, while FoodCubes can last at least 3 weeks. As they are currently being watered at least every week, this means FoodCubes and FoodWalls are being watered too frequently.

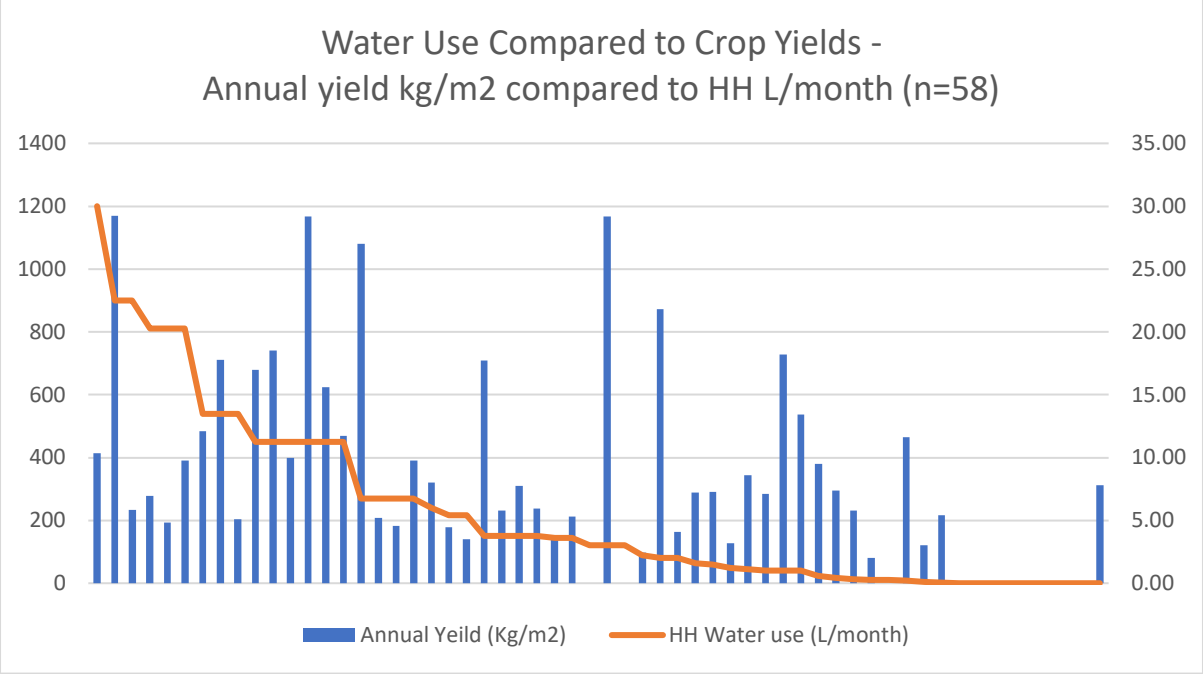
Table 38: Water Usage comparison, FoodWalls and FoodCubes (n=50)

Garden Bed Type	Average (L/week)	Reservoir Size (L)	% refill per week
FoodCubes	37.0	110	34%
FoodWalls	31.0	50	56%

Furthermore there is no correlation between high water use and increased crop yields. This indicates that watering can likely be reduced without impacting on production, particularly for FoodWalls, where water use is very high.

Reducing water use will not increase benefits regarding food security. However given that the water supply for FoodCubes is also the household drinking supply (which is very limited in Tuvalu), more efficient water use should be seen as an important step to reduce potential negative impacts of the program on water security.

Figure 14: Comparison of crop yields to household water use (n=58)



While watering regimes of other vegetable gardening types are not known (this study only compares FoodCubes to traditional agriculture), practices can be assumed to be the same or higher in these other non-wicking, hand watered, raised garden beds.

6.5. Pests

FoodCube horticulture is more prone to pest attack and crop damage (44% of households) than pulaka pits (10% of households). Pulaka is well known for having few pest problems in Tuvalu.

FoodCube households experiencing pests usually have to treat the same pest multiple times - on average 2.6 times per year. However impacts are mostly mild, commonly leading to only a small reduction in harvest (64% of households experiencing pests).

Most common pests for FoodCubes are "red worm"[19] and pigs, with caterpillars snails and even children(!) also reported as impacting on crop yields at times. For pulaka the only reported pest is red worm.

