

Nutrient balance

ACIAR Project SMCN-2016-111: Soil management in Pacific Islands

Objective 2: Nutrient Cycling, Soil Fertility Management, Crop Productivity

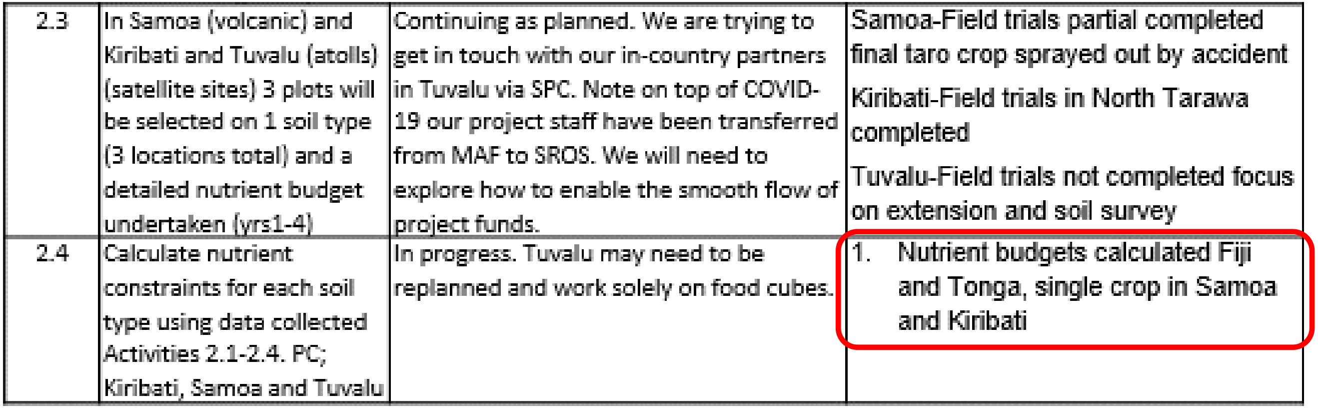
Dr Diogenes L. Antille | 16 November 2021

