Situation Report
Federated States of Micronesia

Impact assessment of past climate change adaptation actions

Sustainable, transformative, and resilient for a Blue Pacific

SPREP PROE

Impacts Assessment of Past Climate Change Adaptation Actions

Situation Report

Federated States of Micronesia

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1 Introduction

The purpose to employ a GIS and remote sensing specialist is the visualisation and quantitative documentation of climate change adaption actions impact. A measurable increase of a beach in Tonga due to the establishment of breakwaters is one of the very few feasible examples. Impact will be visible over time but not directly after the establishment of infrastructure elements.

However, the quantitative[1] documentation of elements such as seawalls, water tanks, groynes, etc. is essential and must be monitored[2]. These elements must still exist before the impact can be monitored. If for example a breakwater partly disappears the impact is reduced. The first documentation has to record the time of establishment, location and dimension. To document the location only is not sufficient. For such a baseline quantitative documentation data is still missing.

The project components covering the Federated States of Micronesia mainly concentrate on water improvement. Most elements cannot be monitored with remote sensing methods, but a database and GIS supported documentation is possible. So far, detailed surveys have been conducted describing the gutter, downpipes and tanks of rainwater harvest systems. It is expected that climate change will create weather extremes where drought periods will increase. It is possible to add a new element which is the catchment area allowing the estimation of the amount of water which can be captured. This can be performed with very high resolution image data, which is a very economic approach and avoids sending a team with a drone to remote islands. A detailed description is shown in chapter 3.2 explaining the potential of rainwater harvest in Nukuoro. Other chapters where surveys have been carried out such as Yap, Satawan or Kapingamarangi explain that the element catchment could be added to calculate the sustainability of villages or households during extended drought periods. A monitoring of rainwater harvest facilities would also enable the government to a direct assistance.

It is recommended to establish for every island a database with spatial component showing the roofs and tabular data documenting the families the roofs are belonging to. The report shows in chapter 3.3.2 (i) that the production of GIS backdrop from Google Earth display copies is possible and (ii) that surveyed infrastructure elements with X and Y coordinates can be imported to GIS.

Working in a GIS environment requires converting spreadsheet based data to a relational database. The connection between tabular and spatial data is easier and a database forces a clear data structure. Chapter 3.2.6 “Display of Annotation Data” also explains the advantage to separate tabular data and GIS layers.

The chapters, describing islands where rainwater harvest survey was conducted, show examples of spreadsheets imported a database. One database training was held for the FSM team, however, more input is required to establish for every island a GIS layer keeping all infrastructure elements of climate change adaptation actions and parallel a relational database.

For Kosrae the project was looking at coastal infrastructure elements to protect the important coastal road. These elements have to be documented at 1:10,000 scale level. Here data is missing so far. Data capture has to be conducted through field survey to achieve the required accuracy.

1 Quantitative = documentation of dimensions such as length, width, height, etc. in opposite to descriptive.
2 Monitoring is the measurement and documentation in regular intervals to record changes.

2 GCCA PSIS Adaptation Fund Project

The GCCA PSIS Project was running from 2013 to 2015 and concentrated on activities in outlying islands of FSM States to increase access to quality of water. The existing catchment, storage, emergency services of water was supposed to improve. One additional 54,000 gallons of rainwater storage was provided in Fais which benefited 65 residential compounds. Community members, particularly women have less time and distance to access reliable and clean water supply. Solar pump installed at Sahagow Well in Fais proved an essential alternative water supply following Typhoon Maysak[3].

Fais Island is a raised coral island in the eastern Caroline Islands in the Pacific Ocean, and forms a legislative district in Yap State in the Federated States of Micronesia. Fais Island is located approximately 87 kilometres east of Ulithi and 251 kilometres northeast of Yap and is the closest land to Challenger Deep, about 290 kilometres away. The population of Fais Island was 215 in 2000[4].

Figure 2-01: *Location Fais*

Figure 2-02: *Fais on Google Earth captured on 15 October 2014*

3 SPREP contract paper
4 Wikipedia

Figure 2-03: *Fais on Google Earth captured on 25 December 2004. The number of roofs increased between 2004 and 2014.*

Rainwater harvest, which is a method to generate quality water for the population, can be supported and the potential can be estimated and monitored employing very high resolution satellite image data in a cost effective way. This is described in chapter 3.2 Rainwater Harvest in Nukuoro.

3 Readiness for El Nino (RENI) Project

The RENI project was running from 2017 to 2020 and focused on the water resources sector. The project actioned on enhancing sustainable water use in the outer islands of Yap and Pohnpei, through the refurbishment of community rainwater storage systems, catchments and instalment of solar pumps and environmental purification systems.

3.1 Enhancing Sustainable Water Use in Yap

Figure 3.1-01: *Location of Yap*

Yap is made up of four separate islands: Yap, Gagil-Tamil, Maap and Rumung. The four islands are separated by relatively narrow water features, and the islands are surrounded by a common coral reef. Gagil-Tamil was once connected to Yap Proper, but a canal, Tagireeng Canal, less than 10 meters wide, was constructed that separated the two landmasses in 1901. Excluding the reef area, the Yap Main Islands are approximately 24 km long, 5–10 km wide, and 98 km^2. The highest elevation is 178 m at Mount Taabiywol in Fanif municipality on Yap Proper[5].

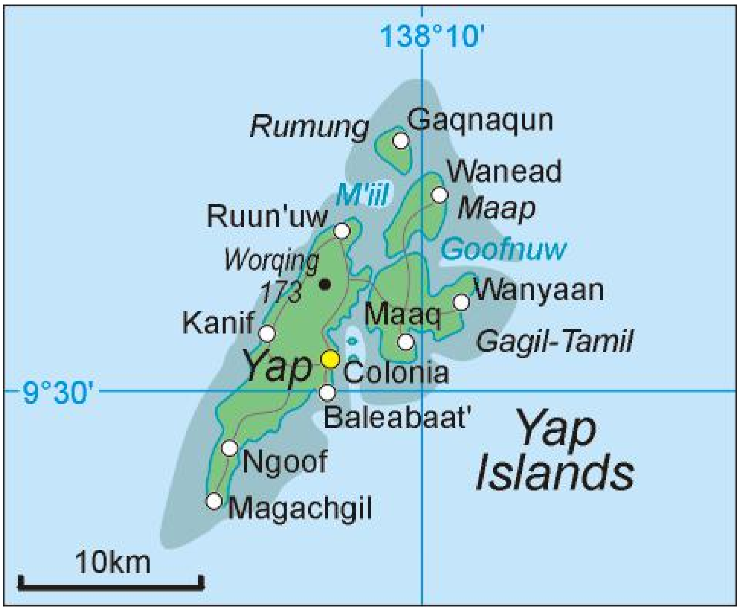


Figure 3.1-02: *The four islands of Yap: Rumung, Gagil-Tamil, Map and Yap.*

During the periods of heaviest population, the Yapese recognised over 180 separate villages. In recent years 91 of those villages contain at least one resident household, and the largest villages have forty to fifty households with up to 300 people in residence. Most of the inhabited villages lie in close proximity to the sea, and households are dispersed over a fairly large area along the shoreline. Since the construction of roads in the late 1960s and the extension of electricity along these roads in the late 1970s, many people are now building houses on the roads for accessibility to the town and to electricity. The largest villages are located in the administrative town of Colonia. The contemporary Yapese house is generally made of plywood and corrugated metal with a planked or cement floor. Some of the more prosperous Yapese are building concrete-block or poured-concrete houses today because of the extensive termite damage to wooden structures. In sandy beach areas and in the urban centre, many people build houses on posts, raised off the ground, closed in with bamboo or plywood, and covered with corrugated iron[6].

