Improving yields and fertilizer efficiency in the South Pacific

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Jeff Reid[1], David Hunter[2], Mohammed Eaqub[2], and Luaiufi Aiono[3]

[1]Wyldham Enterprises Ltd
[2]University of the South Pacific, Alafua Campus, Samoa
[3]Ministry of Agriculture and Fisheries, Samoa

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Wyldham Enterprises Ltd
45 Plassey Street
Havelock North New Zealand 4130

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1 Executive summary

We report a scoping project for developing a system for choosing fertilizer rates for crops in the South Pacific islands, so that crop yield and quality are improved, fertilizers are used profitably, and risks of pollution are reduced. The project commenced in June 2009 and finished in December 2009.

Fertilizers are an expensive input for crops and are little used in the South Pacific. They can greatly increase yield and product quality, but it is very difficult for farmers to identify application rates that will be cost-effective. New computer models are used to solve these problems in New Zealand. We examined the potential to adapt a promising example of these models (PARJIB) for agriculture on Pacific Islands, with Samoa as a test case. Use of this model requires some calibration data, which compares crop yields under different levels of initial soil fertility and fertilizer application.

We addressed three high-level research questions. First, do Pacific Island farmers recognise opportunities from fertilizers and can they envisage using computer models like PARJIB to choose fertilizer applications? Second, how would fertilizer response models be deployed in island agriculture? Third, what is needed to get PARJIB working for island agriculture?

The project team met with key stakeholders at a workshop from 23-29 August 2009. The workshop was hosted by the University of the South Pacific (USP) at Alafua. It was attended by 15 representatives of the Samoan Farmers Association (SFA), Samoan Ministry of Agriculture (MAF), the Institute for Research Extension and Training in Agriculture (IRETA), the Scientific Research Organisation of Samoa (SROS), and USP.

The stakeholders strongly support developing technology for responsible effective use of fertilizers. The farmers' representatives (from the SFA) and MAF staff defined the preferred means of technology transfer to achieve this. Interactive farmer-advisory groups are the best way to ensure that the skills for using fertilizers spread through the farming community. Discussion on how to get site-specific recommendations to growers ranged widely. On some islands, cellphone text messaging may be superior to mail or face-to-face consultations, provided growers have some initial training on interpreting the recommendations.

To identify what is needed to get PARJIB working for island agriculture we collated information already available on crop responses to fertilizers under island conditions. Much relevant information was unearthed, mostly in the form of postgraduate theses and internal reports of MAF and USP staff. Much is not usable for modeling, as some key measurements were not made. However, we found ways of combining a few sources that would contribute towards a taro calibration. This requires some approximations for important information. Mssrs Hunter and Iosefega of USP will shortly start a field program to check and supplement the data available (that is a separate spin-off project, funded by USP).

Scientifically it was not difficult to design a program to calibrate the model for crops under island conditions. However, geographical and social matters must be included. Differences in the resources available for calibration work mean that it is best to concentrate that work initially on better-resourced islands like Samoa, and later combine some “ground truthing” with farmer demonstrations on other islands. This gives extra time to attract committed local extension and technical staff who will be essential for effective technology transfer.

The resources available to calibrate PARJIB exist on many Pacific Islands, particularly Samoa, Fiji, and perhaps Tonga and Vanuatu. On smaller islands or more spread out island groups locals will need

specific training and support to be involved in model calibration and testing. We may need to divide islands into two groups according to whether the soils are of volcanic or coral origin.

Finally, with stakeholders we designed a program of research and technology transfer to improve fertilizer use in the South Pacific Islands. The program would develop a soil fertility management service that arranges soil tests, recommendations and distribution of fertilizers. We propose that initially, the program commences on Samoa, and it is extended to other islands as experience is gained.

2 Recommendations

1. Technology and extension services are initiated as soon as possible to enable island farmers to make effective and safe use of chemical fertilizers.
2. The PARJIB model is very suitable for this and should be the first choice for rapid progress.
3. A further pilot study is carried out to get a preliminary calibration of the PARJIB model for taro. The University of the South Pacific and Samoa MAF have initiated this already.
4. There is a need to prepare farmers for safe, responsible and effective handling of fertilizers, explaining how they work and how to interpret recommendations made by a soil testing/modeling system. That appears to be best addressed by the Participatory Rural Appraisals approach of MAF, given some extra support and impetus from the Samoa Farmers Association. Such meetings will need to be backed up by release of written material, but the crucial steps will involve demonstration and discussion.
5. With a spreadsheet version of the model available, farmers should be provided with some initial recommendations. A rapid way of getting initial recommendations without a large scale soil sampling exercise is to use historic data from large scale soil surveys. This will give broad regional recommendations that are sufficient for farmers to share and gain some significant advantages.
6. We recommend that the model is used to find the likely yield responses per kg/ha of the narrow range of fertilizers currently available on each island. These values can be provided to farmers through say Samoa MAF's current extension network (see above).
7. Within one or two years farmers will need to move to a system that uses soil test results specific for their fields as these change from year to year. We recommend that funding agencies develop a soil fertility service for island agriculture. This could start as a pilot scheme on Samoa looking to extend to other nations as experience accumulates. Development of the service needs to be done through a stakeholder group that combines representatives of the farmers and MAF with scientific and technical support from the University of the South Pacific and NZ. The aim should be a service that is self supporting and enables farmers to gain sufficient income to afford their own fertilizers after a year of using the scheme.

