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2 Executive summary

Declining soil fertility and biological soil health are thought to represent a major threat to sustainable agricultural development in the Pacific, as smallholders respond to economic incentives to supply growing urban and export markets, while lacking the technologies and knowledge to underpin the sustainability of these newly intensified production systems. This situation led the Secretariat of the Pacific Community (SPC) and the Queensland Department of Employment, Economic Development & Innovation (DEEDI) to propose to ACIAR a project (PC/2009/003) on *Improving Soil Health in Support of Sustainable Development in the Pacific*. The proposed project builds on an EU-funded and SPC-implemented program, *Development of Sustainable Agriculture in the Pacific (DSAP)*. The new project focuses on testing, with farmers, best-bet strategies for increasing soil organic matter, supported by developing research-based indicators that growers and extension officers can use to assess soil health status (including key chemical, physical and biological variables), as well as extension approaches to communicate soil health concepts and methods to growers. Internal review by ACIAR recognised the merit of the proposal and approved its further development but asked for further clarification of the cropping systems and pilot sites to be targeted, the research questions to be addressed, and the methods to be used. The present small research activity (SRA), PC/2010/038, was designed to supply this information over a six-month period.

Within the broader development **goal** of improving the economic and environmental sustainability of intensive smallholder crop production in the Pacific Region by developing strategies for improving soil health, the **purpose** of this SRA was to identify the cropping systems to be targeted, the sites for participatory research work and the indicators of soil health to be monitored. Specific objectives of the SRA were to:

1. Develop a research strategy for soil health in the Pacific.

This objective was achieved through an initial planning meeting held in Suva from 27-28 July 2010. The workshop reviewed previous soil health experiences from potential project partners and focussed on developing a more comprehensive research and extension plan for the project. These plans were further strengthened through dialogue with partners during country visits to identify pilot sites. The strategy is outlined in Appendix 1 and this report explains how the proposed project both tests some aspects of the strategy and contributes to its longer-term development.

2. Identify pilot sites for participatory research.

This objective was achieved by visiting potential pilot sites and discussing with the key stakeholders the cropping systems under threat, the main concerns of producers, and the flow-on effects of declining productivity and profitability to others in the broader community. These visits to Fiji, Samoa and Kiribati from 31 October to 18 November 2010, with follow-up communications, provided baseline data on the current situation in each country, identified experimental sites and local project champions, as well as agreeing on 'best bet' options for soil health improvement to be further evaluated through participatory research.

This SRA has already contributed to the understanding of production problems in the target systems. Its main impact will be achieved, however, via the improved design of project PC/2009/003 which is expected to have positive economic, social and environmental impacts through sustainable improvements in the productivity of the export taro industries (Fiji and Samoa) and vegetable production on atolls (Kiribati), as well as the banana industry in north Queensland.

The SRA concludes that soil health issues are at the root of production problems in these cropping systems and recommends an 'action-research' approach to tackling them.

3 Lessons learned during workshop and scoping study

3.1 Workshop

A workshop was held at SPC, Suva, 27-28 July 2010 and was attended by 18 staff from Australia, Fiji, Kiribati, Samoa and the Solomon Islands. The first day consisted of interactive presentations given by a number of speakers including: An overview of the current ACIAR project proposal (Richard Markham, ACIAR), 'The DSAP Experience' (Toki Bakineti, MELAD, Kiribati), 'Science of Soil Health' (Tony Pattison, DEEDI), 'Current Methods for Assessing Soil Health' (Ami Sharma, MPI, Fiji) 'Soil Health in the Pacific' (Stephen Hazelman, SPC) and 'Rationale for Selecting Pilot Sites' (Mike Smith, DEEDI).