5 Wikipedia
6 The complete paragraph: https://storymaps.arcgis.com/stories/1f191fb715f54062b92a26654f800556

Figure 3.1-03: *Villages in Yap state. Image capture 14 December 2015*

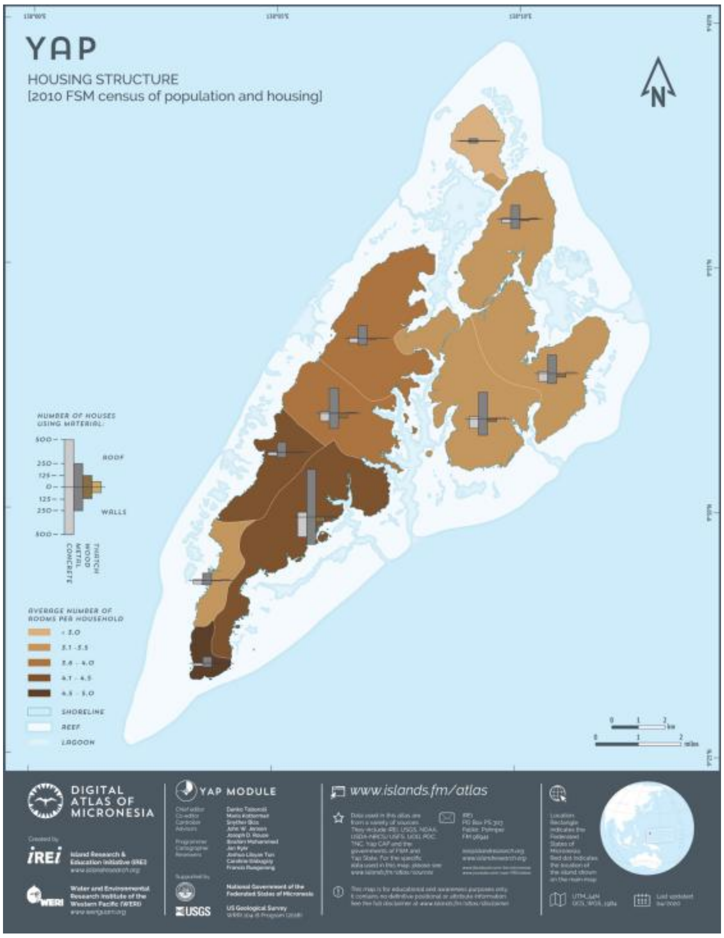


Figure 3.1-04: *Display of housing structure survey Digital Atlas of Micronesia.*

The last paragraph, copied from storymaps.arcgis, stated that the house's construction moves to more solid houses with roofs made out of corrugated iron. This provides the opportunity to monitor rainwater harvest as proposed without expensive employment of drones.

The developed database allows to survey the houses by staff in Yap and analyses the situation to develop necessary activities.

There was already a detailed survey performed in Yap related to the Digital Atlas of Micronesia[7] The map (figure 3.1-4) shows the average number of rooms per household and the building materials used to make house roofs and walls in each municipality on Yap. The attribute tables in the actual dataset also contain information on

7 https://islandatlas.org/yap/population/

specific building types, floor construction materials, age of buildings, and the number of persons per household and per room[8].

Figure 3.1-05: *Location of Colonia, image data 08 December 2019*

When zooming in (next page) it is visible that the recent image data allow an estimation of the roof area as rainwater harvest intake.

It is also visible that there is a dynamic of more buildings during the last decades.

8 This dataset was created by Island Research & Education Initiative (iREi) (2019) using information from the FSM census of population and housing (2010)

Figure 3.1-06: *Roofs in Colonia. Image data from 08 December 2019. The image data allow an estimation of the roof area. Compared with figure 3.1-6 it is visible that the number of roofs increased.*

Figure 3.1-07: *Roofs in Colonia. Image data from 09 February 2005*

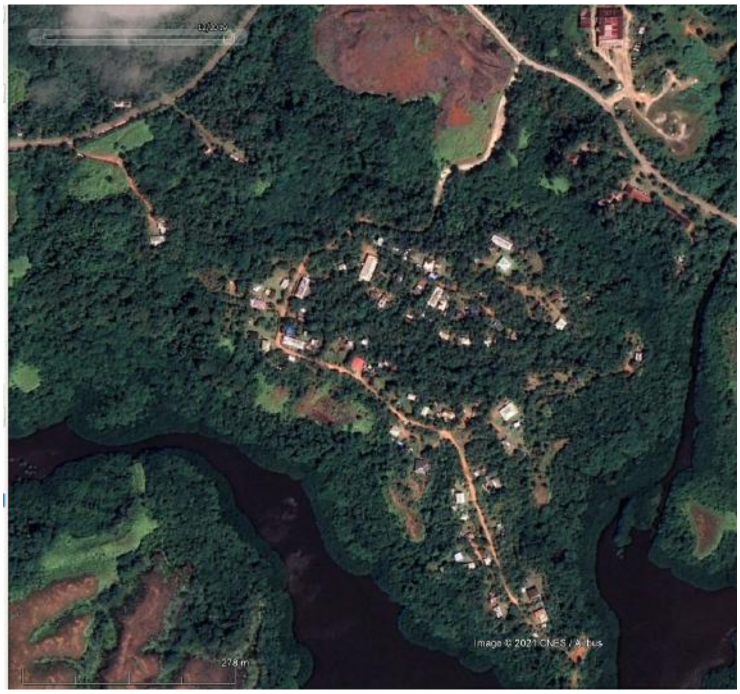


Figure 3.1-08: *Image data recorded 08 December 2019*

Figure 3.1-09: *Image data recorded 09 February 2005 of the same area shown in figure 3.1-07*

3.2 Rainwater Harvest in Nukuoro

Nukuoro is an atoll in the Federated States of Micronesia. It is a municipality of the state of Pohnpei, Federated States of Micronesia. It is the secondmost southern atoll of the country, after Kapingamarangi. They both are Polynesian outliers. As of 2007, Nukuoro had a population of 372, though several hundred Nukuorans live on Pohnpei. Fishing, animal husbandry, and agriculture (taro and copra) are the main occupations. A recent project to farm black pearl oysters has been successful at generating additional income for the island's people.

Figure 3.2-01: *Location of the atoll within the Pacific*

Figure 3.2-02: *Location of Nukuoro island within the atoll.*

Nukuoro is remote. It has no airstrip, and a passenger boat calls irregularly only once every few months. The island has no tourism except for the occasional visit by passing sailing yachts. There is a 4-room schoolhouse but children over the age of 14 must travel to Pohnpei to attend high school.[9]

To estimate the water availability of an island the amount of rain has to be related to the capture and storage capacity. For the capture capacity the roof area as potential intake has to be measured. This was performed with very high resolution satellite image data allowing to map the roofs and import the area figures into a database.

The database requires a unique ID for every roof which was carried out by subdividing the islands into "settlement areas". These areas have nothing to do with physical or demographic boundaries, these "settlement areas" are arbitrary sub-areas of the island to make the identification of houses easier.

3.2.1 The Potential of Rainwater Harvest in Nukuoro

To estimate the water availability of an island the amount of rain has to be related to the capture and storage capacity. For the capture capacity the roof area as potential intake has to be measured. This was performed with very high resolution satellite image data allowing to map the roofs and import the area figures into a database.

9 Text and maps Wikipedia, Peter Mintonderivative

177 roofs were mapped where the mapping distinguished between pandanas and metallic coverage. A total area of 7,057 m^2 was calculated, however, this total area will be reduced significantly during the field work as will be explained in a chapter below.

The average amount of precipitation per year in Nukuoro Island is 3,980 mm. The rainfall drops below 300 mm per month from September to December[10].

The 7,057 m^2 roof area theoretically could capture 28,086,860 litre per year (7,057 x 3,980)[11]. A person uses in average 150 litre per day[12]. Detailed figures show 283 litre per day for Fiji and 165 litre per day for PNG[13]. With an assumption that FSM is with 200 litre per person per day in the middle, the figure of yearly consumption per person would sum to ~ 73,000 litre per year. 384 persons could be supplied with rainwater from the existing roofs. This can be detailed to households if the number of household members can be linked to the rainwater harvest figures. However, this is a theoretical figure under the assumption that all roof areas are capturing the water and the water is captured from all parts of the roof!

3.2.2 The Mapping of the Potential Roof Catchment Area

The project purchased WorldView 3 image data of 15 cm spatial resolution[14]. The image data was recorded 27 January 2022 and arrived rectified to UTM Zone 56 North, WGS84 EPSG Code 32656. The cost covering the complete island was only US$ 104.