Table 39: Pest Attack Frequency (n= 58)

Freq pest attack	Pulaka pits (n=31)	FoodCubes/FoodWalls (n=50)
a. Zero	90%	56%
b. Once	0%	16%
c. Twice	0%	8%
d. 3-4 times	6%	12%
e. 5 times	3%	8%

[19] Requires further investigation to properly identify

Table 40: Impact of Pest attacks (n=58)

Impact Pest Attack	Pulaka pits (n=31)	FoodCubes/FoodWalls (n=50)
a. No impact, or visual impact only	0%	4%
b. Mild – small reduction in harvest	6%	28%
c. Major – moderate reduction in harvest	0%	8%
d. Catastrophic – most or all of the harvest lost	3%	4%
Never has pests	90%	56%
Total	100%	100%

6.6. Weeds

FoodCubes receive weeding approximately twice as often as pulaka pits (average twice a month compared to once a month). This may reflect that FoodCubes are closer to home than pulaka pits, and so receive more regular attention, but also reflects that fewer weeds are able to grow in pulaka pits as they are underwater. Weeds are reported to have negligible impact for both FoodCubes and pulaka pits.

Table 41: Frequency of Weeding (n=58)

Freq Weeding (per month)	Pulaka pit (n=31)	FoodCubes/Walls (n=50)
Total average	0.99	2.07

Table 42: Impact of Weeds on production (n=58)

Impact Weeds	Pulaka pit (n=31)	FoodCubes/Walls (n=50)
a. No impact, or visual impact only	84%	92%
b. Mild – small reduction in harvest	3%	2%
c. Major – moderate reduction in harvest	0%	0%
d. Catastrophic – most or all of the harvest lost	0%	0%
No answer	13%	6%

Figure 15: Luilosa Apisai next to her FoodCube gardens, Nukulaelae Island

7. Conclusion

Survey results and interview data show that LLEE's FoodCube program has increased the number of households growing food at home amongst the sample population (compared to pulaka pit farming and other vegetable gardening), and increased the amount of food being produced per m^2 for these households compared to traditional pulaka pit farming.

In a few cases very high crop yields are reported – indicating that there is still significant potential to increase crop yields across the program for all households. High crop diversity and farmer's level of experience appear to the be the clearest factors affecting high crop yields. Ongoing extension and training, and a focus on crop diversity should be a focus for future programming to maximize crop yields.

Preserving traditional pulaka pit farming is seen as a significant motivation for some households to engage in FoodCube farming, and FoodCubes are also seen as a moderately important means of meeting cultural obligations. These synergies, along with the benefits to FoodCubes of Tuvalu's strong compost making culture should be strengthened to ensure both cultural and food security benefits from the program.

Age and Gender

Working on gardens is generally an adult activity, and more often undertaken by men than women. However FoodCubes and FoodWalls show a more equal engagement between men and women compared to pulaka pits.

Children are never reported as being involved – a possible area for improvement for nutrition outcomes in future programming.

One surveyor responded "other" when asked for their gender. While it is outside of the scope of this study to investigate further, LLEE may wish to verify this result and consider inclusion of "other" as a disaggregated gender category in future surveys and programming.

Vulnerability

LLEE programming already targets the following vulnerability groups well:

- Migrants on Funafuti (74%, n=31)
- Smallholders (47%, n=55), particularly on Funafuti (78%, n=30)
- High Age dependency households, where the sample population shows a much higher age dependency ratio (87.2) than the estimated national ratio (70.9).
- Households with insecure land tenure (30%, n=55), eg: renters and leasers.

These 4 groups are often the same households, especially in Funafuti, where migrants and smallholders with insecure land tenure are often less likely to engage in traditional and subsistence food production (pulaka pit farming, hunting, fishing, raising pigs and chickens) and instead be more reliant on the local economy (local stores, local markets, neighbours, etc).

These Funafuti smallholder families are however much more likely than the average smallholders to be engaged in other vegetable gardening, are well represented amongst the higher producers in the program, and yet have a slightly lower than average uptake of FoodCubes so far. This make them a large and important target group for future programming.