Australian Centre
for International
Agricultural Research

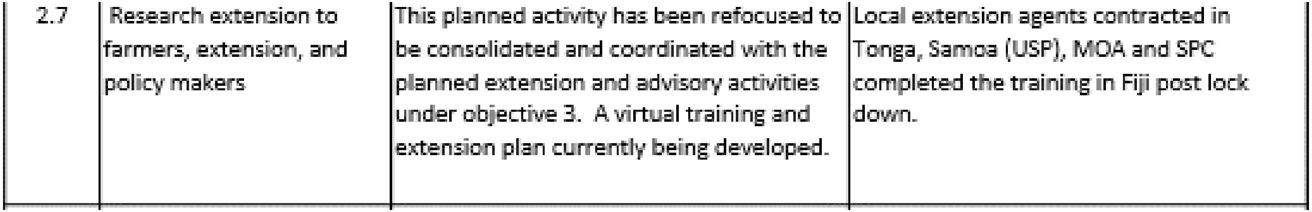
CSIRO

Australia's National Science Agency

Objective 2

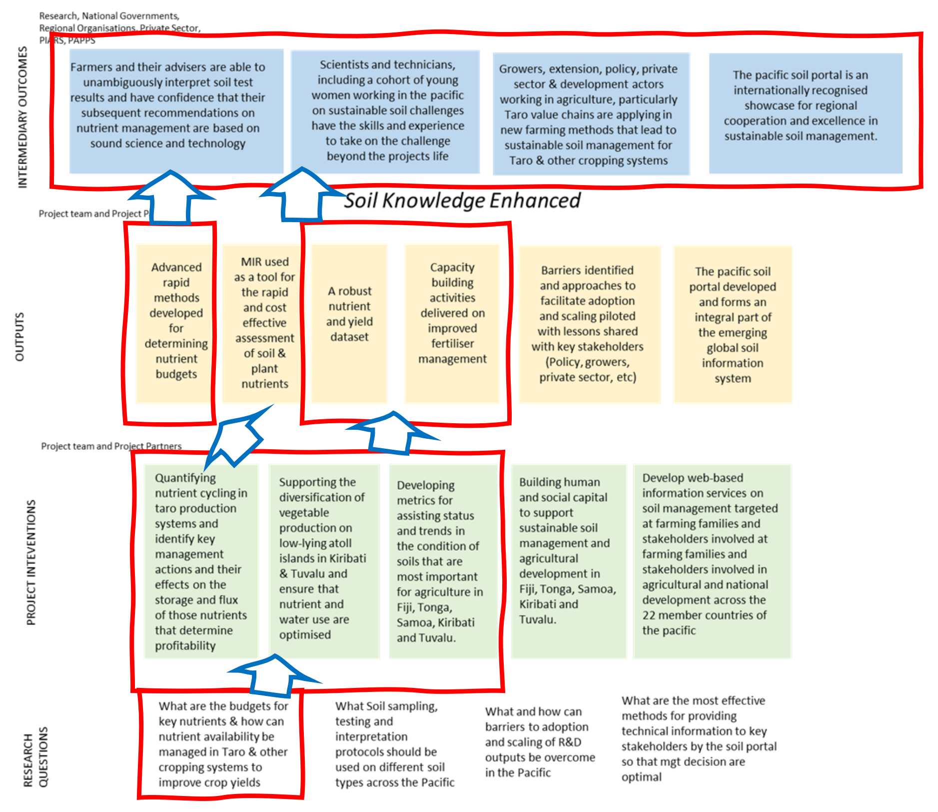


2.3	In Samoa (volcanic) and Kiribati and Tuvalu (atolls) (satellite sites) 3 plots will be selected on 1 soil type (3 locations total) and a detailed nutrient budget undertaken (yrs1-4)	Continuing as planned. We are trying to get in touch with our in-country partners in Tuvalu via SPC. Note on top of COVID-19 our project staff have been transferred from MAF to SROS. We will need to explore how to enable the smooth flow of project funds.	Samoa-Field trials partial completed final taro crop sprayed out by accident Kiribati-Field trials in North Tarawa completed Tuvalu-Field trials not completed focus on extension and soil survey
2.4	Calculate nutrient constraints for each soil type using data collected Activities 2.1-2.4. PC; Kiribati, Samoa and Tuvalu	In progress. Tuvalu may need to be replanned and work solely on food cubes.	1. Nutrient budgets calculated Fiji and Tonga, single crop in Samoa and Kiribati



2.7	Research extension to farmers, extension, and policy makers	This planned activity has been refocused to be consolidated and coordinated with the planned extension and advisory activities under objective 3. A virtual training and extension plan currently being developed.	Local extension agents contracted in Tonga, Samoa (USP), MOA and SPC completed the training in Fiji post lock down.

Objective 2 Impact Pathway



INTERMEDIARY OUTCOMES

Research, National Governments, Regional Organisations, Private Sector, PIARS, PAPPS

- Farmers and their advisers are able to unambiguously interpret soil test results and have confidence that their subsequent recommendations on nutrient management are based on sound science and technology
- Scientists and technicians, including a cohort of young women working in the pacific on sustainable soil challenges have the skills and experience to take on the challenge beyond the projects life
- Growers, extension, policy, private sector & development actors working in agriculture, particularly Taro value chains are applying in new farming methods that lead to sustainable soil management for Taro & other cropping systems
- The pacific soil portal is an internationally recognised showcase for regional cooperation and excellence in sustainable soil management.

Soil Knowledge Enhanced

OUTPUTS

Project team and Project P

- Advanced rapid methods developed for determining nutrient budgets
- MIR used as a tool for the rapid and cost effective assessment of soil & plant nutrients
- A robust nutrient and yield dataset
- Capacity building activities delivered on improved fertiliser management
- Barriers identified and approaches to facilitate adoption and scaling piloted with lessons shared with key stakeholders (Policy, growers, private sector, etc)
- The pacific soil portal developed and forms an integral part of the emerging global soil information system

PROJECT INTEVENTIONS

Project team and Project Partners

- Quantifying nutrient cycling in taro production systems and identify key management actions and their effects on the storage and flux of those nutrients that determine profitability
- Supporting the diversification of vegetable production on low-lying atoll islands in Kiribati & Tuvalu and ensure that nutrient and water use are optimised
- Developing metrics for assisting status and trends in the condition of soils that are most important for agriculture in Fiji, Tonga, Samoa, Kiribati and Tuvalu.
- Building human and social capital to support sustainable soil management and agricultural development in Fiji, Tonga, Samoa, Kiribati and Tuvalu.
- Develop web-based information services on soil management targeted at farming families and stakeholders involved at farming families and stakeholders involved in agricultural and national development across the 22 member countries of the pacific

RESEARCH QUESTIONS

- What are the budgets for key nutrients & how can nutrient availability be managed in Taro & other cropping systems to improve crop yields
- What Soil sampling, testing and interpretation protocols should be used on different soil types across the Pacific
- What and how can barriers to adoption and scaling of R&D outputs be overcome in the Pacific
- What are the most effective methods for providing technical information to key stakeholders by the soil portal so that mgt decision are optimal

Field trials and extension activities were used by the project to enable interventions and provide outputs to increase soil knowledge

Experimental sites

13°49.829’S, 171°50.193’W
elevation: 71-m ASL

14°00.432’S, 171°39.492’W
elevation: 181-m ASL

Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Data LDEO-Columbia, NSF, NOAA
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- **Nu’u 1:** from Aug 2018 to March 2019 (harvested)
- **Faleãlili:** from Sept 2018 to May 2019 (harvested)
- **Nu’u 2:** from Dec 2020 to July 2021 (harvested)
- **Nu’u 1:** from Feb 2021 to May 2021 (sprayed-off)

Experimental sites

- **First set of trials at Nu'u 1 and Faleãlili:**

  Legumes as source of N
  - *Mucuna pruriens* L. (DC) [Velvet bean]
  - *Erythrina subumbrans* Hassk. (Merr.)
  - Controls no-legumes
- **Second set of trials at Nu'u 2:**
  - Source: NPK+S fertiliser (12:8:15+3) vs Compost (75% poultry manure 11:5:8+5, 60% DM, w/w)
  - Rate: 50 g amendment per plant at planting
  - Placement: surface and incorporated
  - Controls (zero-amendment)
- **Planned but discontinued experimental work:**
  - Double-cropping taro/taro at Nu'u 1 (established Feb 2021 as planned, discontinued from May 2021)
  - Demonstration site at Tanumalala (activity not supported by SROS)
- **Taro variety:** Samoa 2 (all sites and years)