In the afternoon we split into 4 groups and listed the key challenges and opportunities for soil health in the Pacific and each group gave a report of the discussions. Some of the key issues discussed included:

- **Disease infestation epidemics** affecting cash and staple food crops. Most of these problems have occurred when such crops have been grown as commercial monocultures. This issue can be addressed through adoption of appropriate systems of integrated pest/disease management both above and below the ground.
- **Ecological deterioration** in terms of accelerated erosion, coastal and inland deforestation, leaching, laterisation, overuse or shortage of surface and groundwater resources, soil and water pollution and loss of biodiversity. These problems must be addressed using conservation agriculture and environmental management strategies.
- **Ignorance of existing/traditional farm systems** with modern agricultural development often advocated without the 'developer' even understanding the ecological, economic and social importance, and rationale for the existing system. The need is to become familiar with traditional systems for managing soils, crops and organic matter and develop a farming system that meets commercial needs and corrects imbalances while being appropriate for the local farming community.
- **Declining terms of trade.** This is happening because prices of exports (i.e. mainly primary agricultural products) have progressively fallen relative to the costs of imported consumer and capital goods, including the agricultural inputs needed for the production of the export crops. The on-farm solution is to maximise self-sufficiency and minimise dependence on imported items.
- **Poor/unbalanced nutrition** amongst urbanized communities (e.g. South Tarawa) and cash croppers. Nutrition-related diseases are mainly due to a change from consumption of fresh local foods to the increased consumption of nutritionally inferior, imported, highly processed foods. The promotion of more diverse farming systems with a better balance between export crops and food crops for both local sale and subsistence use could address this problem.

The final day began with presentations involving examples of how soil health strategies have been implemented on-the-ground and were given from a research perspective (Stephen Hazelman, SPC, presented work on managing taro beetle), from an extension perspective (John Bagshaw, DEEDI, presented work on promoting soil health with the banana industry in North Queensland) and finally from a farmer's perspective (Peter Kjaer, Tei Tei Taveuni, presented experience with export taro production in Taveuni). Two parallel sessions were then held; one focussing on soil health indicators and methods, and the other on extension, social and economic methods. Towards the end of the day the two groups reported back with the purpose of developing a research and extension framework for the project, which has been expanded in subsequent sections of this report.

Among the candidate cropping systems and geographical areas proposed as potential case studies (pilot sites) for research, and meeting at least some of the criteria for selecting pilot sites, were:

- Australia, Queensland: Banana production (intensive, but with reduced pesticide input); (existing sites for DEEDI research)
- Fiji, Sigatoka valley or Tai Levu: Banana production for fresh market or processing (a system under intensification with support from SPC's Facilitating Agricultural Commodity Trade (FACT) project)
- Fiji, Navua basin: Ginger production for fresh export and local processing (intensification also supported by FACT; building on an earlier ACIAR project PC ACIAR PC/2004/049 - on managing soil-borne pathogens of ginger)
- Fiji, Sigatoka valley: Vegetable production for export (aubergines) or local hotel trade (SPC is involved in the latter through development of a Participatory Guarantee Scheme (PGS))
- Fiji, Taveuni and/or Viti Levu: Taro production for export (opportunity to partner with existing efforts of SPC and Fiji-MPI, Tei Tei Taveuni farmer association)
- Fiji, Sigatoka valley and Nadi: Red papaya production for export - conventional or organic (with ACIAR project PC/2008/003; and Nature's Way Cooperative)
- Kiribati, Tarawa: Peri-urban vegetable production for import substitution, supplying South Tarawa (support from SPC and Centre of Excellence in Atoll Agriculture)
- Solomon Islands: Vegetable production to supply the Honiara urban market and PGS to supply hotels (with ACIAR project PC/2005/077)
- Samoa: Taro export (with USP Taro Improvement Program, Samoa Ministry of Agriculture and Fisheries, Samoa Farmers Association and exporters)
- Samoa: Organic *misi luki* banana exports (with Women in Business Development Inc. (WIBDI))
- Samoa: Organic vegetable production (with WIBDI, under developing PGS to supply hotels and supermarkets).

These sites and systems in Kiribati, Samoa and Fiji were ear-marked for further consideration in site visits. For Solomon Islands, it was agreed that, with the ACIAR vegetable project due to conclude in 2011 and the legacy of DSAP technology and expertise dispersed, the platform was not sufficiently strong to support soil health research.