3 Aims

Produce a plan to develop a robust and accurate system for choosing fertilizer rates for crops in the South Pacific islands so that compared to present practice:

1. Crop yield and quality are increased;
2. Fertilizers are used in a much more cost-effective manner; and
3. Risks of pollution are reduced.

Specific key research questions are listed below following the **Introduction**.

4 Introduction

Soil fertility is often poor on the Pacific Islands, and substantial increases in crop yield and quality can be achieved by using chemical fertilizers. Many farmers though are in the position of having to accept low yields because fertilizers seem expensive. Even when a dollar spent on fertilizers could increase their net income by much more, fertilizers are rarely used because of the initial cost, lack of information on how big the return would be, and reliable information on how to achieve that return.

Insufficient or zero fertilizer use can greatly reduce yields, limiting the value of the time and effort put in by growers on other aspects of crop production. However, the most profitable rate of fertilizer application is rarely the one that gives the greatest yields. Excessive fertilizer use can decrease yield and product quality, wasting money, while posing a substantial risk of polluting ground and surface water. The key challenge is to ensure that fertilizer application rates make appropriate allowance for the nutrients already held in the soil as well as the way in which factors like the weather will affect the crops total requirements for those nutrients.

Choosing fertilizer rates

One approach to deciding fertilizer rates is to replace what you expect to be removed from the field when the crop is harvested. This requires you to know typical values of the nutrient concentrations in the crops. It also requires you to be able to estimate yield reasonably well. Applying fertilizers calculated on this basis reduces the risk of pollution from excessive nutrients but it does not guarantee the fertilizer rate is cost-effective nor that yields will be as good as they could be.

Another approach is to apply fertilizer on the basis of target values of various soil tests. Here soil samples are analysed in the laboratory, and the grower or advisor has to estimate how much fertilizer is needed to bring the soil test value up to a target value that gives maximum yields. This approach again has problems. First, we can question the safety of aiming for maximum yields – and there is no way to know if the fertilizer application will be economic. Also, the target soil test values will vary with crop species, varieties, planting dates, seasons and soil types. This means the approach requires access to a substantial historic database of experiments carried out under representative conditions. Building up that database can take many years and be very expensive.

Forecasting fertilizer responses using models

Recently farmers and fertilizer companies in New Zealand have begun using computer models that forecast economic and environmentally optimum fertilizer rates. They do this on the basis of local soil test values and a little knowledge of the crop itself. These models can be very accurate[1-11], and can be calibrated for South Pacific crops. An important example here is the PARJIB model[4-11].

Some models conduct a day by day simulation of the growth of the crop. Typically they require a great deal of site- and crop-specific information, including daily weather, and soil properties that are not routinely measured by farmers. They also require sophisticated and dedicated software to run them. PARJIB though was designed to be much simpler, able to be run on a spreadsheet if necessary and using mostly standard soil test results. It is semi-mechanistic, and in consequence needs to be calibrated or fitted using experimental measurements of crop yield at different levels of nutrient availability. Once a satisfactory calibration is obtained PARJIB can be used to forecast crop responsiveness in other situations, provided that the basic soil test information is available.

All these models are designed to give site-specific information so that **individual** farmers know what the best fertilizer and fertilizer rate is for their crop.

It seems very likely that models like PARJIB will eventually become very valuable for farmers and advisors in the islands. However, the models in their present form require regular use of soil testing and access to computers. These requirements are beyond the present circumstances of most farmers in the South Pacific islands. This project sought to find out if that situation should be remedied.

5 Key research questions addressed in this project

1. Do Pacific Island farmers recognise opportunities from fertilizers? In particular:
    i. Do they see significant economic advantages from using fertilizers?
    ii. Can they envisage using computer models like PARJIB to forecast profitable and environmentally safe fertilizer applications?
2. How would fertilizer response models be deployed and utilized? In particular, if island agriculture was able to access the PARJIB model:
    i. How would the necessary input data be gathered?
    ii. Who would operate the model – would it be distributed widely to farmers and companies with computers, would it be best kept and run by either the agencies carrying out soil testing or those who normally provide advice to farmers?
    iii. What is the best way to get model recommendations delivered to the farmers?
    iv. How can farmers be trained in fertilizer handling and understanding model recommendations for fertilizer application rates?
3. What is needed to get a version of PARJIB working for island agriculture? Here we addressed what information and other resources are needed to develop rapidly an appropriate version of PARJIB:
    i. What information already exists?
    ii. Can we design an experimental program to supplement this information for two crops?

6 Methodology

Key Research Questions 1 and 2

These questions were addressed by consultation with stakeholders and experts. This began with email and telephone discussions among the project team and members of Samoa Ministry of Agriculture (MAF). In August 2009 we held a workshop hosted by University of the South Pacific (USP) at Alafua and facilitated by Dr Reid.

The workshop was attended by 17 representatives of the Samoan Farmers Association (SFA), MAF, the Institute for Research Extension and Training in Agriculture (IRETA), the Scientific Research Organisation of Samoa (SROS), and USP. A full list of participants is given in Table 1.

