Soil sampling guidelines

Strengthening regional collaboration on soil analysis

Pacific Community
Communauté du Pacifique

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CSIRO

Australian Centre for International Agricultural Research

Australian Aid

USP
THE UNIVERSITY OF THE SOUTH PACIFIC

1. INTRODUCTION

Careful soil sampling is critical for accurate soil analyses and reliable nutrient requirement recommendations. Site-specific analysis results can reduce over usage of in-organic fertiliser requirements, reduce the cost of production and safeguard the environment. Analysis can also guide where additional use of inorganic fertilisers are needed to improve crop production and return on investment. Soil test results are of little value unless the samples submitted for testing represent the field, plantation, or area under study and capture the inherent variability exhibited across a defined region. The following are examples of unsuitable soil samples:

- Taking many soil samples carelessly from one or two pits in a field.
- Keeping the samples in a moist state for several days or even weeks before sending to laboratory for analysis.
- Sending soil samples to the laboratory in rusty cans or even old fertiliser bags.
- Packing inappropriately without proper labeling.

If soil samples are not collected properly, one cannot expect the soil test results to provide accurate information about the nutrient or mineral status of the soil. The analysis can only be as good as the sample.

One or two kilograms (kg) of soil collected from a field represents **only about a one to two millionth part of a hectare, i.e., 0.0001– 0.0002%.** Of the collected soil samples, only a few grams (0.1–10 grams) are used in the actual testing, depending on test parameters. It is therefore essential that the sample is carefully collected in the field to avoid contamination and that it also represents the study area. Unusual areas of the field, such as near buildings, gates, field margins, roads, pathways, cow manure pads, recently fertilised areas, stony areas, wet areas, etc should also be avoided. The following points should be considered before taking a soil sample, and if the sample is to be sent overseas for laboratory analysis:

1. Field area (square metre)

2. Sampling depth

3. When to sample

4. Sampling procedure

5. Handling

6. Information form

7. Biosecurity/quarantine import permit and compliance protocol

8. Location of South Pacific Agricultural Chemistry Laboratory Network (SPACNET) affiliated laboratories for soil analysis and other services.

2. FIELD SAMPLING

Prior to field sampling it is critical to identify different soil types, landuse and land units in the sampling location (see Figure 1). This can be done using the Pacific Soil Portal, remote sensed datasets and discussions with local extension officers and the landholder. Once the sampling units are identified the field sampling plan needs to be determined. Sampling can be either be a simple random (design-based/probabilistic) (Figure 2A), stratified random (design-based/probabilistic) (Figure 2B) or systematic random sample (model-based/non-probabilistic) (Figure 3). The soil is very large and variable, it is often not physically or economically possible to measure all of it. Further, soil properties inherently exhibited high spatial variability across the landscape scale. Typically for each land unit a number of samples are required to adequately capture the population mean and variance. If analysis cost is an issue composite soil sample can be collected which represents as closely as possible the average character of the whole land unit. As a general rule, one composite soil sample per 0.5 hectare (5,000 square meters) land unit is ideal, if the whole area is relatively uniform.