Nu'u Station

Faleãlili Farm

Tanumalala Farm

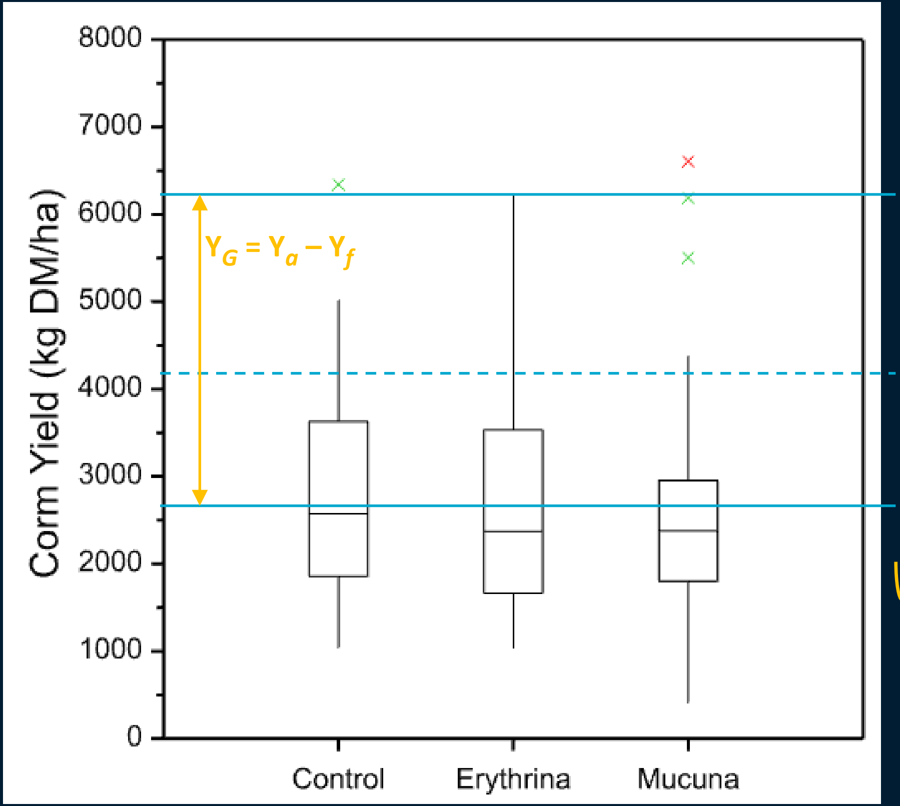
Baseline soil characterisation

Determination	Unit	Nu'u 1	Nu'u 2	Faleãlili	Analytical method
Sand (>20 µm)	% (w/w)	27.6	25.2	25.3	
Silt (2-20 µm)	% (w/w)	42.3	43.4	52.0	Bouyoucos (1962)
Clay (<2 µm)	% (w/w)	30.1	31.4	22.7	
Textural class	-	Clay loam	Clay loam	Silt loam	Australian Soil Texture Triangle
Soil bulk density	g cm^{-3}	0.886	-	0.916	Blake and Hartge (1986)
Cumulative infiltration	mm	$F_t = 363.3t^{0.68}$	-	-	Parr and Bertrand (1960)
Infiltration rate	mm	$I_R = 204.28t^{-0.35}$	-	-	Parr and Bertrand (1960)
Soil $pH_{1:5}$ (soil/water)	-	5.62 ± 0.56	6.60	4.50	Rayment and Lyons (2011)
$EC_{1:5}$ of soil (soil/water)	µS cm^{-1}	2.92 ± 0.60	-	-	Rayment and Lyons (2011)
SOC	% (w/w)	3.30 ± 1.16	12.65	3.50	Walkley and Black (1934)
Total N	% (w/w)	0.66 ± 0.21	1.12	0.25	Bremner (1960)
Soil extractable P	mg kg^{-1}	2.69 ± 4.74	28.7	14.6	Olsen et al. (1954)
Soil exchangeable K	cmol kg^{-1}	0.46 ± 0.07	0.77	0.45	MAFF (1986, Method No.: 63)

Elemental composition of taro corms

Element	Unit	Mean concentration ± SD
Nitrogen, N	%, w/w (dry basis)	0.76 ± 0.142
Phosphorus, P	%, w/w (dry basis)	0.24 ± 0.012
Potassium, K	%, w/w (dry basis)	1.45 ± 0.289
Calcium, Ca	%, w/w (dry basis)	0.10 ± 0.025
Magnesium, Mg	%, w/w (dry basis)	0.15 ± 0.021

Corm yields Nu’u 1 (2018-2019)



P>0.05 (Control vs Treatments)
P>0.05 (Treatments)
LSD (5% level): 694.5
Plant density: 1-m × 1-m

Y_a = 6150 kg DM/ha
(FW ≈9570 kg/ha at 35%, w/w)