On the final day of the workshop the stakeholders decided that they and the project team should assemble a new project proposal to develop and implement a full advisory system for managing soil fertility. To do this the stakeholders and project team continued to correspond mainly by email to evaluate the material and options available.

Key Research Question 3

The University of the South Pacific appointed a Research Assistant (Luaiufi Aiono) for this part of the project. Luaiufi is a junior scientist with the Samoa Ministry of Agriculture and Fishers (MAF). He also registered as a postgraduate student in order to extend the usefulness of this project.

Luaiufi's task was to collate information already available from various sources on crop responses to fertilizers under island conditions. The sources used include books, scientific papers published in journals and presented at conferences, postgraduate and undergraduate theses from USP, and internal reports prepared by staff of MAF and USP.

The project team liaised by email and telephone to develop the criteria that determined whether a particular publication could be used. This was largely based on Dr Reid's experience calibrating the PARJIB model for NZ and Australian conditions.

As part of the stakeholders meeting (see above), the project team then reviewed the information already available, and the information, physical and human resources required to produce a working calibration of the PARJIB model for two crops.

Table 1: Workshop participants. Not all participants were present on all days, but each organization was always represented.

Name	Organization	email
Lasa Aiono	Samoa Farmers Association	luluolecoa@msa.com
Luaiufi Aiono	Samoa Ministry of Agriculture and Fisheries	luaiufi@hotmail.com
Aiolupotea Jeff Atoa	Samoa Farmers Association	tjexport@ipasifika.net
Mohammad Eaqub	University of the South Pacific - SAFT	eaqub_m@samoa.usp.ac.fj
Notise Faumuina	Scientific Research Organisation of Samoa	notise.faumuina@sros.org.ws
David Hunter	University of the South Pacific - SAFT	hunter_d@samoa.usp.ac.fj
Tolo Iosefa	University of the South Pacific - SAFT	iosefa_t@samoa.usp.ac.fj
Tuulima Laiti	Samoa Ministry of Agriculture and Fisheries	tuulimalaiti@gmail.com
Emele Meleisea-Ainuu	Samoa Ministry of Agriculture and Fisheries	emi@lesamoa.net
Junior Iuma Mulitalo	Samoa Ministry of Agriculture and Fisheries	taimua@yahoo.com.au
Vaasiliega Rupeni	University of the South Pacific - SAFT	tamanikaiyaroi_v@samoa.usp.ac.fj
Jeff Reid (Facilitator)	Wyldham Enterprises	wyldham@xtra.co.nz
Aiga Sailo	Samoa Ministry of Agriculture and Fisheries	aiga_sailo@yahoo.com
Afamasaga Toleafoa	Samoa Farmers Association	pacific@ipasifika.net
Kitiona Tugaga	Samoa Ministry of Agriculture and Fisheries	kitiona.tugaga@gmail.com
Mohammed Umar	University of the South Pacific - IRETA	umar_m@samoa.usp.ac.fj
Anesone Vaai	Samoa Ministry of Agriculture and Fisheries	an_vaai@yahoo.com
Tuaopepe F. Wendt	Samoa Farmers Association	plantationhouse@hotmail.com

2 Results

The project was broken down into milestones and tasks. Appendix 1 indicates the timelines and progress with each. Below we describe and discuss this progress in more detail, but addressing stepwise the key research questions listed above.

Question 1: Do Pacific Island farmers recognise opportunities from fertilizers?

Stakeholders representatives at the workshop were excited at the opportunities offered by cost-effective use of fertilizers. They were confident from previous research carried out in the islands that poor soil fertility limited crop yields considerably. Both MAF and SFA representatives were clear that fertilizers are not used in most of the subsistence-style farms on the islands. Common reasons for this are the expense, farmer uncertainty whether the fertilizer will be cost-effective, and a tradition of shifting cultivation in areas where there is sufficient land to support it. In shifting cultivation the land is rested for many years between crops (often reverting to forest) to allow some recovery of natural soil fertility.

The SFA representatives were particularly emphatic that island farmers need to move to more intensive production so island nations can achieve food security and reliable export income. They were keen that farmers had access to fertilizer forecasting models to make sure that money and nutrients were not wasted in this. There was much discussion about how such models would best be deployed and used (see Question 3 below).

Staff members from USP commented that in Fiji, the recent move to intensive production of crops like taro for export has hit problems with declining soil fertility, and the farmers there would be very keen to have access to a system that used modelling technology to recommend the best fertilizer applications. We are much less clear about the situation on other islands. A message was relayed to us from the Solomon Islands that at least one extension specialist there would like to participate in any future project along these lines.

Question 2: How would fertilizer response models be deployed and used?

The stakeholders workshop spent much time discussing this. Much attention was given to the following questions:

1. How would the necessary input data be gathered?
2. Who would operate the model – would it be distributed widely to farmers and companies with computers, would it be best kept and run by either the agencies carrying out soil testing or those who normally provide advice to farmers?
3. What is the best way to get model recommendations delivered to the farmers?
4. How can farmers be trained in fertilizer handling and understanding model recommendations for fertilizer application rates?

In practice the answers to these questions are inextricably linked. We found the questions are best addressed through looking at present methods of technology transfer in the islands.