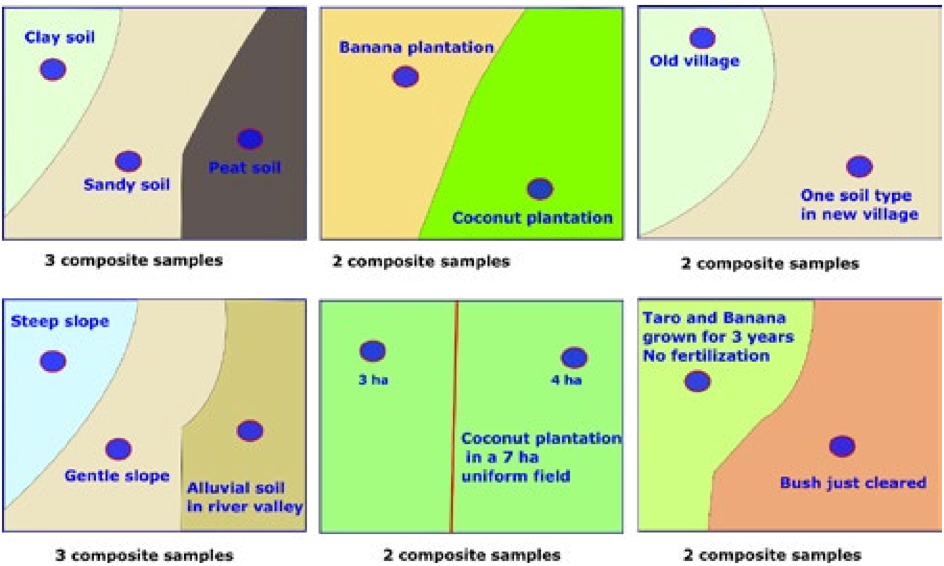


Figure 1. Different land units

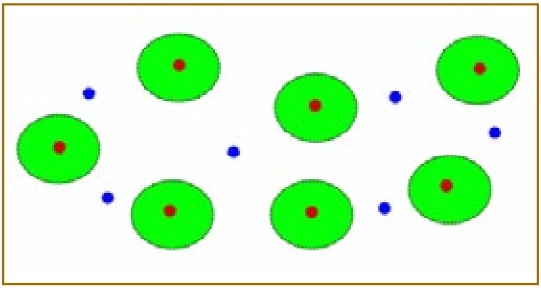


Figure 2A). Random sampling within plant canopies (green circle) and between plant canopies.

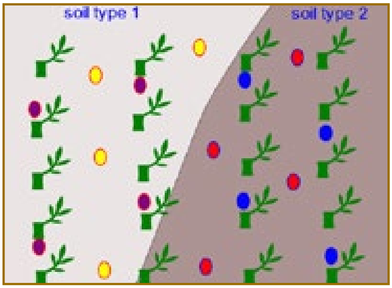
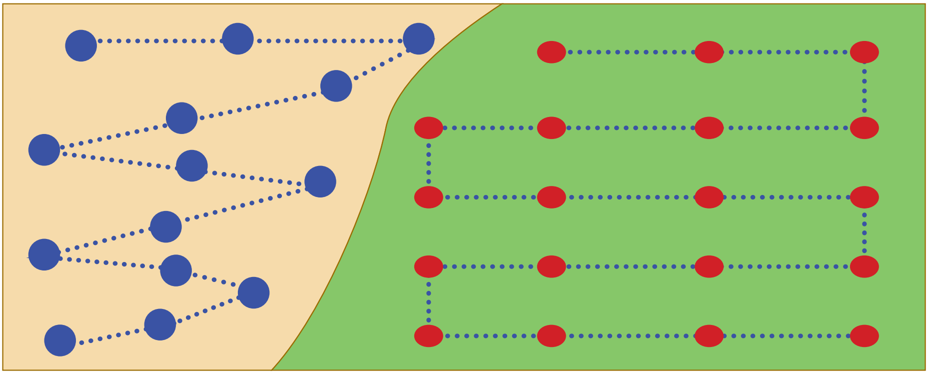


Figure 2B). Stratified random sampling for measured difference in plant-line and interrow for two different soil types.



Zigzag sampling

Grid sampling

Figure 3. Systematic soil sampling: zigzag and grid sampling layout in an uncropped area

2.1 Sampling depth

The depth of soil sampling varies with the sampling objective as well as the types of crops that will be grown in the sampling area. Generally, soil samples are taken from surface soil for assessing fertility and from each soil horizon for studying profile/taxonomy for soil characterisation. Surface soil depth also varies based on the crop that will be cultivated. Assessing soil fertility for field crops that have a fibrous root system, such as rice, maize, etc., requires samples that are taken from 0-15 cm soil depth. However, for root crops such as taro and sweet potato, or plantation crops like cocoa, coconut or fruit trees, orchard samples need to be collected from a greater depth based on the root system of the crop type. Soil sampling depths for commonly grown crops in Pacific Island countries are provided below in Table 1. In a regularly sampled monitored field it is recommended that the nutrient and total carbon status of the whole profile (0-90 cm) be analysed every five years.

Table 1.Soil sampling depth for commonly grown Pacific Island crops

Crops	Depth (cm)
Taro	Sample 0–15, 15–30
Sweet potato	
Cassava	
Yam	
Sugarcane	
Banana	
Bean	Sample 0–15
Cucumber	
Okra/lady finger	
Eggplant/brinjal	
Tomato	
Rice	
Maize	
Watermelon	
Peanut/groundnut	
Perennial crops, plantations and orchard crops	Sampling from 3 depths 0–30, 30–60 and 60–90

2.2 When to sample

It is recommended that soil samples are collected when it is not raining. In general, soil samples should be taken for a soil fertility assessment before planting a crop or applying fertiliser. Thus, fertiliser doses can be determined and applied accordingly based on the soil test results. Usually, fields are sampled every year to assess the fertiliser requirement and every five years they should be sampled to depth (90cm). A monitoring programme such as this can provide data on soil fertility changes. However, soil samples can be taken as the need arises. For example, if it is observed that a perennial crop or a fruit orchard is not performing well and suffering from some nutrient deficiencies, then soil samples can be taken with standing crops.