Figure 3.2.2-01: *Roofs with superimposed unique IDs. These images can be printed for the teams in the field.*

10 https://www.climatestotravel.com/climate/micronesia
11 1 mm per square metre = 1 litre
12 https://www.ccwater.org.uk/households/using-water-wisely/averagewateruse/
13 Worldometer: https://www.worldometers.info/water/
14 The normal 30 cm spatial resolution was increased to 15 cm by artificial intelligence algorithms

The image data were stitched together and then divided into sub-areas with image analysis software. Afterwards the sub-area images were imported to GIS software. The sub-area images covered all houses in Nukuoro.

The image data allow a delineation of the roof area in 1:5,000 scale accuracy see figures 3.2.2-02 and 3.2.2-03. The mapping can be improved at a later stage by zooming in, delineating and zooming out.

Figure 3.2.2-02: *Example of metallic and pandanas covered roofs visible in the image data*

Figure 3.2.2-03: *Polygons superimposed over the roofs visible.*

Each roof area has to have a unique ID to be able to be entered into a relational database. Here it approved to separate the total area into 11 so called "settlement areas", see figure 3.2.2-04. These settlement areas are artificial sub-areas which have nothing to do with political boundaries.

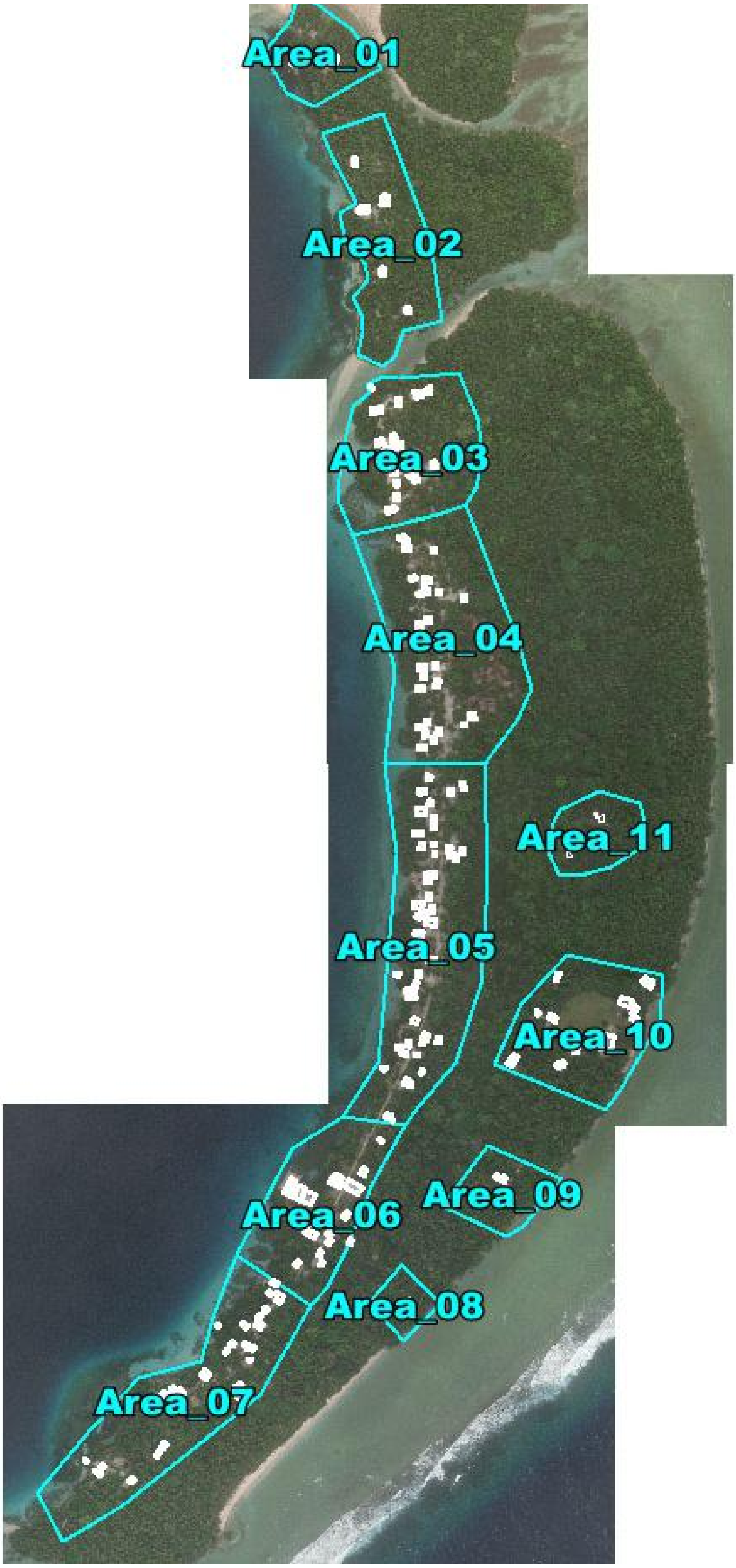


Figure 3.2.2-04: *Overview over the "settlement areas" the roofs were subdivided in.*

3.2.3 Analysis of the Potential Roof Catchment Areas

Within GIS environment following information could be documented:

- The roof area
- The roof centroid[15]
- The roof type

This information was transferred to the relational database, which allows a fast analysis.

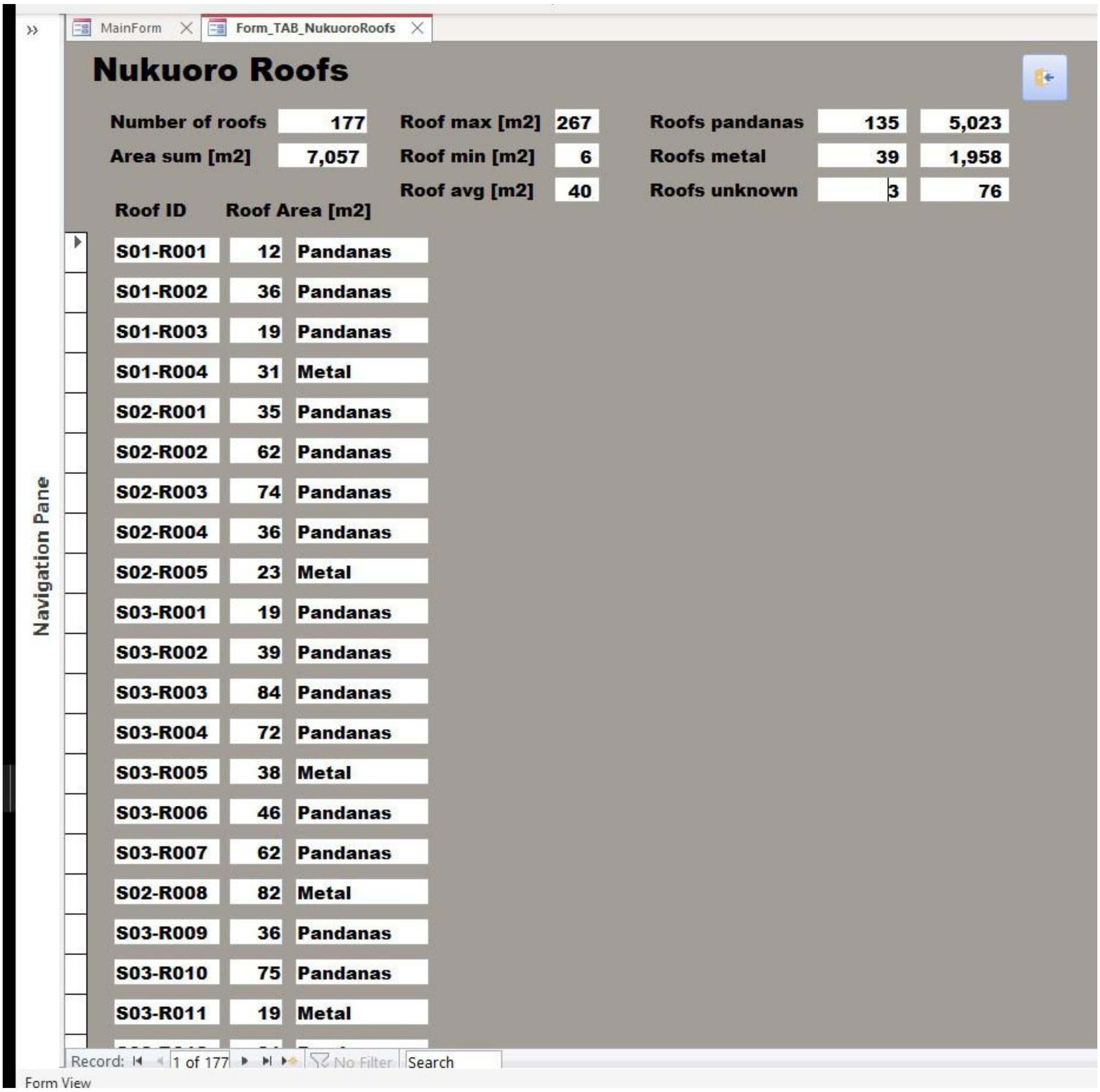


Figure 3.2.3-01: *Display of the first 20 roof records out of 177. The unique ID is built from the settlement area ID such as S03 and a running number for every roof within the settlement area such as R011. The average area is 40 m2 and 39 roofs out of 177 apparently have a metal surface.*