LLEE programming currently does not yet show evidence of targeting the following vulnerability groups:

- Female Headed households (5%, n=55).
- High income dependency households (11%, n=55)
- Disability – not present in the survey.

Female headed households (5%, n=55) and households with high dependency rates per income earner (11%, n=55), have the least diverse range of food sources and low uptake of FoodCubes, indicating the program could further target them in the future to address vulnerability.

Given the size of FHHs in national data (25.7% of households nationally), this group should be further investigated by LLEE to improve targeting of future programs.

While vulnerability appears to be a barrier or disincentive to spending time working on food production in general, no clear patterns of vulnerability can be discerned for those households with low crop yield results - their vulnerability does not appear to be a factor in their low yields.

Furthermore the 20 highest producing FoodCube and FoodWall households have high representation of migrants and smallholders in particular, with good crop yields possible even with lower than average labour inputs

This indicates that that while FoodCubes/Walls are well suited to addressing these households' vulnerability, the technology alone is not a sufficient factor to ensure high crop yields. The most experienced farmers often show the best results, showing that ongoing training and extension are key to ensuring that all households are able to maximise food production from the small space available in a FoodCube.

Uptake and Impact of FoodCubes

FoodCubes already rank as the 5th most important food source across the sampled households, and appear to have increased the number of households growing vegetables at home from 22%-29% of households (for vegetables and fruit trees respectively) to 84% of households sampled (although this is not a fully randomized sample).

On average FoodCubes also rank higher than pulaka pits in importance as a source of food, but only because pulaka pits rank so low in Funafuti compared to Nukulaelae, where pulaka is still slightly more important than FoodCubes as a source of food.

FoodCubes rank as the eighth most important source of produce for selling produce for income, slightly below both other (7th) home gardens and pulaka pits (6th), but rank 5th as a food source for meeting cultural obligations (festivals, church events etc – see below for more detail).

As noted above, Female headed households and households with high dependency rates per income earner have lowest uptake of FoodCubes (33% and 50% respectively), although are both very small sample sizes so results are not strong.

Households with insecure land tenure appear to have the most diverse range of food sources (6.23 per household), and a mid-rage level of FoodCube uptake. This indicates room for further targeting of this group in the program.

Crop Production

Crop Yields

In general, FoodCubes **crop yields** were 7 times more productive in terms of yield (6.97 kg/m2/yr) than pulaka pits (0.87 kg/m2/yr), which require minimum 2 years and a large area to bring their crop to maturity.

FoodWalls are even more productive in the sample (13.96 kg/m^2/yr), almost twice as productive per m^2 as FoodCubes and 14 times as productive as pulaka pits.

Very high harvest yields were recorded by some farmers (up to 47.28 Kg/m^2/year), who appear to be the more experienced Funafuti based farmers, and capable of producing higher yields, particularly for heavy crops such as pumpkin and cucumber. They were almost all part of the first rollout of FoodWalls in late 2018, are the most experienced farmers and have therefore had programme support for longer – somewhat explaining the unexpectedly high yields from FoodWalls compared to FoodCubes. This appears to be a key factor in high crop yields.

Crop Diversity

Crop diversity appears to be the another important correlating factor with high production yields. There is a visible correlation in the data between crop diversity and overall yield per m^2. Crop yields steadily increase from average 5kg/m^2/yr for single crop households to an average of 15kg/m^2/yr for gardeners growing 6 and 7 crops. Furthermore, all the high producing households are growing 3 or more crops.

Yet overall crop diversity is low across the program with 56% of households (n=58) reporting growing 3 crop types or less. In general five crops are most common (Cabbage, Taro, Cucumber, Pepper, Tomato), with cabbage being grown in more than half of all households surveyed.

LLEE should seek to increase the diversity of production as a strategy for increasing overall harvest yields. This will also increase the nutritional benefits of the food available at household level through increased diversity of food types.

Soils

Most FoodCubes tested as having either neutral or slightly alkaline **soil** (7 or 8) – acceptable levels for growing vegetable crops. Limited data means no strict comparison can be drawn, however as supporting Tuvaluan program participants from the negative impacts on food security of climate change related salt water intrusion into ground water, further soil testing of FoodCubes/walls, pulaka pits and standard horticulture should be a priority for further research by LLEE.