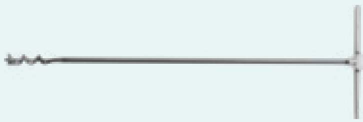
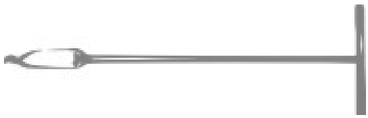
3. SAMPLING PROCEDURES

The colour, texture, structure, and likely physical, chemical, and biological properties of soil, change from place to place. In a field, two spots 15 cm apart might have very different soil properties. Therefore, if a soil sample is taken from only one spot, test results might be non-representative and unusable. However, soil samples (sub-samples) should be taken from various parts of a field or plantation as previously shown in Figures 2 and 3. Step-by-step soil sampling procedures are described below for collecting a composite sample for a single land unit.

3.1 Step 1: Collection of equipment and stationery

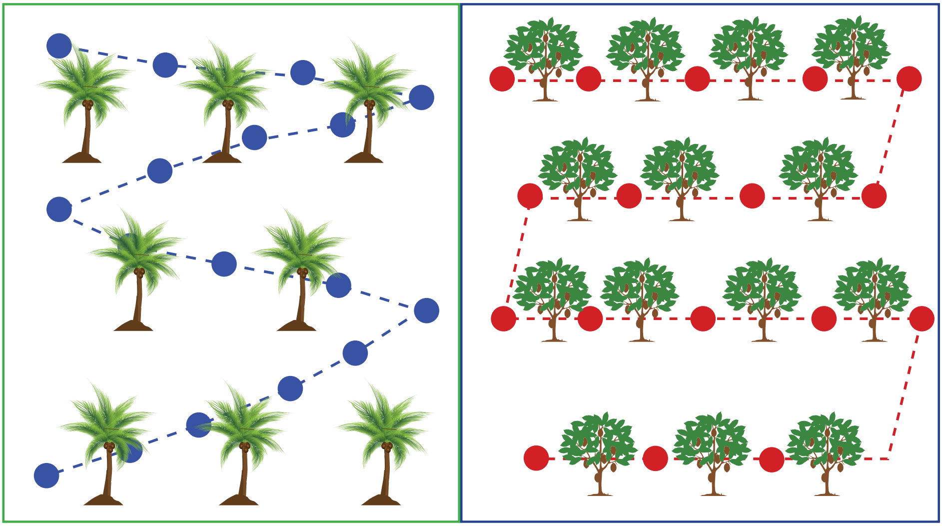
Sampling tools may include a spade, screw auger, tube auger or trowel as shown in Table 2, and a GPS-enabled smart phone or handheld GPS unit. A trowel and spade used together work when an auger is not available. A plastic bucket is used for collecting and mixing the samples, or the samples may be put into plastic or polythene bags. Whatever equipment is used, it must be adequately cleaned between samples to prevent cross-contamination.

Table 2. Soil sampling tools

Tool name	Use	Figure
Bucket auger/ standard auger/ tube auger	Useful for sampling common soils, e.g., loam soil.	
Screw auger/ spiral auger	Useful for sampling gravelly soil.	
Clay auger	Useful for sampling clay or wet soil but can be used for other soil types too.	
Spade	Used for soil sampling when auger is not available. It can be used for making a 'V' shaped soil cut.	
Trowel	Used for soil sampling along with a spade when an auger is not available. Used for collecting a uniform slice of soil from a 'V' shaped soil cut.	

3.2 Step 2: Determination of sub-sampling spots

First, decide the number of composite samples that need to be collected from the identified land unit as shown in Figure 1. A composite sample must include 10-20 sub-samples. Leave 1-1.5 m distance along the boundaries of the sampling field and determine 10-20 sampling spots for collecting sub-samples to get a composite sample from a uniform area as shown in Figure 4. Generally, the distance between two sub-sampling spots varies from between 10-20 walking steps (one walking step equals 70-80 cm) based on the size of the field. Sub-samples can be collected by following a zig-zag pattern or layout or grid layout pattern as shown in Figure 4 below.