15 The X and Y coordinate of the centre of the polygon of the roof delineation.

3.2.4 Survey of Water Harvest Facilities

A survey carried out documented details about the situation of rainwater harvest with information about:

- Elements of rainwater harvest available;
- Rainwater harvest preformed or not;
- Gutter quality;
- Downpipe quality;
- Tank capacity
- Tank type;
- Tank location in form of geographical coordinates;
- other information such as supporting projects, year of establishment, etc.

The survey also established a unique ID for each rainwater harvest system. The information about the tanks was linked to the households. Missing is the link of roofs and households.

MainForm | NUKURORO-WSM

Infras	Villag	WSM	WSM_YN	GutterQuality	DownpipeQua	Har	Tank	TankMateri	Projec
CT004	North	Tank, guttering system, Roof	YES	2,3	2,3	NO	2,000	Cement	UNK
CT01	South	Tank, guttering system, Roof	YES	5	5	YES	800	Concrete	UNK
CT02	South	Tank, gutter, roof,	YES	5	5	YES	2	Plastic	AF
CT03	South	Tank, guttering system, Roof	YES	5	5	YES		Concrete	UNK
CW1	South	Community well	NO	NO PUMP	NO Cover	NO		Concrete	AF
CW2	South	Community well	NO	PUMP	COVER	NO		Concrete	AF
PT001	South	Tank, guttering system, Roof	YES	1	4	NO		Concrete	UNK
PT002	South	Tank, guttering system, Roof	YES	4	4	YES		Concrete	UNK
PT003	South	Tank, guttering system, Roof	YES	5	5	YES		Concrete	UNK
PT004	South	Tank, guttering system, Roof	YES	5	5	YES		Concrete	UNK
PT005	North	Tank, guttering system, Roof	YES	3	4	YES	700	Cement	UNK
PT006	North	Tank, guttering system, Roof	YES	3	1	NO	1,000	Cement	UNK
PT007	North	Tank, guttering system, Roof	YES	3	1	NO	1,000	Cement	UNK
PT008	North	Tank, guttering system, Roof	YES	1	1	NO	700	Cement	UNK
PT009	North	Tank, guttering system, Roof	YES	1,2,4	1	NO	1,000	Cement	UNK
PT010	North	Tank, guttering system, Roof	YES	3,4	1	NO	1,000	Cement	UNK
PT011	North	Tank, guttering system, Roof	YES	5	1	NO	1,500	Cement	UNK
PT012	North	Tank, guttering system, Roof	YES	1,2	1,2	NO	600	Plastic	UNK
PT013	North	Tank, guttering system, Roof	YES	4	4	YES	2,000	Cement	UNK
PT014	North	Tank, guttering system, Roof	YES	5	5	YES	5,000	Cement	UNK
PT015	North	Tank, guttering system, Roof	YES	1	1	NO	5,000	Cement	UNK
PT016	North	Tank, guttering system, Roof	YES	4	4	YES	5,000	Cement	UNK
PT017	North	Tank, guttering system, Roof	YES	5	5	YES		Concrete	UNK
PT018	North	Tank, guttering system, Roof	YES	4	1	NO	700	Concrete	UNK
PT019	North	Tank, guttering system, Roof	YES	4	1	NO		Concrete	UNK
PT023	North	Tank, guttering system, Roof	YES	5	5	YES		Concrete	UNK
PT024	South	Tank, guttering system, Roof	YES	3	3	YES		Concrete	UNK
PT025	South	Tank, guttering system, Roof	YES	5	5	YES		Concrete	UNK

Record: 1 of 31 No Filter Search

Figure 3.2.4-01: *Database table of imported spreadsheet as output of the rainwater harvest survey.*

3.2.5 Link between Roofs and Households

As the tanks have recorded geographical locations the positions can be visualised in GIS environment. This allows to indicate the next roof performed through a visual interpretation.

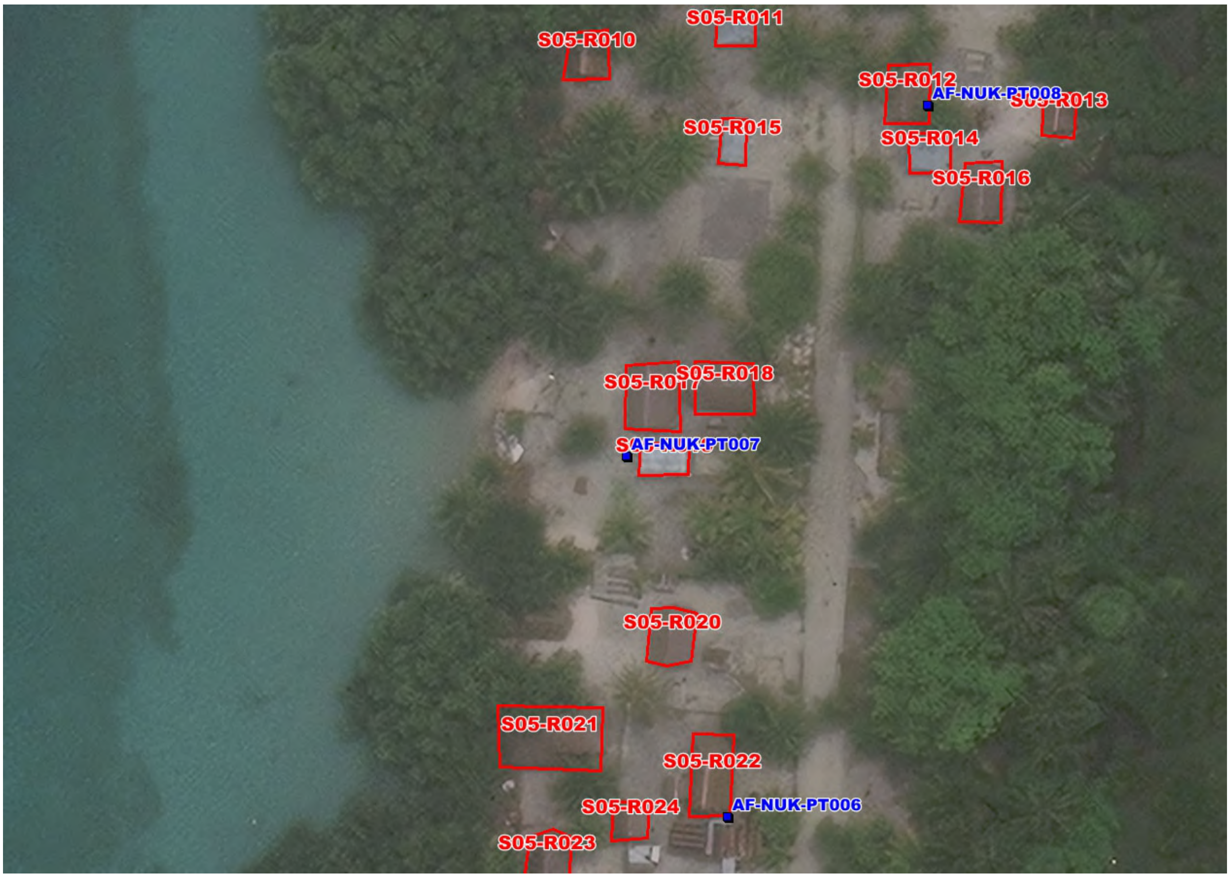
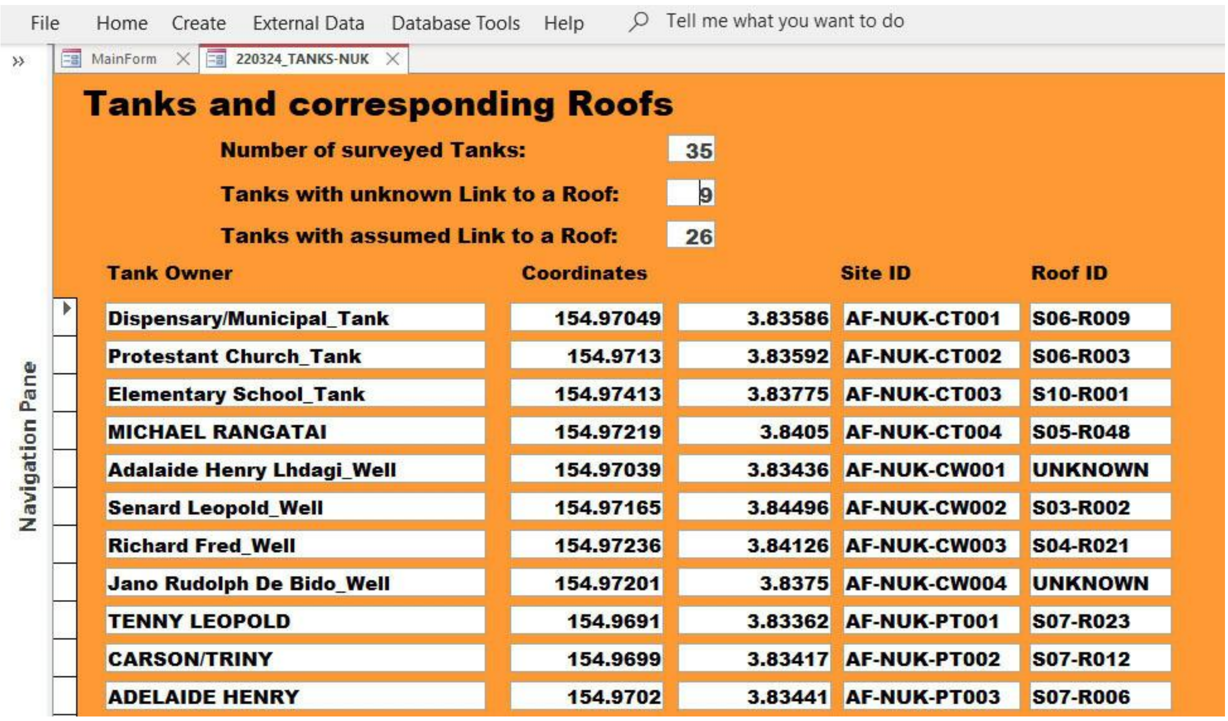