Existing processes for technology transfer

This was discussed in some depth as there have been success and failure stories for new agricultural technologies introduced to Samoa.

Throughout the Pacific Islands, USP has an important role in training the next generation of farmers and agribusiness professionals. While that is important, here we need to be more concerned with technology transfer to existing farmers – who are unlikely to attend university but could well attend field days and seminars organised by USP.

In Samoa, the Samoa Farmers Association is an important conduit for information, but MAF has the prime responsibility for technology transfer.

The Crops Division of MAF has advisory stations throughout Upolu and Savaii islands. These stations are an important link for transfer of information to and from farmers. Through them MAF organises direct training (hands-on training, open days, farmer Field Schools, career days and demonstrations). It also carries out monitoring and farm visits for policy and technology transfer objectives. Most crucially, MAF has a consultative network that carries out “Participatory Rural Appraisals” with farming communities. These are important for identifying farmers’ needs and problems. MAF produces a considerable quantity of extension materials (pamphlets, manuals etc) and uses media like television, radio and newspapers. These services are free to farmers. The workshop participants discussed in some detail which of these extension methods would work best for fertilizer advice.

Technology transfer using a fertilizer response model

We identified two key aspects of fertilizer recommendations that need to be recognized.

1. There is a need to prepare farmers for safe, responsible and effective handling of fertilizers, explaining how they work and how to interpret recommendations made by a soil testing/modeling system. That appears to be best addressed by the Participatory Rural Appraisals approach of MAF, given some extra support and impetus from the Samoa Farmers Association. Such meetings will need to be backed up by release of written material, but the crucial steps will involve discussion and demonstration.
2. Once soil testing has been carried out for farmers and a recommendation is produced using the model there is a need to get that information to the farmer in a timely and unambiguous way. Mail, telephone calls and site visits by advisors all have disadvantages, particularly in remote regions. The Samoa Farmers Association came up with the idea that text messaging on cell phones should be used. Cell phone reception is often good even in quite remote parts of the islands, and farmers are surprisingly tuned into that technology already. It certainly should be pursued further.

Gathering information to run the model

The intent here is to use the PARJIB model (probably through a spreadsheet) with crop and soil test information for each farmer's fields As noted already, in NZ and Australian practice, recommendations for one field will most likely NOT be optimal for a different field, and broad regional recommendations can lead to excessive or inadequate fertilizers use by each farmer. Soil test information at the individual field level is scant in Samoa and in the other islands. However, there is a way around this.

Workshop participants pointed out that because so little fertilizer has been used in Samoa, the historic data left from large scale soil surveys could be used initially. This will lead to broad regional recommendations that are probably sufficient for farmers to share and gain some significant advantages from.

However, once fertilizers have been used on a field, the historic soil test results for the same soil type will become less and less reliable. As this happens then farmers will need to move to a system that uses soil test results specific for their fields as these change from year to year.

We recommend that the model is used to find the likely yield responses per kg/ha of the narrow range of fertilizers currently available on each island. These values can be provided to farmers through say Samoa MAF's current extension network.

At this point the problem of how to best use the technology becomes more complex. At the workshop we came to the conclusion that an integrated service is required for island farmers. This service would arrange the sampling, collection and analysis of soils for farmers, run the results through the PARJIB model (in spreadsheet or other form), and sends to the farmers recommendations that are specific to the fields sampled and crops they plan to plant in them.

A full description of that proposed service is beyond the required scope of this report, and developing the service will be the subject of a later application for funding. However, a summary of our deliberations so far follows in Section 8.

Table 2: Data requirements for calibrating the PARJIB model. Soil measurements should be made to the standard testing depth (15 cm for crops in NZ).

	Variable	Preferred level of recording	Notes
Soil	N availability	By plot or replicate block	Compatibility or conversion factors needed if experiments used different techniques
	P, exchangeable cations (Ca, Mg, K, Na), cation exchange capacity	By plot or replicate block	Compatibility or conversion factors needed if experiments used different techniques
	Lab. bulk density	By plot or replicate block	As measured when sampling in lab for N, P etc)may be experiment or block average
	Field soil bulk density	Expt or block average	
	Available water capacity, maximum water deficit during crop, days of water excess	By plot if soil variable, but usually an experiment or block average	May not be essential if drought insignificant, may be OK to look up values based on texture.
Crop	Yield, % dry matter	By plot	
	Maximum yield	Experiment mean or treatment mean	This is the yield unrestricted by fertilizer or water. Treatments that differ in plant population, planting date or variety may differ in maximum yield. Often we can estimate it from the experimental data.
	Population (plants/m2)	By plot or replicate block	By block or experiment if variation is minimal – but usually much better to have population in the harvested areas of each plot
	Crop cover or light interception (time course)	Treatment or experiment means	Needed to do water balance calculations if drought or water excess likely to have occurred, and to calculate potential yield if possible.
	Disease and weed incidence	By plot if possible	Score of incidence or severity by species. Essential if weeds and disease significantly affected yield
Fertilizer	N, P, K and Mg (kg element /ha) separately for broadcast, side-dressed or banded applications	By plot or replicate block	The calibration process may be able to cope with elemental composition and rate of manures or composts
Weather	Daily radiation, or sunlight hours, rainfall, irrigation	By site, by day. Irrigation by treatment if necessary	Used to calculate potential or maximum yield

Question 3: What is needed to get PARJIB working for island agriculture?