Coconut Plantation *Cocoa Plantation*

Figure 4. Zig zag (left) and grid sampling (right) layout in a cropped area

3.3 Step 3: Collection of sub-samples

First, clear away any surface litter. If an auger is available for collecting the sub-samples, insert the auger slowly down into the hole a number of times until the pre-determined soil depth is reached. After each auger insertion, pull it out gently with soil and put the soil in a bucket or plastic bag. Most augers will collect soil to about 10 cm depth only. Therefore, for example, to collect a soil sample at 30 cm depth, insert the auger then extract it and remove the soil. Put the auger back into same hole for the next 10 cm, and so on until 30cm is reached (Figure 5).

If an auger is not available, a spade and trowel can be used. First dig a 'V' shaped hole up to the pre-determined depth as shown in Figure 6 (1). Take a slice of soil of approximately 5-7 cm uniform thickness from one side of the hole covering the entire depth as shown in Figure 6 (2). Size the sub-samples by discarding excess soil from both sides of the slice and put the soil slice in the bucket or plastic bag. Collect sub-samples from all the pre-determined spots in the same way. Record the GPS coordinates of locations where each sample is collected. This information is useful for tracking the locations of samples, or it can be helpful if there is a need to return to the same sampling locations in subsequent sampling occasions.

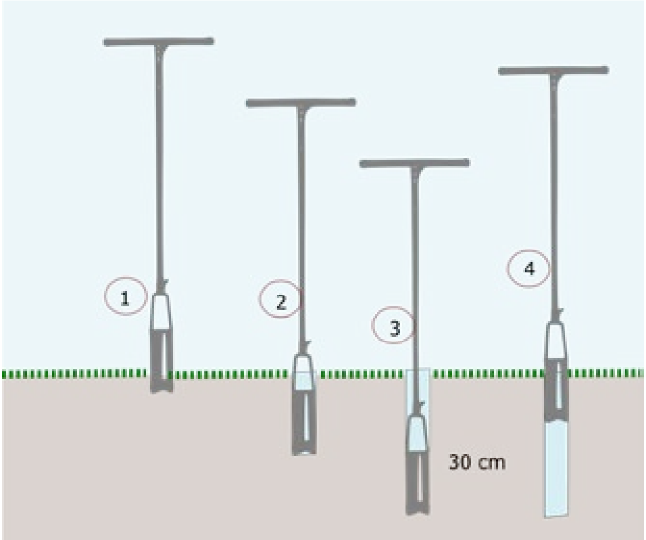


Figure 5. Soil sampling using an auger (1, 2 and 3: show inserting auger into the soil a number of times into the same hole to collect soil; 4: pulling out auger with soil at the pre-determined depth)

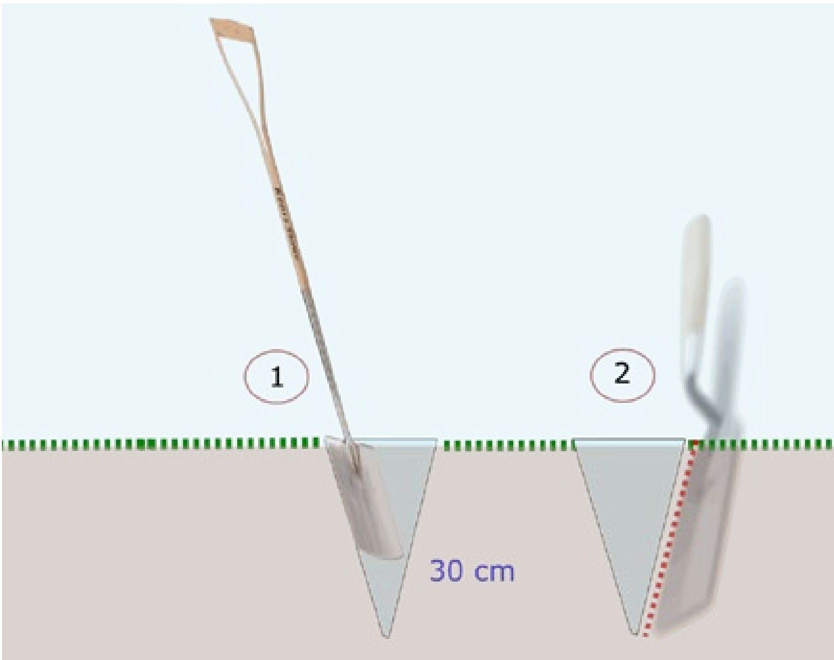


Figure 6. Soil sampling using a spade and trowel (1: making a 'V' shaped hole by a spade; 2: collecting a uniform soil slice from one side of the 'V' shaped hole by a trowel)

3.4 Step 4: Mixing sub-samples for compositing and discarding additional soil volume

All sub-samples should be mixed thoroughly for making a composite sample for a uniform field as shown in Figure 7. The samples should be free from stubble, stones, grass, rubbish, plant roots and stems, etc. before mixing. In most cases, 15–20 sub-samples make up approximately 3–5 kg soil. However, only about 400–500 grams of soil is needed for a routine soil fertility analysis. Therefore, additional collected soil samples should be discarded. For discarding, divide the mixed composite sample into four components on a plastic sheet or brown paper as shown in Figure 8. Discard any two components from the opposite corners (shown as a red X in Figure 8) and mix the remaining two components again. Continue this process until the volume of soil reaches the expected amount.