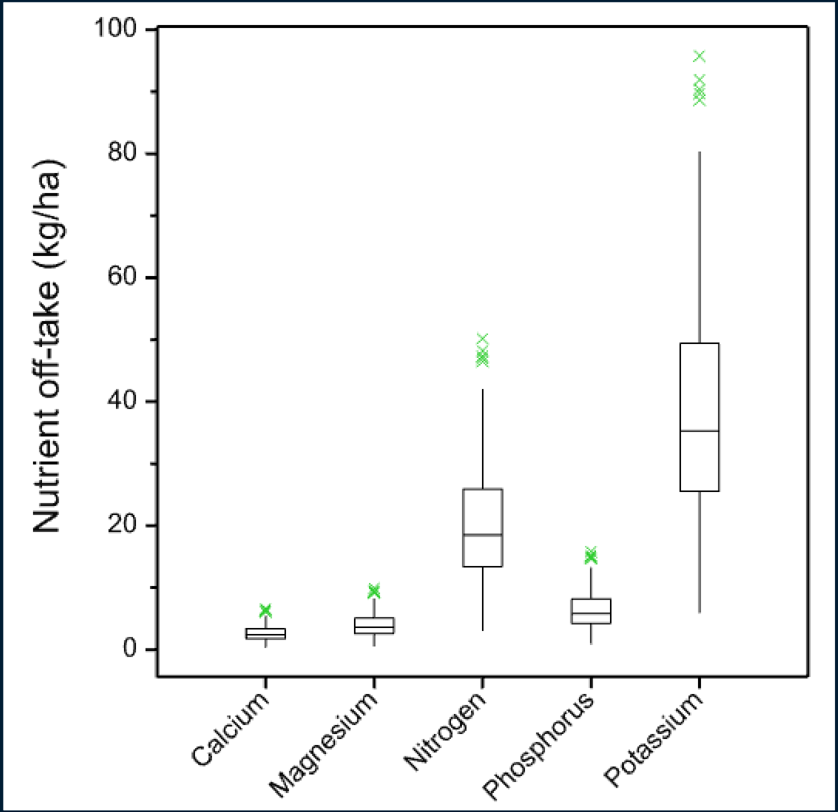
National Avg. = 4100 kg DM/ha
(FW ≈6250 kg/ha at 35%, w/w)

Y_f = 2730 kg DM/ha
(FW ≈4250 kg/ha at 35%, w/w)

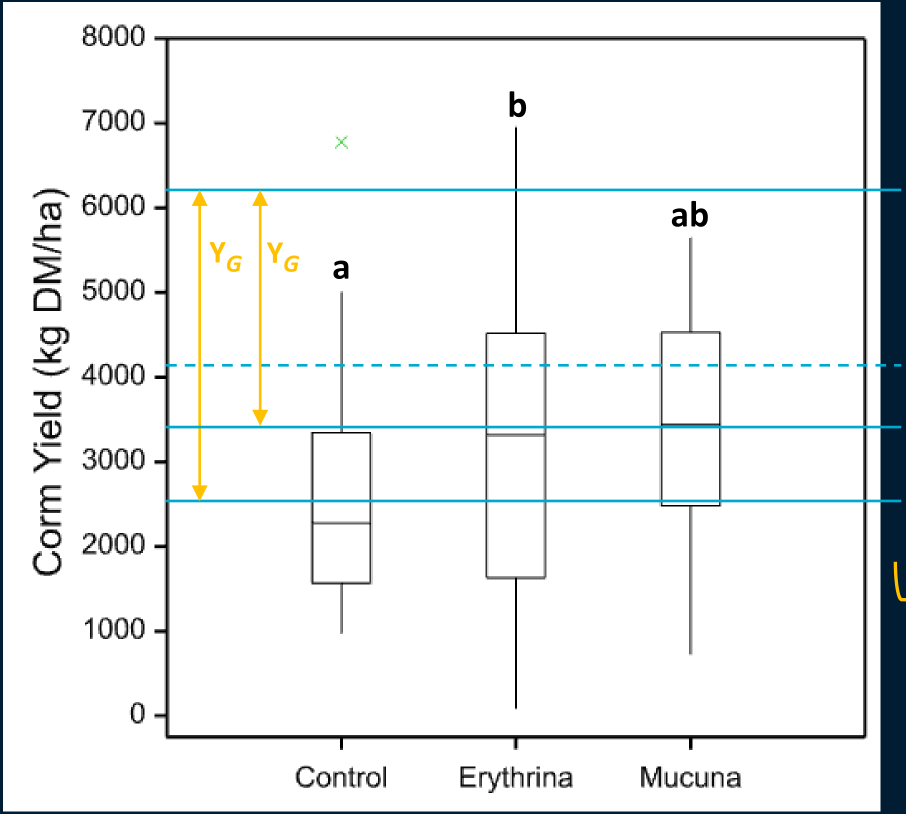
Y_G = 3420 kg DM/ha
(FW ≈5320 kg/ha at 35%, w/w)

Key: Y_a (attainable yield), Y_f (actual yield), Y_G (yield gap)

Nutrient off-take Nu'u 1 (2018-2019)



Corm yields Faleãlili (2018-2019)