3.2 Scoping Study

Visits were made to Kiribati, Samoa and Fiji from 31 October to 18 November 2010. With a draft proposal (developed after the workshop) in hand, the purpose of the visits was to meet with project partners in their own work environment and assess their ability to undertake the research and extension program, conduct on-the-ground surveys of potential pilot sites, conduct simple soil tests and introduce some of the newer biological indicators to staff; an important objective in all three countries was to explain the project to senior management, farmers and other interested stakeholders. Although some participatory priority setting and exploration of options was undertaken with stakeholders, especially in Taveuni (Fiji), this fell short of the formal Participatory Rural Appraisal (PRA) foreseen; priority was necessarily given at this stage to establishing relationships with potential partners and selecting cropping systems and partners for research. The diagnostic PRAs, within the areas now selected, remain to be conducted at the outset of the full project.

3.2.1 Kiribati

Toki Bakineti was a key contact and he is a Principal Agricultural Officer with MELAD and stationed at the Centre of Excellence for Atoll Agriculture, Tarawa. The Centre's R&D mandate is to address the special challenges of atoll food production and water use efficiency, while addressing the most pressing development needs including food and nutritional security, climate change mitigation and sustainable management of the environment. Toki was instrumental in implementing the DSAP program in Kiribati and initiated a number of community-based agricultural initiatives that were very successful and presented in the SPC publication, 'Case Studies, Lessons from the Field: The DSAP Experience'.

One of the striking results from soil tests conducted during the scoping study was the very low levels of organic carbon in agricultural soils (less than 0.5%), poor water retention and high levels of lime-induced chlorosis of plants. However soil samples taken from traditional taro pits had the opposite characteristics and were a testimony to the power of composting and soil management in improving soil health in these atoll soils. We explored composting options and strategies in Tarawa and saw that organic matter, in many situations, was being taken away from the villages as municipal waste and could be utilised in small peri-urban vegetable gardens. Other sources from coconut wastes, leaf litter and seaweed could also be better utilized. A number of women's and youths' groups were involved in trialling a range of vegetable varieties under DSAP and similar community-based extension methods could be used to show the benefits of composting and soil management for improved vegetable production.

Of further interest is that Toki has been awarded a scholarship to undertake an MSc program at USP-Alafua (he would like to eventually upgrade to a PhD) and he wishes to undertake a research program investigating improvements to soil health in atoll agriculture. We therefore conclude that we have staff commitment, experience, facilities and support from management to undertake a soil health research and extension project in Kiribati.

3.2.2 Samoa

David Hunter, an experienced soil scientist and senior lecturer at USP-Alafua, was our main contact and liaison in Samoa. We also worked closely with Tolo Iosefa of USP, who leads Samoa's Taro Improvement Program (TIP), in collaboration with the Ministry of Agriculture and Fisheries (MAF). The main objective of the TIP is to come up with varieties that are acceptable to consumers (including buyers of Samoa's taro exports) and resistant to taro leaf blight, a disease that decimated Samoa's taro production in 1993 and has since largely excluded Samoa from its previously dominant position in the Pacific taro trade. A key strategy of the TIP is to distribute the progeny of breeding crosses at an early stage to an established network of farmers for their evaluation of the new materials.

A workshop was convened at USP, bringing together representatives of the Samoa Farmers' Association, taro exporters, and researchers involved in high-value crops and soil fertility research. It was not possible during the visit to make contact with the groups involved in *misi luki* banana exports and although representative of the organic vegetable production group attended the workshop, it became clear that they already have a soil fertility strategy based on liquid fertilisers and technical support provided by Organic Matters Foundations (a Queensland-based NGO). From the workshop it was therefore decided that our focus would be with the taro export farmers and that experimental work could focus on farmer involved in the TIP network, who are accustomed to work with researchers and have a strong interest in testing and adopting soil improvement measures.

While in Samoa six taro farms were visited, as was a taro pack-house, currently operated by MAF staff, as part of their support to private sector growers and exporters, in their concerted effort to re-establish Samoa as a major taro exporter. More formal meetings

with leading figures in the industry were arranged both at the University and in a taro farming village on the southern end of Upolu.

The pack-house visit showed considerable corm and root damage that appeared to be caused by soil-borne pathogens, particularly nematodes. Discussions with farmers and industry figures revealed that there has been a decline in A-grade sized taro, that there are mounting concerns about deforestation as farmers try to move into the foothills (in search of more fertile soils for taro production), and at least some of the farmers at the stakeholder meeting were emphatic that a 'soil health' issue is at the root of their problems. A recent MAF newsletter article sent to us by an Australian Volunteer, Ros Jettner, whom we met at the pack-house, showed a strong yield response of taro to organic matter.