Pulaka pits show more consistently better quality soil texture types (97%) than FoodCubes (81%) and FoodWalls (66%), indicating improvements can be made here in the program. However, there is not a strong correlation between soil texture and crop yields. This means that while a good quality soil mix is necessary, it is not the most important factor in creating high yields.

Horticultural Practices

Access and Labour

91% of all gardens owned by respondents are in use (n=58), higher for both FoodCubes and Pulaka pits in Nukulaelae than in Funafuti.

FoodCubes are significantly **closer to home** than pulaka pits, a significant positive benefit sited by many program participants.

More **labour** is spent on FoodCubes each week than pulaka pits, both per household and per garden bed, particularly regarding more regular watering, weeding and pest control. However the overall labour burden is low at 2.62hrs on average spent gardening on all plot types per week, and this disparity may be as a result of closer proximity and possible overwatering.

Compost

The most common approach reported is to replenish beds with **compost** every month (for all bed types). However on average compost application for pulaka pits is 1.5-2 times more frequent per month than FoodWalls and FoodCubes (every 8 days as opposed to every 12 or 17 days for FoodWalls and FoodCubes) – a significant labour saving for FoodCubes. FoodWalls however appear to be receiving unnecessarily high volumes of compost – either over application or potentially a bias in the data.

There appears to be no strong correlation between high crop yields and either high or low compost application, nor types of mulch used. This indicates that while important, these are not the primary determinants of increased crop yields.

No farmers reported using fertiliser on pulaka pits or FoodCubes/walls. Production of home made, organic fertilisers (liquid compost, EM4 etc) should be investigated for future programming.

Watering

FoodCubes are **watered** much more frequently than pulaka pits, which are either never watered (rainfed or ground water fed) or are only watered during a drought (13% of pulaka pit farmers).

However amongst FoodCube and FoodWall farmers, there is no correlation between high water use and increased crop yields. This indicates that watering can likely be reduced without impacting on production, particularly for FoodWalls, where water use is very high.

Reducing water use will not increase benefits regarding food security. However given that the water supply for FoodCubes is also the household drinking supply (which is very limited in Tuvalu), more efficient water use should be seen as an important step to reduce potential negative impacts of the program on household water security.

Pests and Weeds

FoodCube horticulture is more prone to pest attack and crop damage (44% of households) than pulaka pits (10% of households). Pulaka is well known for having few pest problems in Tuvalu. However impacts are mostly mild, commonly leading to only a small reduction in harvest (64% of households experiencing pests).

FoodCubes receive weeding approximately twice as often as pulaka pits. Weeds are reported to have negligible impact for both FoodCubes and pulaka pits.

Interaction between FoodCubes and Traditional Culture

FoodCubes rank 5th as a food source for meeting cultural obligations (festivals, church events etc), equal to their importance as a household food source. This shows significant potential for using FoodCubes to support traditional Tuvaluan culture.

While only two households report growing pulaka in the survey, interview data shows this is a very important motivation for some households to engage in FoodCube gardening. LLEE should continue to maximize links between traditional pulaka pit farming and FoodCubes as a means of motivating engagement with FoodCubes for boarder food security outcomes.

Pulaka pits show more consistently good quality soil texture (97%) than FoodCubes (81%) and FoodWalls (66%), indicating that traditional knowledge from pulaka pit farmers could positively impact the quality of soil mix being used in FoodCubes and FoodWalls.

8. Recommendations

Crop Yields

- Invest in ongoing training and extension for FoodCube users to build their skills and experience
- Increase crop diversity to improve crop yields and the nutritional value of production
- Investigate training in household production of home made, organic fertilizers (eg: liquid compost, EM4 etc) to increase crop yields
- Increase intensity of crop production through organic horticulture techniques (see figure 9 for details), such as:
    - Intensive/high density cropping methods
    - Rapid succession planting & crop rotation
    - Vertical planting and climbers (corn, beans, choko, bitter melon, cherry tomatoes)
    - Vine crops allowed to ramble outside the FoodCube (eg: pumpkin, cucumber, melons, kang-kong etc)
    - Multi harvest plants that produce more than one food type (eg: Pumpkin, Cassava, Sweet potato,)

Horticultural Practices

- Train program participants in more efficient watering of FoodCubes to reduce drain on household water supply
- Investigate possible over application of compost, particularly for FoodWalls in Funafuti
- Continue household training on high quality compost production to improve soil texture – particularly for FoodWalls in Funafuti. Where possible use existing pulaka pit composting knowledge to increase uptake of training and quality of compost.
- Continue implementation of National Compost Strategy to ensure high quality compost and mulch is available to program participants, particularly in Funafuti.
- Provide pest management training for affected FoodCube participants – home made pesticides, companion planting, crop rotation, etc.