The key issue is how to calibrate and test the PARJIB model for island crops. This was examined in a desk-top study that included ways to make the model calibration process more suitable for the resources available to researchers in the South Pacific islands. We looked for information to develop PARJIB calibrations for two significant crops.

PARJIB requires different calibration data for each crop – but it does not need to be recalibrated if crop varieties change. In NZ and Australia PARJIB has been calibrated with a series of field experiments.

The key characteristic of the information required to calibrate PARJIB is that the data covers a range of maximum yields (which may be achieved through variations in crop variety, weather, planting date or population for example), and covers a wide range in measured soil conditions. So, experiments are best executed in several locations, and preferably in different years. Often data from previous research projects have been pooled with fresh information from experiments designed specifically to fill gaps in the existing data. Clearly however, the resources need to produce a calibration should include access to farmers crops, analytical chemistry services (for soil testing), and local staff who can help design and service the experiments in keeping with local culture and environmental conditions.

These resources exist on many Pacific Islands, particularly Samoa, Fiji, and perhaps Tonga and Vanuatu. On smaller islands or more spread out island groups locals will need specific training and support to be involved in model calibration and testing. We may need to divide islands into two groups according to whether the soils are of volcanic or coral origin.

We designed a generic experimental program to calibrate PARJIB for island conditions. We also identified how this needs to be adapted for the crops for which we have the best initial chance of rapid progress.

Generic protocol for obtaining a calibration

1. Identify the key measurements required from historic and new experimental work. These are summarised in Table 2.
2. Collate all existing information into a standard spreadsheet. Wherever possible it is preferable to take data from experiments that involve fertilizer treatments, but we can also use experiments on plant population and irrigation. Replication is not always essential, provided we can pool data from several sources on the same crop species
3. Identify the key gaps in this information. For example, is there adequate information on responses to N fertilizer, or is all the available information from one experiment in which there was no variation in maximum yield. In general we want at least 60 data points for calibration purposes – but this number may need to increase if the data are of low precision or cover a narrow range of conditions.
4. If a range of farmer properties are available, at each establish experimental plots with at least two treatments – an unfertilized control and a fertilized treatment. The fertilizer treatment may be a simple or combined (N, P, K or Mg) fertilizer and it does **not** have to be the same at all sites. Wherever possible include an extra treatment where the fertilizer applied should be sufficient for maximum yield. Replication (2-4 times) at each site is desirable. From each plot take soil samples for chemical analysis **before fertilizers are applied**. Sample soil to the standard 15 cm depth, or the same depth as used for the historical data. Check soil texture by hand. Plot size will depend on the crop – but make sure it is large enough for soil sampling (pool up to 20 core samples per plot) and for an adequate yield measurement from the plot's centre. It is a good idea to make the plot big enough to leave ample yield for the farmer to appraise after the experimental harvest.
5. A month or so before harvest measure soil dry bulk density in the field (take samples to the same depth as the chemistry samples were taken). For each site a set of 6 measurements taken randomly through the experimental area will be sufficient. Use the mean value for each site when calibrating the model.

6. If possible get soil available water content data from previous reports, or take samples back to the laboratory for this determination. If either option is possible then mid to late in the season you will need to estimate available water capacity from rooting depth and soil texture using published data. If possible dig some pits at the site to determine soil texture and the maximum rooting depth. Where texture information is unavailable you may approximate available water capacity as 0.15 times the rooting depth. This will be inaccurate though for many sandy soils. Again you can usually use a single average value for each experimental site.
7. The farmer plants and manages the crop as usual. Wherever possible, gather weather data close to the experimental site. Mid-way through the season, measure the plant populations and note any disease or problems on each plot whenever possible. A few days before the farmer's harvest, harvest a predetermined area or number of plants per plot. For crops like taro this should be at least 10 plants. Count the plant population, count or score the incidence of pest, disease and weeds in the plots, and measure the fresh yield in the field. Score or measure crop quality in the field if possible. Weigh sub-samples fresh in the field and take these back to the laboratory to determine % moisture.
8. If possible enter the weather data into a water balance spreadsheet and calculate the maximum soil water deficits and number of days where soil water content was likely to be in excess of field capacity.
9. Enter the crop yield, soil chemistry and soil water data into the standardized spreadsheet (see below), and calibrate the model.
10. **Calibration**: we developed a spreadsheet that contains the basic equations of PARJIB for calculation purposes and a special page for calibration. On this page, the experimental data is summarized and a set of cells are set up for the user to calibrate the model using the "Solver" function in MS Excel. This is arranged to try automatically different values for model parameters until it achieves the best overall agreement between the observed and predicted yields. In our tests the answers obtained by this method are very close to those obtained by the genetic algorithm technique used previously[7].

Testing model performance

Standard tests of model performance are included in the sophisticated calibration software used in NZ. Here though the only test of model performance during the calibration process is the root mean square error of prediction (which is minimised by the Solver software). Accordingly, the model's performance with the calibration data set should be checked subsequently by computing the mean residual error of prediction, and the slope intercept and %variation accounted for by a linear regression of actual yields upon simulated. Model performance with non-calibration data sets should be checked in the same way wherever such data is available.