Y_a = 6150 kg DM/ha

National Avg. = 4100 kg DM/ha

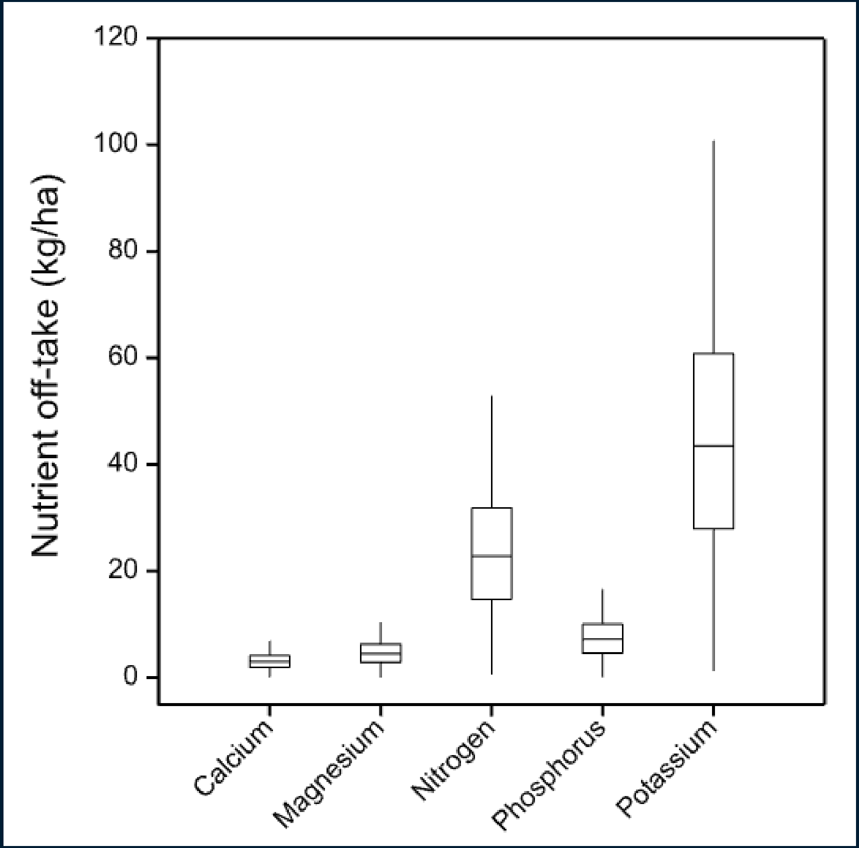
Y_f (legumes) = 3340 kg DM/ha

Y_f (control) = 2660 kg DM/ha

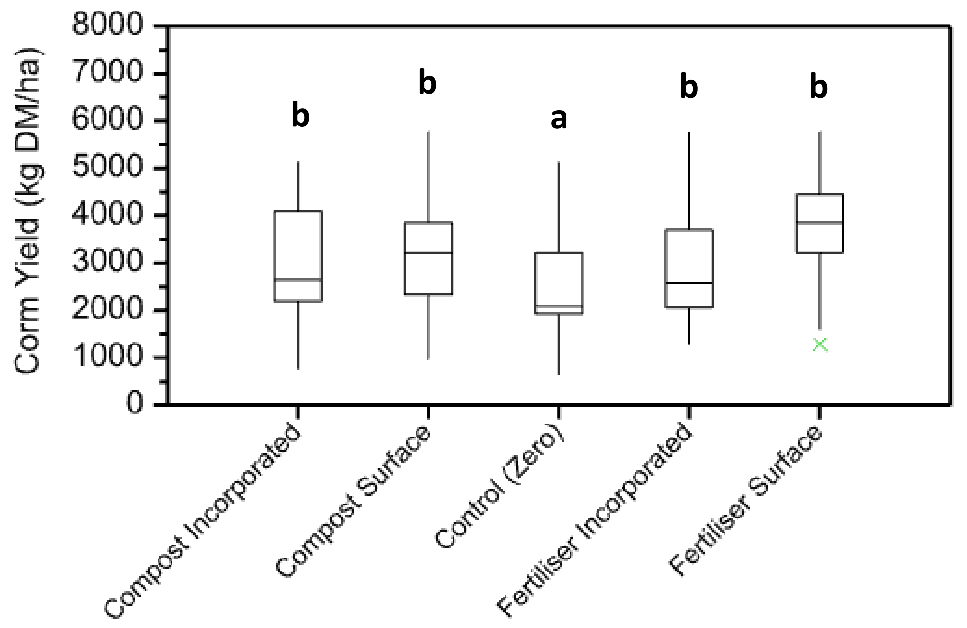
Y_G between 3490 (control) and 2800 kg DM/ha (legumes)

Key: Y_a (attainable yield), Y_f (actual yield), Y_G (yield gap)

Nutrient off-take Faleãlili



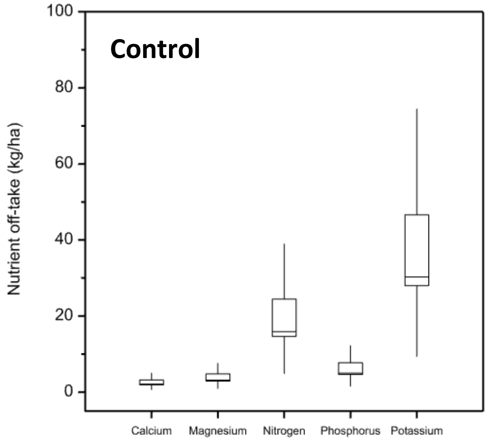
Corm yields Nu’u 2

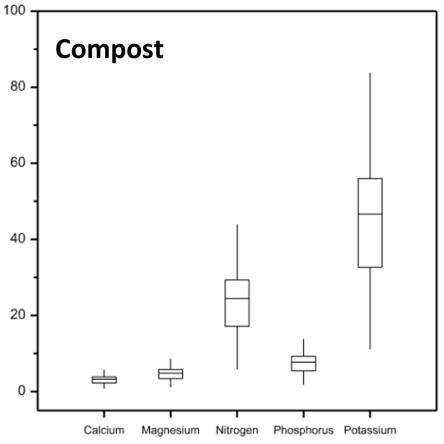


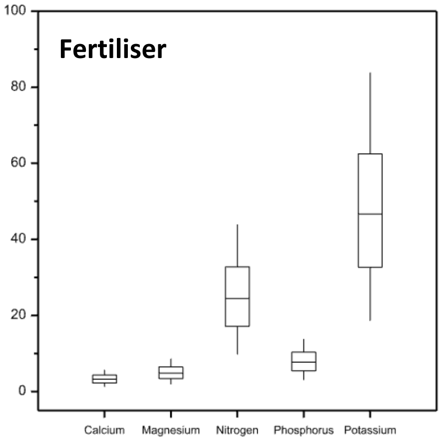
P<0.05 (Control vs Treatments)
P>0.05 (Treatments)
P>0.05 (Placement)
Plant density: 1-m × 1-m