Figure 3.2.5-01: *Roofs and tank positions in GIS environment*


File Home Create External Data Database Tools Help Tell me what you want to do

MainForm 220324_TANKS-NUK

Navigation Pane

Tanks and corresponding Roofs

Number of surveyed Tanks: 35

Tanks with unknown Link to a Roof: 9

Tanks with assumed Link to a Roof: 26

Tank Owner	Coordinates		Site ID	Roof ID
Dispensary/Municipal_Tank	154.97049	3.83586	AF-NUK-CT001	S06-R009
Protestant Church_Tank	154.9713	3.83592	AF-NUK-CT002	S06-R003
Elementary School_Tank	154.97413	3.83775	AF-NUK-CT003	S10-R001
MICHAEL RANGATAI	154.97219	3.8405	AF-NUK-CT004	S05-R048
Adalaide Henry Lhdagi_Well	154.97039	3.83436	AF-NUK-CW001	UNKNOWN
Senard Leopold_Well	154.97165	3.84496	AF-NUK-CW002	S03-R002
Richard Fred_Well	154.97236	3.84126	AF-NUK-CW003	S04-R021
Jano Rudolph De Bido_Well	154.97201	3.8375	AF-NUK-CW004	UNKNOWN
TENNY LEOPOLD	154.9691	3.83362	AF-NUK-PT001	S07-R023
CARSON/TRINY	154.9699	3.83417	AF-NUK-PT002	S07-R012
ADELAIDE HENRY	154.9702	3.83441	AF-NUK-PT003	S07-R006

Figure 3.2.5-02: *Roofs and tanks as database display. There are 177 mapped roofs and only 35 surveyed tanks. Partly it seems to obvious which roofs belongs to which tank (29). However, this has to be verified in the field. Some tanks cannot be connected with remote sensing data only (9).*

3.2.6 Display of Annotation Data

The data collected by the field team conducting the water catchment infrastructure survey should not be stored in the GIS as update would be more difficult compared to an update of a stand alone relational database.

***Figure 3.2.6-01:** Display of tank type in GIS environment. The information (i) Community Tank, (ii) Community Well and (iii) Private Tank is stored in a relational database and can be linked to the spatial layer "Nukuoro Tanks". The unique ID with which database table and GIS table are linked is displayed in the left part of the figure.*

The example in figure 3.2.6-01 shows the display of information (i) Community Tank, (ii) Community Well and (iii) Private Tank, which is stored in a relational database and can be linked to the spatial layer "Nukuoro Tanks". The link utilises the unique ID which is the same in both tables. This ID is visible in the left side of the figure and also in figure 3.2.5-02 as "site ID".

Any other information can be used to create a thematic map with the same procedure such as (i) tank material, (ii) tank capacity, (iii) tank condition, etc.

The procedure is a SQL database command[16] which tells the system in the case of the displayed example: Link the GIS table “TANKS_NU” with the database table “NUKUOROT” using the fields ““NUKUOROT’Site_id” and “TANKS_NU.Site_id” for all records where both fields have the same content and store it in a new table “TankType”.

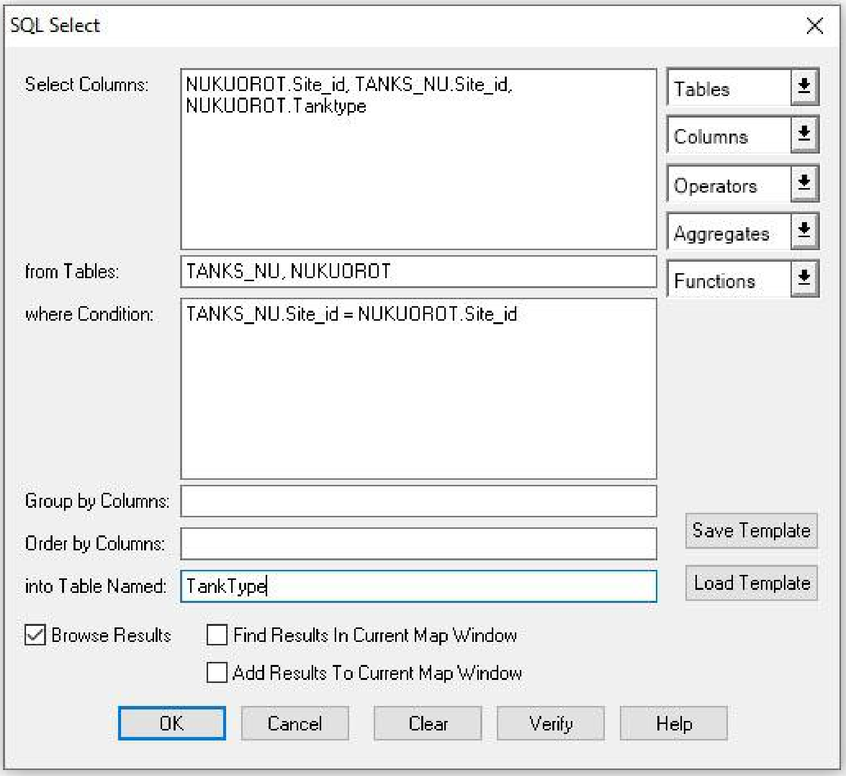


Figure 3.2.6-02: *GIS menu driven establishment of a SQL “table combine” command.*

A GIS user does not have to learn SQL language. GIS software (in figure 3.2.6-02 MapInfo) of all types provides the option to link external tables.