We also strongly suggest that residual errors (predicted minus actual yields) are plotted against any information that is available at the same level as the input data. So if data are available for say disease incidence on the experimental plots, these numbers should be graphed against the residual yields to check for any systematic errors or trends.

Information already available

The majority of the information available is from USP Postgraduate theses and MAF internal reports, as well as Scientific Journals and Bulletins. About 70 references in total were consulted for calibrating the PARJIB model. These covered relevant field studies on economically-important crops carried out in Samoa, Fiji, Tonga, Vanuatu and Kiribati. The experiments were originally designed to investigate things such as disease resistance and yield evaluations of different varieties, soil fertility status and fertilizer responses (including organic amendments), spacing and depth of planting. The crops studied were taro, banana, papaya, sweet potato, cabbage (Chinese and Head), eggplant and other vegetables. The experimental data available from these field studies generally include soil physical and chemical parameters, crop growth and yield components at the plot, block and site levels.

A consistent feature of the reported experiments is that soil nitrogen status was measured only in terms of total N in the top 15 cm of soil. Existing calibrations of PARJIB all use incubation measures of the amounts of ammonium and nitrate released from the soil organic matter (which in theory is a much better approach to assessing the amount of N that will be available to crops). The absence of immediately useful measures of crop available N prevents us from immediately using the historic information. However, some of the experiments included soil organic C measurements also. From the total N, the C:N ratio, and the crop duration we might be able to estimate sufficiently well the amount of N mineralized (converted to ammonium and nitrate and so available to plants). This approach needs to be investigated in future experimental work. Provided that is successful then we can use one particularly good sources of calibration information for taro.

This source of information is the work of Reynolds[12], who conducted a number of fertilizer trials that yield useful information. There is sufficient information from two of those trials for our purposes. Reynolds suggested that responses to N, P and K fertilizers in particular were strong, although his Analysis of Variance on his experiments did not indicate significant effects (perhaps because usually replication was only x3). Those experiments would provide a total of 48 calibration data points (45 from one experiment, 3 from the other). However, at each site the soil properties were measured across the whole site, not at an individual plot or replicate block level. We will need extra data to help take into account site-to-site variations in soil conditions.

So, for taro there is already some information available, but not enough for a reliable calibration. Accordingly some fresh experiments are needed. Also we will need to check empirically some of the assumptions and approximations necessary to utilise the historic data – in particular how we should best use the soil C and N measurements. Also we need to check that fresh matter yield recorded in previous experiments can be accurately converted to the dry matter yields used for PARJIB calibration.

Tolo Iosefa of USP carries out many trials to check the performance of old and new taro varieties in Samoa. These trials are located in a number of different farmers' fields, and Tolo has kindly agreed to allow us access to those crops to apply some fertilizer treatments. Overall then it seems that there are good resources available to develop a PARJIB calibration for taro in future work.

The likely candidates as the second crop for a preliminary PARJIB calibration are papaya and eggplant (chosen by the stakeholder workshop on account of the crops' potential for export and as import substitutes). Though few field studies have been carried out on these two crops in Samoa, results from field studies conducted in other Pacific Island countries such as Fiji and Vanuatu have arrived at appropriate agronomic practices which are effective in achieving reasonably good yields. These agronomic practices can be adopted and replicated in Samoa given similar agro-climatic conditions and farmers' practices.

For eggplant, several experimental studies have been completed in Fiji[13] and these look promising as they involved very suitable experimental treatments. We have requested full details of soil test results for these experiments.

Information still required

We have examined the information required to produce a preliminary model calibration for Samoan conditions that can be tested and adjusted as necessary subsequently for other islands in the Pacific.

For Taro, we specifically need new experiments that measure yield responses to fertilizer when the soil is already moderately fertile, and under conditions where we can ascertain the potential yield (or yield without any limitations due to mineral nutrition). Ascertaining the latter can be difficult as we do not have access to a potential yield model, nor the environmental data for such a model. However, we are confident that we can approximate potential yield by including some treatments where there is ample fertilizer applied. At least one multi-location experiment is required for this.

For eggplant and papaya, we need the same data for potential yield, but we also require rather more measurements of the direct effects of fertilizer treatments on yields. In all we will probably require two more experiments each for eggplant and papaya.

All of these above experiments will need to include measurements of soil fertility status using modern methods, and some extra measurements using the methods used in the historical experiments. This information can be used to convert the older data into a form that can be pooled with the new. As mentioned in the preceding section we particularly need some new information on the relationships between total and readily available N in Samoan soils, so we can use the historic measures of total N in a PARJIB calibration process.

Running the model

In NZ the PARJIB model is deployed in a variety of stand-alone software applications for farmers and advisors. This is probably not appropriate for island conditions. The stakeholders agreed that they would prefer to see the model held and run by a small number of trained advisors (see below). Furthermore, programming and maintaining a stand-alone application for island agriculture is an expensive option at present. The best solution is to develop a spreadsheet version. We have done this included it in the calibration spreadsheet referred to above.