At the taro pack-house, we were also able to meet up with Mr Roy Masamdu (SPC - Biosecurity and Trade) who was conducting an ACIAR scoping study under SRA PC/2010/032 *Defining the quarantine environment for Pacific horticultural exports*. This provided an opportunity to plan close collaboration between project PC/2009/003, which is expected to produce, as an outcome, higher quality taro with lower pest and disease loads at the farm gate, and Mr Masamdu's planned project, PC/2007/118 *Developing cleaner export pathways for Pacific agricultural commodities*, which will develop better handling of export taro from the farm gate onwards.

We conclude from these various elements that: research is needed to investigate soil health issues in taro production in Samoa; several farmers involved in the TIP network are ready to undertake pilot investigations; and that there is a willingness among farmers to adopt practical measures that improve taro production. Furthermore a strong research team exists at USP-Alafua, backed-up by a well-run soil testing laboratory, to undertake these studies. It is complemented by the extension network provided by MAF which is already strongly committed to the effort to rejuvenate Samoa's taro exports.

3.2.3 Fiji

The Australian project team made a visit to the Sigatoka Valley to examine banana farms along the river's flood plain but determined that production constraints were related to poor management practices rather than being primarily of a soil health nature. However, a Fijian researcher under the ACIAR-USP scholarship scheme is already conducting research on the relationship between soil organic matter and nematode infestation in Fijian banana production, linked to this SRA and with advice from the Australian team, so these results will be available in due course to the soil health project. This arrangement provides a model for broadening the approach of the soil health project, in due course, to other cropping systems and validating the approach on different soils and with different crops. The team also visited a major red papaya exporter (working with ACIAR project PC/2008/003) and an aubergine exporter; however, there was no indication that soil-borne pest and disease problems or soil fertility were of major concern.

On the other hand, when the team toured some of the taro production areas on Taveuni, Fiji's main export taro region, soil-borne pathogens such as *Pratylenchus coffeae*, *Meloidygyne* spp., root-infesting mealybugs (provisionally identified as *Paraputo* sp., probably *leverii*) and unspecified root rots were observed. Any one or combination of these soil-related problems could account for poorer taro yields and failure to meet export size grades.

A taro farmers' meeting was held at MPI's research station on Taveuni on 12 November 2010 and was attended by about 40 farmers, together with MPI's research and extension staff, SPC and DEEDI project staff. Rohit Lal, Siosuia Halavatau and John Bagshaw facilitated discussions and we were able to determine that:

- Taro contributes approximately \$16M to Taveuni's (and Fiji's) economy but rejects have climbed from 5% to 30-40% in recent years. The importance of taro production to the island's economy and its importance to the 17,000 residents was highlighted.

- A taro commodity profile, with gross margins for export taro, was tabled.
- Challenges and opportunities for taro production were discussed. Tei Tei Taveuni, a progressive farmers' association, highlighted the work they are doing with their 'Soil Schools' and mentioned the support they are receiving from AusAID in their cyclone recovery efforts. They wish to lend support and see complementarity between their own work and that of the ACIAR project.
- The majority of farmers were very interested in the ACIAR project and we openly discussed issues relating to soil health, the importance of organic matter in their farming systems and ideas for implementing some 'best bet' action research.

The next few days were spent visiting existing field sites, and potential new sites, at three locations on the island and discussing work with the lead farmers in the community. Taro was examined from both good and bad patches, soil samples collected and analysed, and the awareness of soil health in controlling diseases and pests highlighted. It was particularly gratifying to see 'the light go on' in the heads of extension officers and growers as we were able to show the relationship between low labile C levels, low taro yield and increased incidence of soil-borne pathogens, and conversely, the opposite result with higher inputs of organic matter.

In Taveuni, we believe we have a good grasp of the situation leading to yield decline in taro and we, the project team, feel confident we can resolve the problem and achieve good adoption of the project results by the taro growing community, as well as generating research results that will serve as the platform for soil improvement strategies that can be more broadly applied in the Pacific islands.