The advantage is that data update such as tank capacity, tank type, tank ownership, etc. is handled in the tabular side of data. Only if the tank location changes, a tank disappears or a new tank is recorded the GIS layer requires change.

In addition, a stand alone relational database allows a faster analysis of the data as many queries can be inbuilt in a form as shown in figures 3.2.3-01 and 3.2.5-02. During the data input the display changes already.

More complex questions about the relation of (i) water capture through the roof, (ii) water run off through gutter and down pipe and (iii) tank storage capacity require the tools of a database not just tables within the GIS environment. The relational database will be enhanced if population data can be added such as (i) how many people are in the particular household, (ii) which gardening area has to be watered, (iii) how many pigs need water supply, (iv) etc.

Questions might be relevant such as:

- where the tank capacity does not match the roof catchment,
- where the gutter or downpipe does not allow to drain the water into the tank
- where the number of people cannot be supplied with the water which can be stored.

Here a database provides a fast answer. Such an answer can be immediately displayed in a GIS environment for example red dots for households with insufficient water.

16 SQL = Structured Query Language is a language for managing data held in a relational databases

3.2.7 The next Steps to detail Rainwater Harvest Potential

The first mapping concentrated on the roof only. The roof area was not subdivided yet into separate catchment areas of the roof draining into different tanks.

177 roofs were mapped where the mapping distinguished between pandanas and metallic coverage. A total area of 7057 m^2 was calculated, however, this total area will be reduced significantly during the field work. Following issues have to be identified:

1. Is the roof connected to a water tank?
2. Was something else mapped instead of a roof.
3. What is the percentage of the roof from which the water is captured by a gutter?

The field work also has to establish and check the link between the roof and the family it belongs to. All rainwater harvest facilities have already a unique ID

The average roof was calculated with 40 m^2, the smallest with 6 m^2 and the largest with 267 m^2.

Regarding the rainwater harvest facilities the last survey only recorded 35 water tanks.

Connection between Roof and Water Tanks

A field team equipped with printed images or tablets where tanks and roofs can be displayed have to carry out a survey detailing which tank is connected to which roof. Possibly there is no need to send a team to the islands; it can be handled by people living in Nukuoro. At the same time the visual mapping will be verified. Even with the extremely high quality image data there is a possibility that containers or other objects are mapped as roofs.

Roof and Catchment Area

Figure 3.2.7-01: *Display of the roof layer over satellite image data.*

Figure 3.2.7-02: *Subdivision of roof area into catchment areas with satellite image data.*

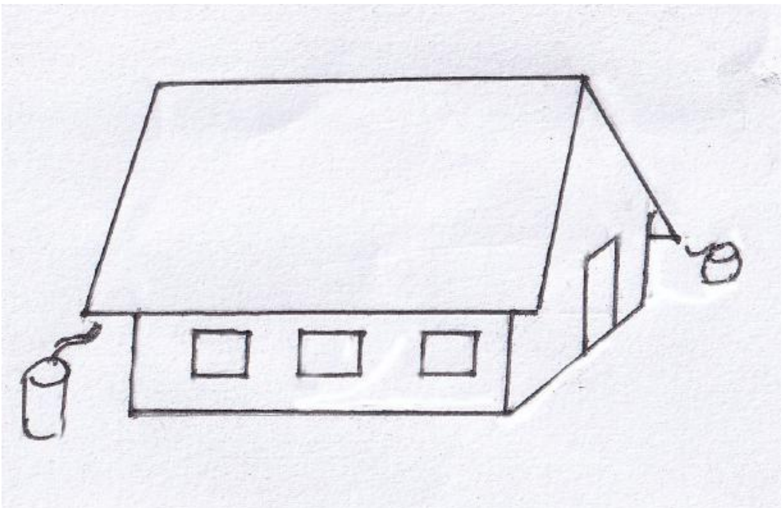


Figure 3.2.7-03: *Subdivision of roof area into catchment areas draining into separate tanks. It becomes even more complicated in case of a hipped roof.*

Figure 3.2.7-02 shows the roof visible in figure 3.2.6-01 within the roof layer. A roof has to be subdivided as long as not all gutters drain into the same tank.

This can be performed in the field as an estimation of percent of the complete roof. It is also possible to map the catchment areas and calculate the area by GIS tools.

It is understood that the roof area is only an estimation as inaccuracy during the digitising process and perspective distortion[17] have an input.

Nevertheless, if the roof area is divided into catchment areas with a quality assessment of the rainwater harvest infrastructure of gutters and downpipes the potential harvest capacity becomes more realistic.

The database requires new unique IDs where a catchment ID is added to the roof ID. See figures 3.2.7-01 and 3.2.7-02. Catchment 01 (C01) and 02 are added to roof ID S06-R003.

17 The image data is normally not captured from a strict nadir view, mostly there is a slight oblique view.

Link to Households

The tanks are already linked to families see figure 3.2.5-02. Additional socio-economic data would allow to link the rainwater harvest capacity to the expected water consumption. In chapter 3.2.1 a figure of 200 litre per person and day was used. This figure includes:

- Drinking water
- Shower
- Washing of cloths
- Little amount of watering the nearby garden
- Water for pigs and other animals.

In some atoll islands the water consumption apparently can be reduced to 100 litre per person per day[18]. Important are that (i) roof catchment potential, (ii) quality of harvest infrastructure such as gutter, downpipe and tank and (iii) estimated consumption are linked.

18 Statement of water specialists at SPC

3.3 Water Supply in Kapingamarangi

Kapingamarangi is an atoll and a municipality in the state of Pohnpei of the Federated States of Micronesia. It is by far the most southerly atoll or island of the country and of the Caroline Islands, 300 km south of the next southerly atoll, Nukuoro, and 740 km southwest of the main island of Pohnpei state; it forms a Polynesian outlier.

Figure 3.3-01: *Location of Kapingamarangi in the Pacific.*

The total area of the atoll, including the lagoon, is 74 km^2. Out of this, 1.1 km^2 is land area, spread over 33 wooded islets on the eastern side of the atoll. The western reef rim of the atoll is almost submerged at high water. Kapingamarangi is the southernmost point of Micronesia.

Kapingamarangi has a population of about 500 (as of 2007). Several hundred Kapingamarangi people also live in Porakied village in Pohnpei. Their language is Polynesian. The main industry is fishing.

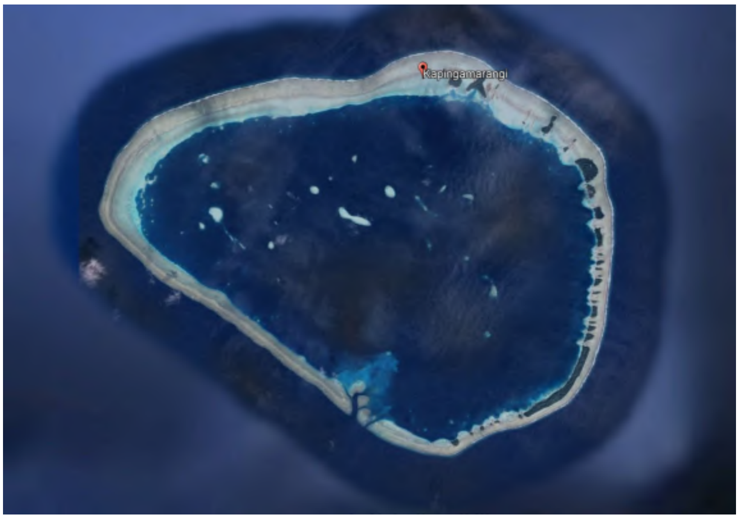


Figure 3.3-02: *Kapingamarangi atoll Goole Earth*

Touhou Island, which reaches a height of 890 mm and is connected to Welua Island (Ueru Island) in the north by a causeway, is the capital of the municipality, the centre of population and the home of a native chief. Most of the population resides on these two islets, plus the remnant on Taringa (south of Touhou), although many of the remaining islets are used for growing fruit and vegetables.[19]

Kapingamarangi has an average rainfall of 3,090 mm per year most sufficient to harvest the rain.