Other comments

Scientifically it was not difficult to design a program to calibrate the model for crops like taro, papaya and eggplant under island conditions. However, geographical and social matters must be included. Differences in the resources available for calibration work mean that it is best to concentrate that work initially on better-resourced islands like Samoa, and later combine some “ground truthing” with farmer demonstrations on other islands on a case by case basis. This gives extra time to attract committed local extension and technical staff, who will be essential for effective technology transfer.

7 Proposed soil fertility service – a brief summary

Below we have summarised our recommendation to develop a soil fertility service for island agriculture. This could start as a pilot scheme on Samoa. As experience with the service accumulates then we recommend it is extended to other nations.

Samoan Soil Fertility Service

The target outcome is that the majority of Samoan farmers will be capable of producing a surplus of key crops by 2015. At a national level this will lead to enhanced food security, stability of rural populations, and as those benefits become entrenched it will lead to opportunities for sustained economic growth through exports.

It will achieve this by easing the choke-hold of poor soil fertility without compromising the environment. It will establish a service of advice and training in scientifically proven methods to increase crop yields and quality. These methods will use chemical fertilizers and crop rotational techniques as appropriate, backed by modern soil testing and interpretation techniques. Existing evidence indicates that taro yields alone could be increased by 20% by judicious use of fertilizers, but very few Samoan farmers use them and native soil fertility is low. Initially the service developed will address the needs of taro (as a major component of the food security issue), moving on to papaya, eggplant and other crops where improved yields and quality has significant domestic and export potential. So, while it starts by raising yields and income for the majority of farmers including those who farm at a subsistence level, eventually this project will include best-practice guides for intensive production.

We recommend a new project that sets up a pilot service, developing the required knowledge, logistics and distribution systems, and training farmers and other stakeholders to utilise the system effectively. Wherever possible it will utilise existing resources (e.g. laboratories, farmer-advisor networks, transport services). Hence the project would not seek funding for capital items of equipment. It should seek funds for initial fertilizer supplies to farmers who join, initial operation of the prototype service, technical consultancy, and the costs of research for the underpinning knowledge.

The project has a high chance of success because it has realistic, high priority, aims and because it is planned, administered and implemented by the key stakeholders. The stakeholders group will ensure a practical pilot system is developed, tested and used concurrently. In particular the Samoan Farmers Association will ensure the project delivers services appropriate to farmers’ needs and abilities, the Samoan Ministry of Agriculture and Fisheries will provide the technology transfer mechanisms, and the University of the South Pacific will arrange the necessary laboratory services and develop the underpinning scientific knowledge. Technical support to adapt a successful fertilizer-response model will be provided by Dr JB Reid of Wyldham Enterprises. Other stakeholders will be invited to join as appropriate. These may include telecommunications companies and banks or business experts (some farmers will see the need to move to a system of seasonal finance to make best use of the opportunities this project will provide).

A key decision to be made by the stakeholder group is which existing or new organisation will provide the service after the project is complete. This decision will be made in the second half of the project once the group and funding agencies have experience of the service, to ensure a smooth transfer of responsibilities. One aspect of that decision is how the ongoing service will be funded. Options may include direct fee for service, a fertilizer or marketplace levy, and a subsidy from the Samoan government. It is important that this is addressed after the stakeholder group and the wider community has direct experience of the economic and other gains that the service offers.

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10 Appendix 1: Project milestones and tasks

			Target		Actual	
Milestone	Task	Description	Start	Completed	Start	Completed
1		*Project commences, job specification for Research Assistant drawn up, and search to fill position commenced*	13-May-2009	31-May-2009	16-May-2009	
	1.1	Project commences - contract signed and returned to NZAid	13-May-2009	13-May-2009	16-May-2009	16-May-2009
		Job specification for Research Assistant drawn up, and search to fill position commenced	25-May-2009	05-Jun-2009	01-Jun-2009	05-Jun-2009
2		*Initial search of available literature complete, project team meets in Apia, choice of two experimental crops made, experimental program designed to calibrate the model for those crops*	01-Jun-2009	31-Oct-2009	29-Aug-2009	
	2.1	Research Assistant appointed and commences work	5-Jun-2009	19-Jun-2009	5-Jun-2009	14-Jul-2009
	2.2	Project team agrees search criteria for information already available on crop responses to fertilizer under island conditions. Achieved via conference call or video conference, confirmed by email.	16-Jun-2009	30-Jun-2009	16-Jun-2009	26-Jun-2009
	2.3	Initial search of literature complete, results collated into bibliography, and document filing system	23-Jun-2009	21-Aug-2009	27-Jun-2009	24-Aug-2009
	2.4	Arrangements made for project team meeting in Apia. Appropriate government and USP staff and other stakeholders identified and invited to meeting, necessary resources (rooms, data projector etc) booked	14-Jul-2009	31-Jul-2009	14-Jul-2009	21-Aug-2009
	2.5	Interim Invoice for USP services raised and sent to Wyldham Enterprises (max NZ$3788.50)	12-Aug-2009	13-Aug-2009	16-Oct-2009	
	2.6	Interim payment for USP services made by Wyldham Enterprises	13-Aug-2009	14-Aug-2009	NOTE USP decided to combine the 1st and 2nd invoices at completion of the project	
	2.7	Project team meets in Apia. 1: existing information reviewed	24-Aug-2009	24-Aug-2009	24-Aug-2009	25-Aug-2009
	2.8	Project team meets in Apia. 2: Identify most suitable technology transfer methods	25-Aug-2009	24-Aug-2009	26-Aug-2009	28-Aug-2009
	2.9	Project team meets in Apia. 3: Reconcile resources available to those required to calibrate and use PARJIB model in Samoa and other islands	26-Aug-2009	26-Aug-2009	26-Aug-2009	26-Aug-2009
	2.1	Project team meets in Apia. 4: Experimental program designed to calibrate the model for at least two crops and achieve	27-Aug-2009	27-Aug-2009	27-Aug-2009	28-Aug-2009