If soil samples are collected from different soil horizons or depths, it is recommended not to composite the samples. In this case, soil samples should be kept separate and labelled accordingly based on the horizons or depths.

Figure 7. Mixing sub-samples by hand to make a composite sample

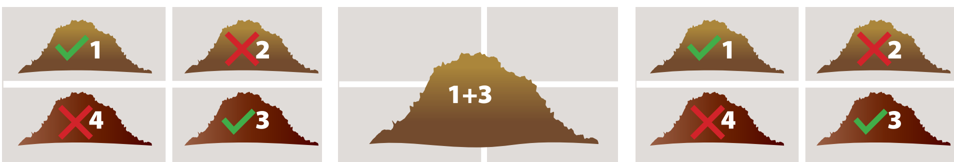


Figure 8. Discarding additional soil volume (left picture: dividing into 4 components and discarding component 2 and 4, middle: mixing again component 1 and 3; right: repeat the process by dividing again into 4 components and discarding component 2 and 4)

4. BULK DENSITY

Bulk density is an indicator of soil compaction and soil health. It is a measure of soil weight in a given volume, so it provides useful conversions of units such as percentage of soil (e.g. % organic carbon) or weight per unit soil (e.g. nitrogen, mg/kg) to an area basis unit. Results from bulk density testing will provide easy to understand indication of the carbon storage or nutritional status of the soil in a given area. Measurement of bulk density should be done in the topsoil at various depths between 20–40 cm and sampling is best done when the soil is moist. The coring method is commonly used but light sandy or organic soils cannot be sampled using this method, therefore, the pit extraction method can be used.

4.1 Materials

- Cylindrical steel/core cutter ring (size 75 mm long x 75 mm) with internal thickness of 3 mm
- Mallet or sledge hammer
- Wood block
- Garden trowel
- Flat-bladed knife
- Ziplock (plastic) bags
- Brown paper bags
- Marker pen
- 30 ml measuring scoop
- Scale (0.1 precision)
- Access to drying oven at 105°C

4.2 Procedure for soil sample collection

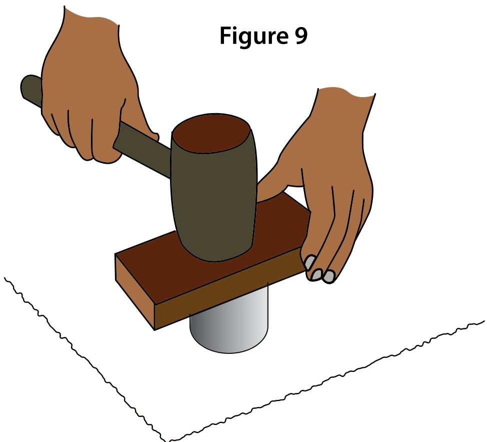
1. Determine the actual height of the cylindrical ring above ground before taking soil samples. This is to determine the exact depth for accurate measurement of soil volume.

2. Drive the ring into the soil using a sledge hammer and block of wood over the ring (Figure 9).

3. Remove the ring from the ground by digging around and underneath it, carefully lift the ring out to stop any loss of soil.

4. Remove excess soil from the sample at the ends of the core with a flat blade knife. The bottom of the soil sample should be flat and even with edge of the ring (Figure 10).

Figure 9



5. Reject core samples that are not completely filled with soil. If the soil core is satisfactory, proceed with the next step.

6. Remove the soil sample from the ring using a flat blade knife to push out the sample into a plastic bag. Make sure the whole sample is placed in the plastic bag. Seal and label the bag.

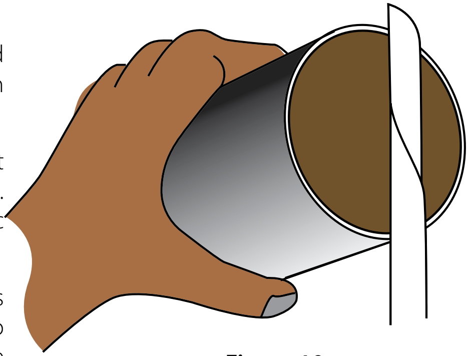


Figure 10.