- **Fertiliser Blaukorn Classic: 12:8:15+3 ($N:P_2O_5:K_2O+SO_3$)**
- **Compost: unknown (contains chicken manure, desiccated coconuts, coral chips, malt waste)**

Nutrient off-take Nu'u 2

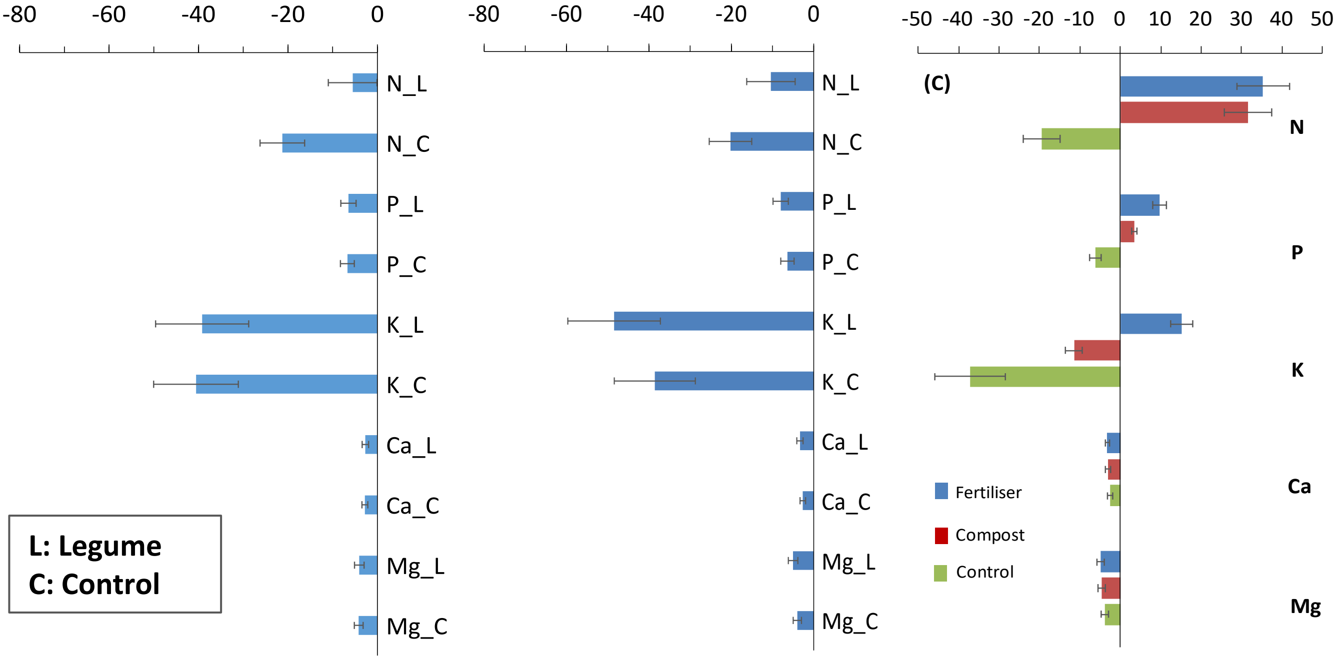






Nutrient balance

Nutrient balance (kg ha^{-1})

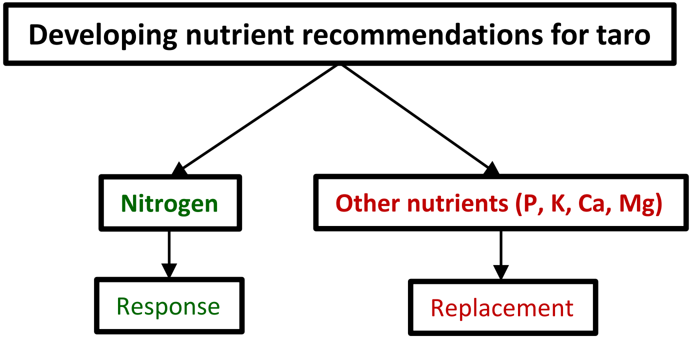


Nu'u 1 (Legumes)

Faleãlili (Legumes)

Nu'u 2 (Fertiliser, Compost)