3.3.1 Rainwater Harvest Facility Survey

The rainwater harvest facilities were surveyed[20] and results are stored in a spreadsheet which could be imported to an Access database.

There were four wells and 12 catchments reported with detailed recording of the roof material. Also the tank capacity is documented in the same spreadsheet[21].

19 Text and overview map copied from Wikipedia.
20 By Elson, Quintin, Strick, Gordon, Snyther, Richard, Morthy
21 Pohnpei-AF Project sites data.xlsx

3.3.2 Images for Catchment Survey

It was possible to download at large scale in TIF file format and to register the TIF file in GIS environment with a linear transformation to GIS backdrops.

Figure 3.3.2-01: *Large scale screen dumps were registered and could be used as GIS-Backdrops.*

To register the image data Ground Control Points (GCP)[22] are necessary. They were located on Google Earth displays and exported as KMZ file.

Figure 3.3.2-02: *The latest image data was captured on 15 December 2007. The best resolution was 61 cm.*

The newest image data available on Google Earth were captured on 15 December 2007. Most probably recorded by the QuickBird satellite with 61 cm resolution. It is recommended to purchase 30 cm WorldView images and enhance the resolution to 15 cm for subsequent digitising of roof areas.

The tanks and wells of the survey could be imported to GIS as the geographical location was documented, see figures 3.3.2-03 and 3.3.2-04.

22 Synonym to *Reference Image Points*, points visible in the image data and know X and Y coordinate.

Figure 3.3.2-03: *The figure shows that the image tiles fit to a seamless image backdrop and that well and tank location can be shown from the imported spreadsheet.*

Also figure 3.3.2-04 shows that the image tiles fit seamlessly and can be used as GIS backdrops to locate the surveyed tanks and wells.

As mentioned before 15 cm image data would be appropriate to map and monitor the roof as catchment areas.

It is not necessary to transport a crew with a drone and GPS to the islands. The survey could be also performed by trained people of the island if images can be shifted to these outer islands.

Figure 3.3.2-04: *Tank location and roofs on the main island.*

3.4 Enhancing Sustainable Water Use in Pohnpei

It will be difficult to employ remote sensing methods to monitor the enhancement of sustainable water use in Pohnpei. If the water pipe network, the consumer and the consumption is available a GIS layer leakage can be calculated and the assumed area visualised. This data, however, is not available yet.

4 Adaption Fund (AF) Project

The Adaption Fund project was running between 2018 and 2022 and focused on the water resources sector like the RENI project. The project actioned on aspects of strengthening community-based water and livelihood security measures and construction of self-composting toilets across the states of Yap, Chuuk and Pohnpei. The Kosrae state activity was the coastal protection.

Self-composting toilets cannot be made visible with remote sensing data, however, the position of installed toilets can create a GIS layer which then can be correlated with the spatial distribution of diseases. Self-composting toilets normally drop the spread of some diseases and the effect can be monitored. This, however, requires: (i) a GPS survey of all toilets and (ii) the spatial information when patients enter the hospital. The household has to be recorded and the households have to be linked to the roofs a spatial GIS component.

4.1 AF Activities Yap

In chapter 3.1 it was explained that a mapping of roof areas would allow to estimate the roof ara available for rainwater harvest and would allow to locate each household. A monitoring (mapping of roofs over time) would allow to predict the need for several types of assistance where rainwater harvest would be one of them.

Currently there is no data for Yap available.

4.2 AF Activities Chuuk

Data was only available for Satawan.

4.2.1 Mapping of Rainwater Harvest Potential in Satawan

Satawan Atoll is an atoll located about 250 kilometres southeast of Chuuk Lagoon proper. Geographically it is part of the Nomoi or Mortlock Islands in the Carolines and administratively it is part of Chuuk State in the Federated States of Micronesia. About 3,000 people live on a land area of 5 square kilometres. A Japanese airfield was located on the atoll during World War II.

Figure 4.2.1-01: *Location of Satawan in the Pacific Ocean.*

Satawan Atoll administratively consists of four of the 40 municipalities of Chuuk State, named after the principal islets:

- Satowan (Satawan) (east)

- Ta (south)
- Kuttu (Kutu) (west)
- Moch (More) (north)

Satawan Atoll had a population of 2,935 as of the 2000 census. Satawan Atoll is located at 5.30°N 153.70°E and has a total area of 419 square kilometres (including the lagoon), but a land area of only 4.6 square kilometres[23].

On 26 January a survey recorded infrastructure elements including detailed capture of water storage. This was conducted by Johnny, Gordon, Snyther, JK, Kerson stated in the available