7. Weigh the soil sample in its bag. (If the sample is too heavy for the scale, transfer half of the sample into a second plastic bag. The weights of the two sample plastic bags must be added together). Record the weight of soil sample and plastic bag. Weigh and identical clean empty bag to account for the weight of the bag. Record the weight (sum of two bags, if applicable).

8. Transfer each soil sample into a brown paper bag then label the bag with sample details and dry to constant weight at 105°C in an oven. Drying may take several days.

9. Weigh the dry soil with the paper bag and record the weight (W1), then weigh an identical clean, empty paper bag separately to account for the weight of the bag and record the weight (W2).

10. To calculate the weight of dry soil, minus the weight of the paper bag from the weight of the dry soil and paper bag: (W1-W2 = weight of dry soil).

11. Calculate the internal volume of the core cutter, in cubic centimetres from its dimensions measured to the nearest 0.5 mm.

4.3 Calculation of bulk density

$$\text{Bulk density (g/cm}^3) = \frac{\text{Weight of dry soil (g)}}{\text{Volume of soil core (cm}^3)^*}$$

*Volume of soil core (cm^3) = $\pi \times r^2 \times$ height

$\pi = 3.14$,

r = radius (radius of inside of ring)

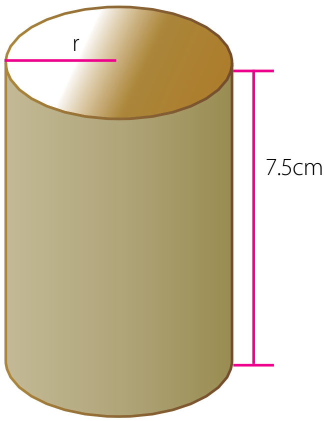


Figure 11. Soil core dimensions showing the radius and height to use in soil volume calculation

5. HANDLING SOIL SAMPLES

Some laboratories do not allow fresh samples due to biosecurity requirements, or to reduce the risk of soil property alteration during collection of biosecurity permits and sample transportation to a laboratory in another island country. If the laboratory is in the same island country and it is possible to submit the soil samples within 1-3 days, fresh samples can be sent. Generally, the chemical and biological properties of fresh samples become altered very quickly compared to dry samples if they are not stored at a low temperature (4°C). In consideration of this, sending air-dried samples to Pacific Island country laboratories is recommended, particularly for countries that do not have their own soil laboratory. Samples should be air-dried in a shady place by spreading on a brown paper or plastic sheet as shown in Figure 12. The drying room should be cleaned and kept dust free to avoid contamination. One composite sample requires approximately 0.5-1 m^2 area for drying. Avoiding sun drying is strongly recommended as it alters chemical properties of the soil. Dried samples should be pulverized with a wooden hammer or a piece of clean hard dried wood (not metal to avoid contamination). Fresh or dried and pulverized soil samples should be placed in a plastic or polythene bag, zip locked or closed tightly with a thread and placed inside another plastic bag before sending to the laboratory. A one-gallon size or (25.4 cm x 25.4 cm or 25.4 cm x 30.5 cm) Ziploc freezer bag is preferable, but any other type of clean plastic bag may be used.

6. LABELLING SOIL SAMPLES

An information sheet (tag) should be placed between the two plastic bags. An additional information sheet should be tied at the neck (where the bag is tied with thread) of the outside bag. This information has considerable value in interpreting test results. The sheet should contain the following information:

1. Site location (field number or plot number, village name, any specific identification marks (e.g., 100 m north from Robert Louis school) including farmer's name
2. Geolocation (GPS coordinates recorded as latitude and longitude)
3. Date of sampling
4. Depth of sampling
5. Previous crop and crop to be cultivated
6. Drainage characteristics (e.g., well drained, poorly drained, etc.)
7. Soil type or field texture (e.g., sandy soil, clay soil, loam soil, etc.)
8. Past fertiliser use (if any)
9. Previous soil test results (if any)
10. Nutrient deficiency and disease symptoms (if identified)

Figure 12. Drying, bagging, and tagging a soil sample

7. BIOSECURITY/QUARANTINE COMPLIANCE

When sending soil samples to a registered soil laboratory in another country for analysis, the following biosecurity/quarantine compliance protocols must be observed:

1. Apply and obtain a biosecurity/quarantine import permit from the biosecurity authority to send soil samples to the registered laboratory in that country
2. Dry soil samples properly before packing in sample bags
3. Label soil samples properly and pack them in double Ziploc bags to avoid spillage and contamination
4. Ensure a copy of the import permit in clear plastic is placed in the carton of soil samples. Also paste a copy of the import permit on the side of the carton or in the document pouch attached to the carton
5. Pack all the soil samples in the carton and label it properly. State the following information given in the example below:

- **1 carton said to contain**: 8 packages soil samples for research purposes/soil analysis.
  Overall weight: 8kg

- **Sender**: Ministry of Agriculture-Niue
  Name: Mr. Niue
  Contact: Email: ……………..…. Phone: …………………

- **Receive**r: The University of the South Pacific Agricultural Chemistry Laboratory.
  Name: Dr. USP
  Contact: Email: ……..……………Phone: …..……..…..……..

- Biosecurity Authority of Fiji **Import Permit** attached: …………….

8. SUMMARY OF IMPORTANT POINTS

1. Number the areas and label the plastic bags accordingly before starting to collect the soil.

2. Avoid unusual areas, such as near buildings, gates, field margins, roads, pathways, cow manure pads, recently fertilised areas, stony areas, wet areas, etc.

3. Take a composite sample from each (if more than one) of your identified areas (Figure 1). This is done by walking over each area at random and collecting approximately 20 soil sub-samples. Within each sampling area, each leg of the sampling walk should be of a similar length, but as the size of the area increases, so does the length of leg. The sub-samples are mixed together in a plastic bucket.

4. At each sampling point, scrape away the surface litter (if any) before inserting the auger, trowel or spade into the soil. Take only a small sample at each point, but always take a sample of about the same size. After collecting the sub-samples, and mixing each composite sample, clean out the bucket and clean the implements, so as not to contaminate the subsequent samples.

5. Do not delay bringing the sample to the laboratory if it is not dried. If wet soil is left unattended for two or more days, chemical changes will begin to take place in the sample, which may modify its characteristics.

ANNEX 1. CERTIFIED SOIL LABORATORIES

The South Pacific Agricultural Chemistry Laboratory Network (SPACNET) comprises several laboratories in the region as follows:

- Three in Fiji (Institute of Applied Sciences, USP – Laucala Campus; Sugar Research Institute of Fiji; Fiji Agricultural Chemistry Laboratory, Koronivia, Ministry of Agriculture),
- Two in PNG (National Agriculture Research Institute, Boroko; PNG University of Technology (UNITECH), Lae,
- Analytical Laboratory, Minister of Agriculture, Food and Forests, in Tonga,
- Analytical Laboratory, Alafua College, USP, Samoa,
- Institute of Research for Development (IRD), New Caledonia,
- The Solomon Islands Ministry of Agriculture analytical laboratory at Dodo Creek was an inaugural SPACNET member but the laboratory was destroyed during civil unrest in 2001. A new lab is due to be opened at another location in the future.
- The Analytical Laboratory, Manaaki Whenua Landcare Research, Palmerston North, is the SPACNET coordinating laboratory.

Soil sample shipping routes are provided in Figure 13 and information on laboratory/country names, staff in charge and contact details are presented in Table 3. More information on SPACNET and certified laboratories can be found at: https://www.aspac-australasia.com/certified-labs.