Nutrient management framework



Developing nutrient recommendations for taro

Nitrogen

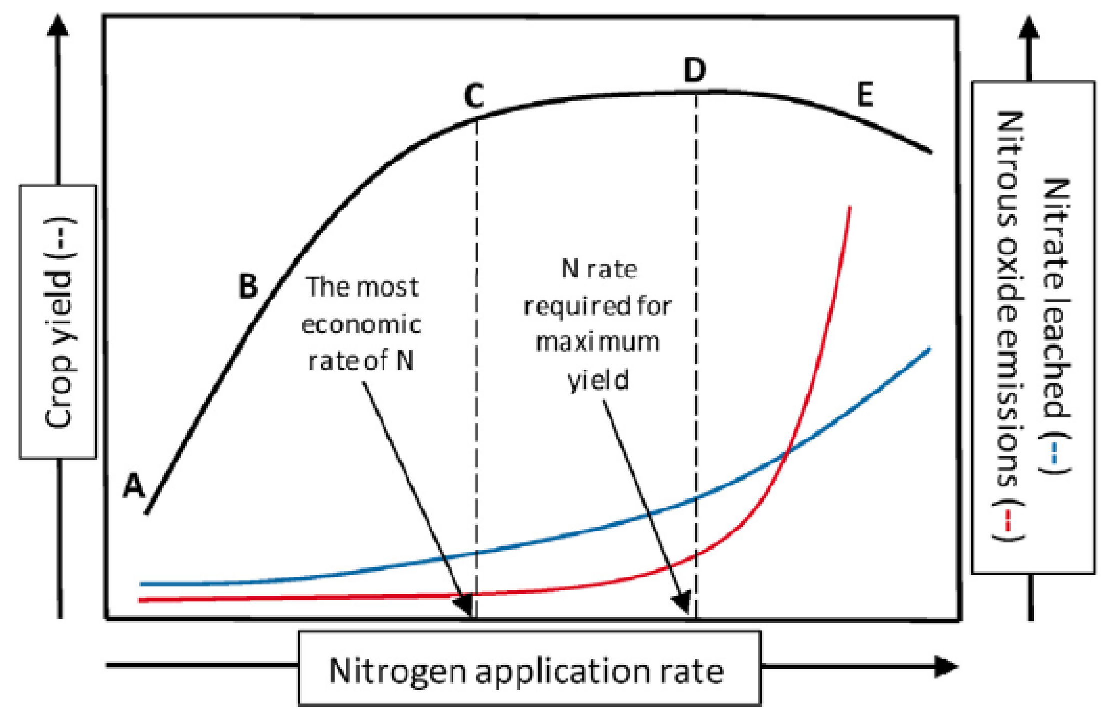
Response

Other nutrients (P, K, Ca, Mg)

Replacement

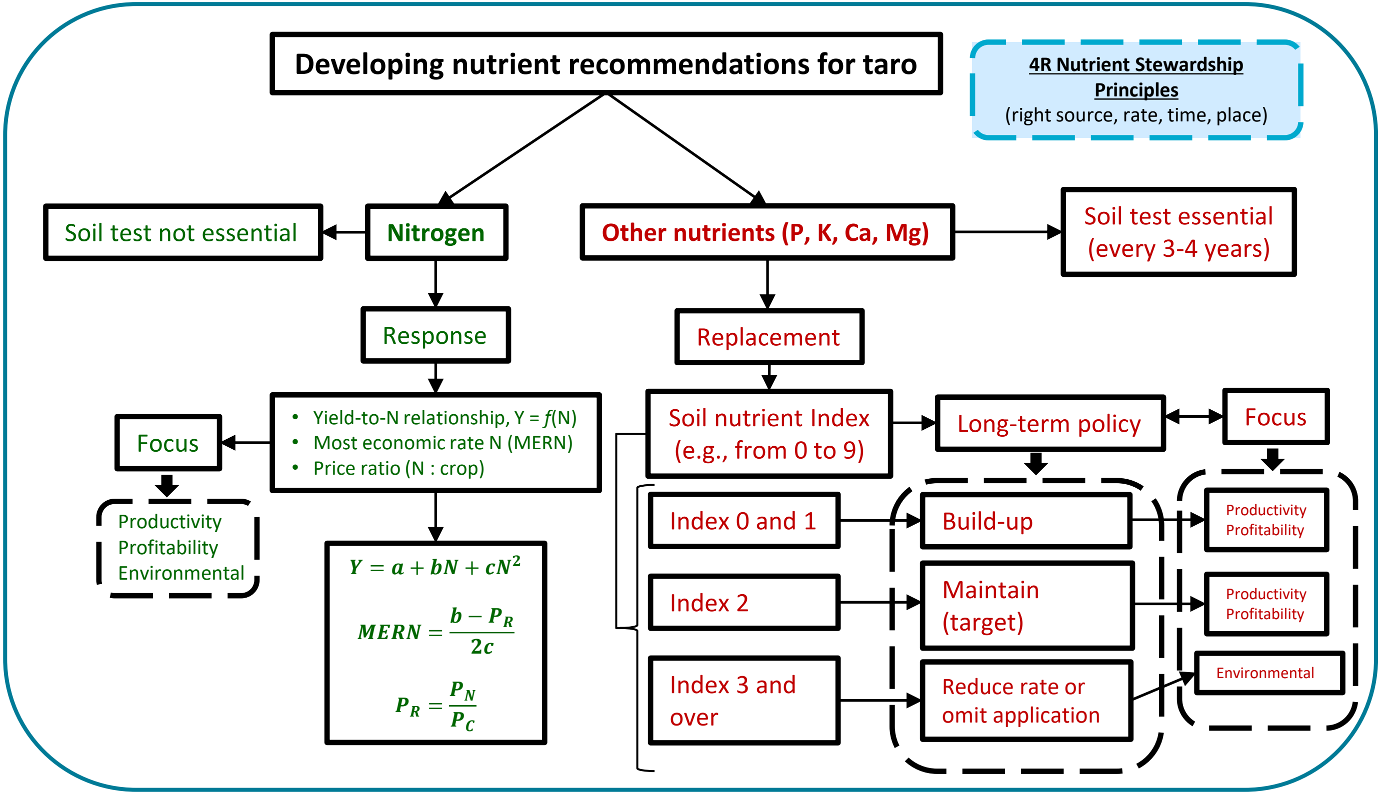
after Antille et al. (2022), https://doi.org/10.13031/aim.202200065