Milestone	Task	Description	Target Start	Target Completed	Actual Start	Actual Completed
		effective technology transfer				
	2.11	Project team meets in Apia. 5: Discussions on future grant applications held and plans made for applications.	28-Aug-2009	28-Aug-2009	28-Aug-2009	28-Aug-2009
	2.12	1st Draft final report prepared, circulated to project team	31-Aug-2009	7-Sep-2009	16-Oct-2009	18-Oct-2009
	2.13	1st Draft final report comments and corrections returned to Jeff	08-Sep-2009	15-Sep-2009	18-Oct-2009	02-Nov-2009
	2.14	2nd Draft final report prepared, circulated to stakeholders for comments/corrections, financial reports completed	16-Sep-2009	02-Oct-2009	02-Nov-2009	50-Nov-2009
	2.15	Final report prepared, submitted to NZAid and other stakeholders	06-Oct-2009	31-Oct-2009	6-Nov-2009	16-Dec-2009[1]
	2.16	Final Invoice for USP services raised and sent to Wyldham Enterprises	31-Oct-2009	1-Nov-2009	16-Oct-2009	16-Nov-2009
	2.17	Final payment for USP services made by Wyldham Enterprises, (max NZ$3788.50)	5-Nov-2009	6-Nov-2009	24-Nov-2009	24-Nov-2009

[1] An extension from the original due date to 15-Jan-20010 was granted by NZAid.

11 Appendix 2: Summary for the National DevNet Research Database

Project: Improving yields and fertilizer efficiency in the South Pacific

Reid, J.B., Hunter, D., Eaqub, M., and Aiono, L. (2009) *Improving yields and fertilizer efficiency in the South Pacific*. Final report on project funded by NZAid, Koru record ID: 13954. Report 2009/04, Wyldham Enterprises Ltd, Havelock North, NZ. 19pp

This was a scoping project to develop a plan for developing a system for choosing fertilizer rates for crops in the South Pacific islands, so that crop yield and quality are improved, fertilizers are used profitably, and risks of pollution are reduced. The project commenced in June 2009 and finished in December 2009.

Fertilizers can greatly increase yield and product quality, but it is very difficult for farmers to identify application rates that will be cost-effective so they are little used in the South Pacific. New computer models are used to solve these problems in New Zealand. We examined the potential to adapt a promising example of these models (PARJIB) for agriculture on Pacific Islands, with Samoa as a test case.

The project team met with key stakeholders at a workshop hosted by the University of the South Pacific (USP) at Alafua from 23-29 August 2009. It was attended by representatives of the Samoan Farmers Association (SFA), Samoan Ministry of Agriculture (MAF), the Institute for Research Extension and Training in Agriculture (IRETA), the Scientific Research Organisation of Samoa (SROS), and USP.

The stakeholders strongly support developing technology for responsible effective use of fertilizers. We recommend that technology and extension services are initiated as soon as possible to enable island farmers to make effective and safe use of chemical fertilizers. The PARJIB model is very suitable for this and should be the first choice for rapid progress.

Farmers need to be prepared for safe, responsible and effective handling of fertilizers, with explanations of how they work and how to interpret recommendations made by a soil testing/modeling system. This is best addressed by meetings of interactive farmer-advisory groups. Such meetings would be backed up with written material, but the crucial steps will be demonstration and discussion.

Some relevant information is available to calibrate and adapt PARJIB for island agriculture. This is mostly in the form of postgraduate theses and internal reports of MAF and USP staff. We found ways of combining a few sources that would contribute towards a calibration for taro crops. Further experimental work is needed.

A spreadsheet version of the model was prepared and this can be adapted to use historic data from large scale soil surveys. This will give broad regional recommendations for farmers to share and gain some significant advantages. The recommendations can be provided to farmers through for example Samoa MAF's current extension network.

Within one or two years of this, farmers will need to move to a system that uses soil test results specific for their fields as these change from year to year. The best means to distribute site-specific recommendations will vary between islands. On some islands, cellphone text messaging may be superior to mail or face-to-face consultations, provided farmers are trained to interpret the recommendations.

We recommend that funding agencies develop a soil fertility service for island agriculture. The service could start as a pilot scheme on Samoa, extending to other nations as experience accumulates. Development of the service should be done through a stakeholder group that combines representatives of the farmers and MAF with scientific and technical support from the USP and NZ. The aim should be a service that is self supporting and enables farmers to gain sufficient income to afford their own fertilizers after a year of starting with the scheme.