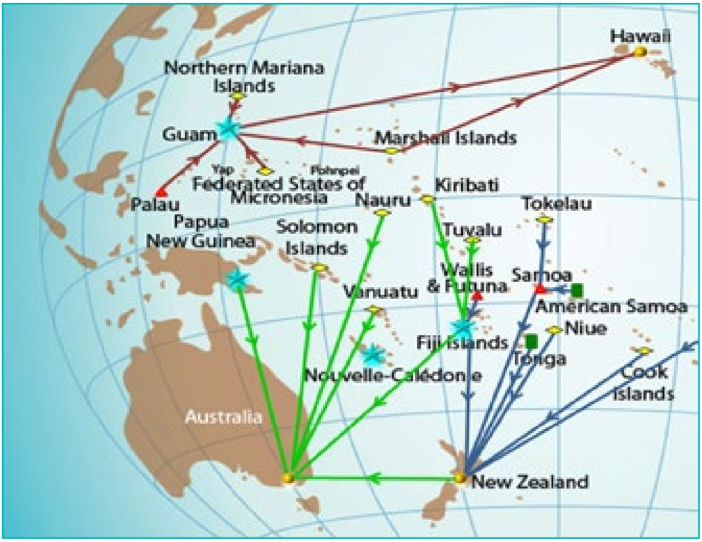


Figure 13. Soil samples shipping routes

Table 3. Laboratory name/country, analytes and contact details

Laboratory name & country	Analytes	Contact and address±
CSIRO Analytical Chemistry Group	Soil, plant, water	CSIRO Analytical Chemistry Group, Building 101, Clunies Ross Street, Black Mountain, ACT 2601, Australia
MWLR Analytical Laboratory, NZ	Soil, plant	Ngaire Foster, Laboratory Manager, Soils & Landscapes, Manaaki Whenua Landcare Research, Palmerston North, New Zealand
Fiji Agricultural Chemistry Lab, Suva, Fiji	Soil, plant	Mr. Ami Sharma, Principal Research Officer, Koronivia Research Station, PO Box 77, Kings Highway, Nausori,Fiji Phone: +679 347 7044 Email: ami.sharma@govnet.gov.fj
Fiji National University College of Agriculture, Forestry and Fisheries; Koronivia, Suva, Fiji	Soil, plant	Dr Deeksha Krishna, Soil Scientist, FNU, CAFF, Koronivia, Suva, Fiji Islands, (679) 347 9200 Ext: 5001. (679) 340 0275 Deeksha.krishna@fnu.ac.fj
Institute of Research for Development (IRD), Noumea, New Caledonia	Soil, plant, water	Leocadie Jamet Laboratoire des Moyens Analytiques Noumea Leocadie.jamet@ird.fr
MAFF –Vaini Research Station, Nukualofa, Tonga	Soil, plant	Mr. Vunivesi Minoneti, Soil Scientist, Vaini Research Station, MAFF, Tonga, Hala Vuna, Queen Salote Wharf, Nuku'aloa Address: P.O.Box 14 Nuku'alofa, Tonga. Phone: +676 23038. Fax: +676 27401 Email: minonetivesi@gmail.com
National Chemistry Analysis Laboratory, Kila Kila, PNG	Soil, plant	The Laboratory Manager, National Chemistry Analysis Laboratory. PO Box 8277, BOROKO NCD, PNG; Landline: (675) 3212690 / 3202345 / 3201516. Mobile: (675) 70569862 / 75792487. Fax: (675) 3202411 Email: narichemistry@nari.org.pg Email: Morris.oromu@nari.org.pg Email: Janet.lipai@nari.org.pg
Scientific Research Organisation of Samoa (SROS), Apia, Samoa	Food, nutrients, soil, plant	Dr Seuseu Tauati, CEO, SROS P.O. Box 6597, Nafanua, Apia, Samoa. Ph:(+685) 20664 or (+685) 20352. Email: seuseu@srosmanagement.org.ws
Sugar Research Institute of Fiji (SRIF), Lautoka, Fiji	Soil, plant	SRIF, Drasa Rd., 679 Lautoka, Fiji Email: info@srif.org.fj
PNG UNITECH	Soil, biological tissue, plant, feed, water	Ngayamo Antonio, Executive Secretary, ngyamo.antonio@pnguot.ac.pg
USP-IAS, Chemistry Lab, Laucala Campus, USP, Fiji	Food, feed, nutrients, water	Dr. Vincent Lal, Manager, Laboratory Services, Faculty of Science and Technology, Private Bag, Laucala Campus, Suva, Fiji. Contact: +679 323 2976 Email: vincent.lal@usp.ac.fj
USP -SAFT, Alafua, Apia, Samoa	Soil, plant	Dr. Md. Abdul Kader, Senior Soil Science Lecturer, USP-SAFT. Samoa Campus, Private Bag, Apia, Samoa. Tel: (685) 21671. Fax: (685) 23424 Email: mdabdul.kader@usp.ac.fj
Solomon Islands, Ministry of Agriculture and Livestock, Honiara, Slolomons	N/A	Mr Jules Damutalau Email: Jules.Damutalau@sig.gov.sb

University of Guam	Soil, plant	Prof. Dr Mohammed Golabi Email: mgolabi@triton.uog.edu
Land Resources Division, SPC, Suva, Fiji	Pests and disease diagnostics	FeretiA@spc.int, EllenI@spc.int, SPC-LRD, Narere Campus, Suva
Agricultural Diagnostic Service Center (ADSC)	Soil, plant	adsc@ctahr.hawaii.edu; Sherman Laboratory 134 , Honolulu, Hawaii 96822

Source: *https://www.aspac-australasia.com/certified-lab and others* ±Information may need to be updated.

ANNEX 2. REFERENCES

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