Yield-to-nitrogen response



after Antille and Moody (2021), https://doi.org/10.1016/j.indic.2020.100099

Nutrient management framework



Developing nutrient recommendations for taro

4R Nutrient Stewardship Principles
(right source, rate, time, place)

Nitrogen

Soil test not essential

Response

- Yield-to-N relationship, Y = *f*(N)
- Most economic rate N (MERN)
- Price ratio (N : crop)

Focus

Productivity
Profitability
Environmental

$$Y = a + bN + cN^2$$

$$MERN = \frac{b - P_R}{2c}$$

$$P_R = \frac{P_N}{P_C}$$

Other nutrients (P, K, Ca, Mg)

Soil test essential (every 3-4 years)

Replacement

Soil nutrient Index (e.g., from 0 to 9)

Long-term policy

Focus

Index 0 and 1	Build-up	Productivity Profitability
Index 2	Maintain (target)	Productivity Profitability
Index 3 and over	Reduce rate or omit application	Environmental

after Antille et al. (2022), https://doi.org/10.13031/aim.202200065

Conclusions

- **Project activities**
  - Impacted by measles outbreak (Sept. 2019- Feb 2020), COVID-19 (from March 2020), relocation from MAF to SROS.
  - Experimental, analytical and extension and communication work satisfactorily completed.
- **Soil properties**
  - Evidence of significant rundown in SOC, soil extractable P and exchangeable K, and reduced soil pH as a result of (low-input) cropping.
  - Short-term changes (2 cropping seasons) in soil chemical properties were not significant.
- **Legume intercropping**
  - Nitrogen supply via fixation in year 1 (establishment) does not meet taro demand for N.
  - Impact of legumes on P, K and water-use and availability to taro, particularly in low fertility soils.
  - Nutrient/fertiliser management plan should account for nutrient demand of both taro and legume.
- **Agronomic performance**
  - Yield gaps can be narrowed by developing and implementing appropriate nutrient management plans, and through improved crop husbandry (weed control).
  - Yields recorded with either compost or fertiliser application were higher than with legumes.
- **Nutrient balance**
  - Negative balance with legumes.
  - Apparent surpluses of N, P and K at Nu’u 2 explained by poor nutrient use efficiency (weeds).

Recommendations

- **Development of nutrient recommendations**
  - Validation of the proposed nutrient management framework.
  - Understanding yield to nitrogen response relationship.
  - Understanding of relative effects of nutrient source and placement on crop agronomic performance and nutrient-use efficiency.
- **Nutrient balance and intensification of taro production systems**
  - Refine field-scale nutrient balance calculations (establishment of long-term, permanent monitoring sites).
  - Investigate the feasibility of double taro cropping systems (taro-taro/break crop/taro-taro), suitable rotation and the required fertilisation program for maintenance of soil carbon and fertility.
  - For systems transitioning to ‘organic-like’ systems there is a need to develop tillage and stubble management protocols.
- **Development of the taro module in APSIM**
  - Initially developed by Crimp et al. (2017) using data collected from Fiji, Vanuatu and Tonga.
  - Site and variety specific with rather limited application at present.
  - Further development will enable improving its capability to:
    - Simulate the response of taro to projected changes in climate in the Pacific,
    - Evaluate and identify strategies for farming systems adaptation,
    - Assist the analysis and quantification of the soil water balance, carbon and nutrient cycling/flows.

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Agronomic response of rainfed taro to improved soil and nutrient management practices in Samoa

Diogenes L. Antille, Aleni Uelese, Angelika Tugaga, Michael J. Webb, Seuseu Tauati, Jennifer Kelly, Uta Stockmann, James Barringer, Ben C. T. Macdonald
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July 17–20, 2022

ABSTRACT. *Declined soil fertility in taro (Colocasia esculenta L., Schott) production systems in Samoa has resulted in reduced crop productivity and farm profitability. This paper reports the results of ongoing field investigations aimed at improving soil nutrient management and crop productivity in those systems. Experimental sites have been established at the Nu'u Crop Development Station of the Ministry of Agriculture and Fisheries (Apia, Samoa) to determine the effect of management practices on soil nutrient dynamics, taro yield and quality. These included: (1) application of NPK+S fertilizer, (2) application of compost based on poultry manure, and (3) legume intercropping using Mucuna pruriens and Erythrina subumbrans. Results are presented and discussed based on soil and agronomic data collected during the first two taro seasons. This work received financial and operational support from Australian Centre for Agricultural International Research (https://www.aciar.gov.au/).*

Keywords. *Composted poultry manure, Fertilizer recommendations, 4R Nutrient Stewardship Principles, Legume intercropping, Nutrient balance, Soil nutrient Index*

Thank You

Olo Aleni Uelese
Angelika Tugaga
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MAF Technical Officers

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