Age and Gender

- Engage children in FoodCube gardening for improvement in nutrition outcomes in future programming.
- Continue to engage women as gardeners in future programming to build on existing successes and continue to move towards equal participation of men and women in the programs activities.
- LLEE may wish to verify survey results showing gender as “other” result and consider inclusion of “other” as a disaggregated gender category in future surveys and programming.

Vulnerability Strategy

LLEE should target the vulnerability groups identified, as follows in order of priority:

- Smallholders (particularly in Funafuti) – this will also capture migrants and households with insecure land tenure.
- High age dependency households
- Female Headed Households – further investigate definitions, prevalence, food insecurity profile and FoodCube uptake.

- Disabled participants – no data, investigate further
- High income dependency households – low priority, inconclusive data, investigate further.

Further Research

- Complete soil pH testing of existing soil samples as a proxy indicator of salinity from salt water intrusion – consider replacing with electrical conductivity if logistically possible as this is a more direct measure of salinity
- Research Female Headed Households regarding definitions, prevalence, food insecurity profile and FoodCube uptake.

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10.Appendixes

Appendix 1: Key Questions

Ref#	Key Question	Measure	Data Source
	Core Questions		
R1	Crop yields produced.	Kg/m2 per crop	LLEE reports
R2	Soil/planting mix quality used (ph, texture).	Soil ph Soil texture	Plot survey
R3	Frequency of soil/planting replenishment required for FoodCubes.	L per year (based on sacks, buckets or similar)	HH Survey
R4	Soil additives/fertilisers required	volume, frequency, cost	HH Survey
R5	Water volume used	L/week	HH Survey
R6	Water source used	Multiple choice	HH Survey
R7	Irrigation/watering method use.	Multiple choice	HH Survey
R8	Labour input per m2	hrs/week/m2	HH Survey Plot survey
R9	Crop diversity crops per unit area.	# crops/m2	Plot survey
R10	Number of FoodCubes distributed (to households; to groups/institutions).	# FoodCubes; #FC/hh	LLEE reports
R11	Continued usage of FoodCubes after 6 months	#FC in use after 6/12/24 months	LLEE reports
R12	Number of households receiving extension support for traditional agriculture.	#hh receiving extension for traditional Ag	Survey
R13	Continued usage of traditional agriculture after 6 months, 12 months, 24 months.	#ExHH in use after 6/12/24 months	Survey
R14	Crop types produced (planted/harvested).	Text, list of crops marked by frequency	LLEE reports HH Survey
R15	Crop diversity produced (planted/harvested).	Number of crops per HH	LLEE reports HH Survey
R16	Perceived difference in taste for same crops in FC vs trad Ag	Multiple choice for set number of crops (6-10)	HH Survey
R17	Usage patterns amongst key target social groups	Meta data track the following to allow cross tabulation: • Gender • Disability • Marital status • Remote/urban • Migrant status • Land tenure	HH Survey
R18	Ranking importance of crops from FoodCubes and traditional agriculture as a family food source.	Ranking score (e.g. 2nd out of 7 food sources)	HH Survey
R19	Ranking importance of crops from FoodCubes and traditional agriculture as a family income stream.	Ranking score (eg 2nd out of 7 food sources)	HH Survey

R20	Location of FoodCubes and traditional plots	Multiple choice	HH Survey
R21	Distance travelled to FoodCube location vs traditional plot	Distance (m) Time? (minutes)	HH Survey, plot survey
R22	Comparison Types of mulch used	Multiple choice	HH Survey
R23	Ranking importance of crops from FoodCubes and traditional agriculture as for festivals to community and church food obligations	Ranking score (eg 2nd out of 7 food sources)	HH Survey
R24	Plant health (frequency of disease/insect attacks).	Frequency	HH Survey