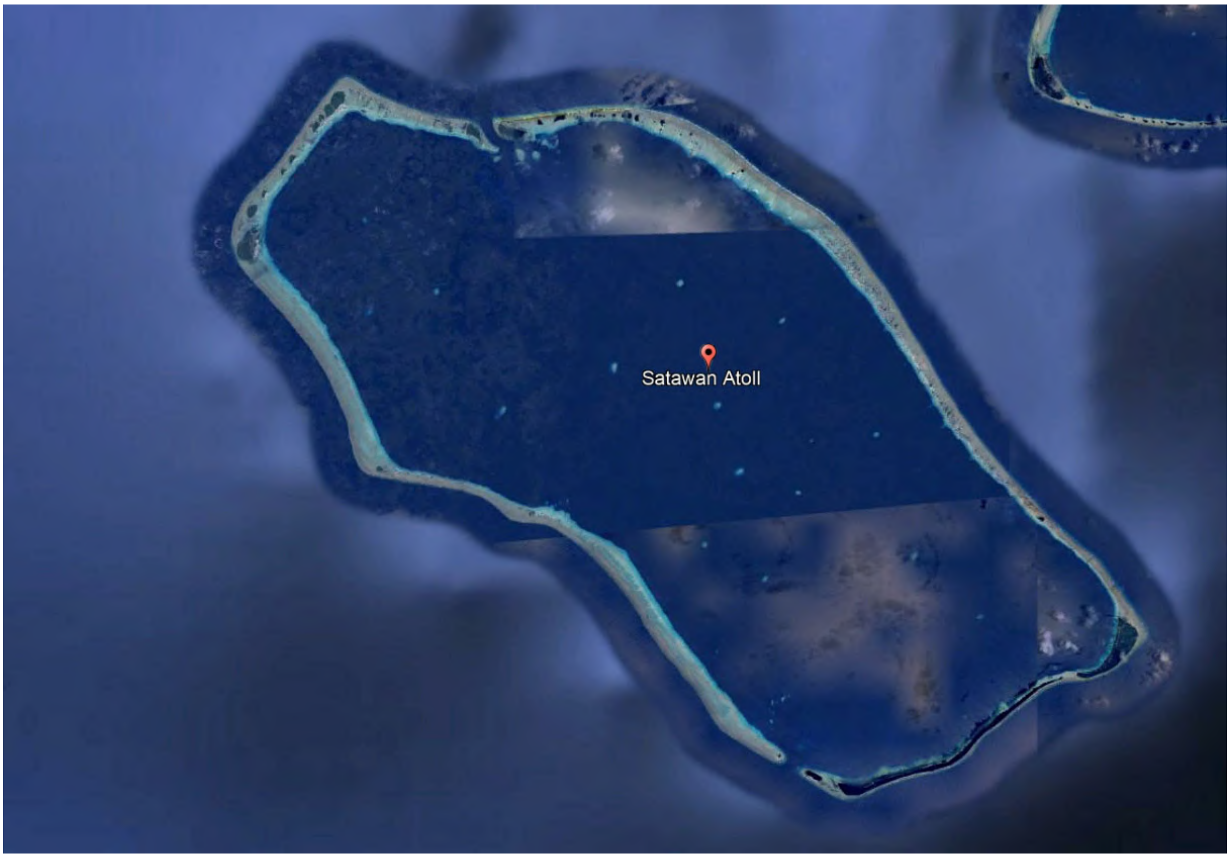


Figure 4.2.1-02: *Shape of the Satawan atoll, image data from 14 December 2015*

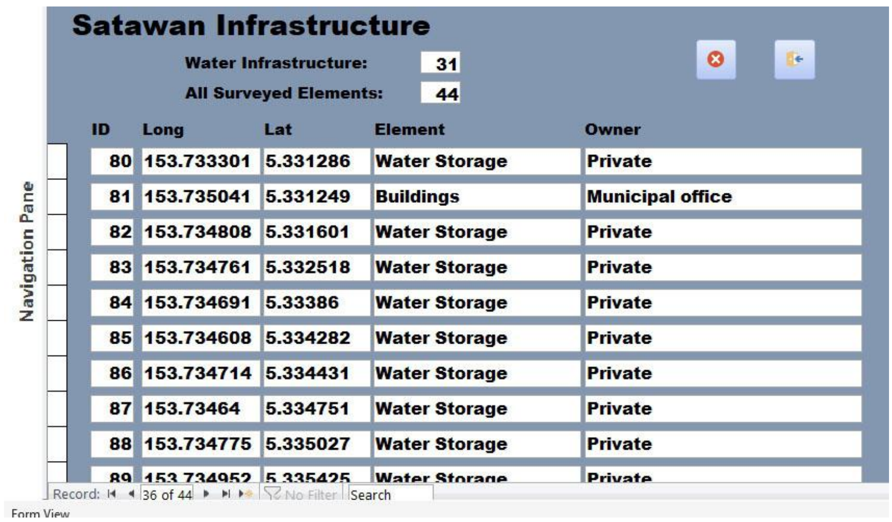
spreadsheet. The visible houses are concentrated on the south eastern part of the atoll. The current latest image data was recorded 14 December 2015. Figure 4.2.1-03 shows the resolution of the available free image source. A roof mapping is possible.

However, it is recommended to purchase just for the small south east part of the lagoon up-to-date, very high resolution image data (15 cm) to create the base layer “roofs”. In the following years free image data can be utilised to document of a roof disappears or new roofs have been created.

23 Text and map from Wikipedia. https://en.wikipedia.org/wiki/Satawan

Figure 4.2.1-03: *Houses near the airstrip. The image data was recorded on 14*

The survey recorded very detailed information about the infrastructure elements in Satawan. Figure 4.2.1-04 just demonstrated that the surveyed elements can be easily imported to a datbase and that they have X and Y coordinates enabling the establishment of a corresponding GIS layer as demonstrated in chapter 3.3 “Water Supply in Kapingamarangi”.



Satawan Infrastructure

Water Infrastructure: 31

All Surveyed Elements: 44

ID	Long	Lat	Element	Owner
80	153.733301	5.331286	Water Storage	Private
81	153.735041	5.331249	Buildings	Municipal office
82	153.734808	5.331601	Water Storage	Private
83	153.734761	5.332518	Water Storage	Private
84	153.734691	5.33386	Water Storage	Private
85	153.734608	5.334282	Water Storage	Private
86	153.734714	5.334431	Water Storage	Private
87	153.73464	5.334751	Water Storage	Private
88	153.734775	5.335027	Water Storage	Private
89	153.734952	5.335425	Water Storage	Private

Navigation Pane

Record: 36 of 44 No Filter Search

Form View

Figure 4.2.1-04: *Database display of surveyed infrastructure elements.*

5 PACC Coastal Protection Project

Figure 5-01: *Location Kosrae*

The PACC project was running from 2009 to 2014. The project focused on climate proofing the coastal road design in Kosrae to withstand torrential rain, surface water run-off and/or storm waves[24].

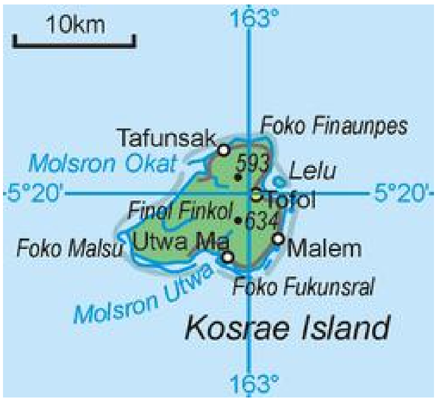


Figure 5-02: *Topographic map of Kosrae showing the coordinates*

Kosrae is an island state in the Federated States of Micronesia. The State of Kosrae is one of the four states of the Federated States of Micronesia, and includes the main island of Kosrae and a few nearby islands and islets. Kosrae's land area is 110 square kilometres, sustaining 6,600 people. Tofol is the state capital, and Mt. Finkol is the highest point at 634 metres[25].

The main road is a tar-sealed link between the airport in the north to Ute Harbour in the south. This road following the coastline and has to be protected from storm waves on one side and water coming down during heavy rainfall the steep slope on the other side.

Figure 5-03: *Thematic map of Kosrae showing the main road following the coast from the airport in the north to Utwe Harbour in the south*

24 Project document
25 Wikipedia

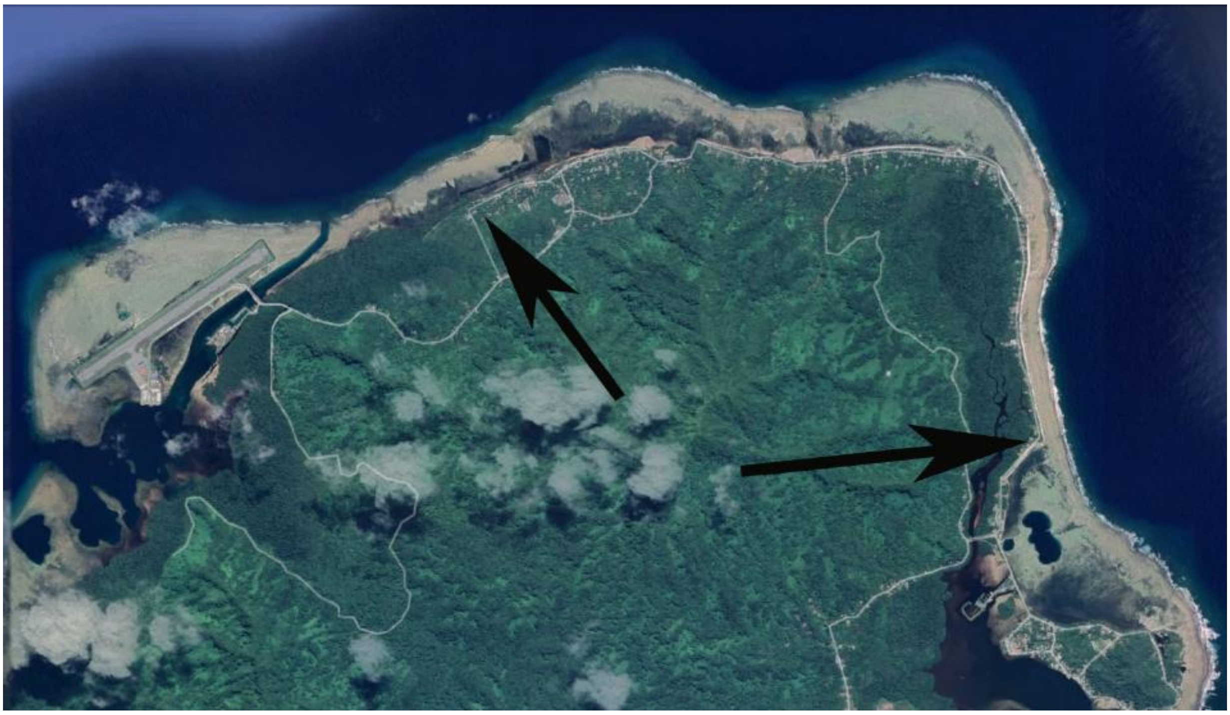


Figure 5-04: *WorldView image data from 18-July-2020 plus Google Earth road layer. Between the two arrows is the part of the road which needs protection.*

Figure 5-04 shows satellite image data (most probably WorldView data) recorded on 18th July 2020. There is no protection visible in the image data as the detailed information is missing which protection was implemented. It is recommended to carry out a GPS survey recording the location and length of the seawalls or other protection measures.