3.3 AusAID collaboration

In Fiji, the project team had an opportunity to discuss current AusAID support (and that of other donors), both with soil health research partners and with the Program Manager, Economic Growth and Rural Development, of AusAID-Fiji, Mr Malcolm Bossley. An AusAID program, initiated as part of a post-cyclone recovery effort, is already supporting on-farm research relating to soil fertility in taro production in Taveuni, carried out by Fiji-MPI, with support from SPC and USP-Alafua. Currently this work is focusing on trialling the use of *Mucuna pruriens* (velvet bean) as a fallow/rotation, with and without the addition of mineral fertiliser. Our project team has offered input to the design of these trials and AusAID is keen that we should strengthen the technical support for this work through the new soil health project, which AusAID has now agreed to co-fund.

In addition, the Tei Tei Taveuni farmers' group has successfully applied to the Global Environment Facility of the United Nations Development Programme, with support from NZ Aid, to support farmer 'soil schools' (initially for 175 farmers), to be followed up with on-farm visits and demonstrations, soil chemistry testing, tree planting and conservation awareness. The soil schools will provide an excellent testing ground for extension approaches for soil health concepts and practices, from the ACIAR soil health project, and the participation of our soil health team with greatly strengthen the on-farm research component of this work.

To further reinforce the farmer training and technical support effort, Tei Tei Taveuni have applied to Australian Volunteers International (AVI) for a volunteer to assist in this work. The application has been positively received and selection of a volunteer will be undertaken in early 2011, with a view to the person starting work in mid 2011. As a result of these discussions, the support for the AVI position will be provided through the ACIAR soil health project and this cluster of training activities will be closely coordinated with our research effort.

4 A research strategy for soil health in the Pacific

4.1 Rationale

The discussions conducted with stakeholders and potential partners, allowed the SRA team to draft a 'Soil Health R&D strategy for the Pacific Islands' (Appendix 1) considering both longer-term regional objectives and the kind of immediate strategy that could be used to address 'production systems in crisis' - where evident problems provide an 'entry point' to engage with farmers on soil health issues and an incentive for farmers to change their current practices.

The soil health concept is well-grounded scientifically on accepted principles and practical experiences in Australia, the United States and elsewhere in the world - and in these countries is gaining mainstream recognition. In the Pacific, however, the practical demonstrations of the effectiveness of soil health approaches have been quite limited and poorly documented. Thus, although there is some support for soil health approaches among R&D leaders and among specific sectors of the horticultural industry in the Pacific (especially those involved in the Pacific Organic movement), the dominant paradigm in the research and extension community in the Pacific remains that of conventional soil science (and market incentives to boost production). In view of the rapid erosion of the natural resource base that is occurring, as Pacific islands seek to intensify agricultural production to meet economic aspirations, without in general being able to offer growers new and more sustainable technologies to underpin this intensification, changes in production practices and land management are urgently needed.

Whereas conventional approaches to soils research have tended to focus on the physical and chemical *properties* of soils and, perhaps, the function of soils in plant nutrition and water relations, a 'soil health' approach focuses explicitly on the *functions* of soil - including plant nutrition and water relations, but giving attention also to biological processes and to the 'ecosystem services' provided by soils, for instance in the biological suppression of soil-borne pests and diseases. Although these underlying processes may be complex, hard to measure directly and difficult to understand completely, considerable practical progress can be made in solving soil-related production problems through adaptive research, especially to restore the biological functions of degraded soils.

Such research, based on soil health concepts, will focus on selecting those soil improvement tactics, chosen from a range of options that have proven effective elsewhere, that are best adapted to local social and environmental conditions. Emphasis must be placed on cost-effectiveness, especially return to labour, and all costs and benefits need to be well quantified and documented, so that experiences gained in pilot sites can be used as a model for developing and advocating solutions for comparable problems elsewhere. Emphasis is also placed on the development of 'indicators' that can be used by researchers, extension workers and farmers (at least the more progressive among them), to monitor their progress towards restoring the biological health of soils. Because soil processes can be cryptic and hard to measure directly, these indicators need to be rapid, inexpensive tests that can provide evidence of the current status of soils. Finally, emphasis needs to be placed on developing appropriate participatory research and extension techniques for communicating soil health concepts to farmers and their intermediaries and, in due course, enabling them to use soil health principles and practices to solve production problems.

A concept for soil health interventions to change current unsustainable management practices and improve soil health status is presented in Figure 1.

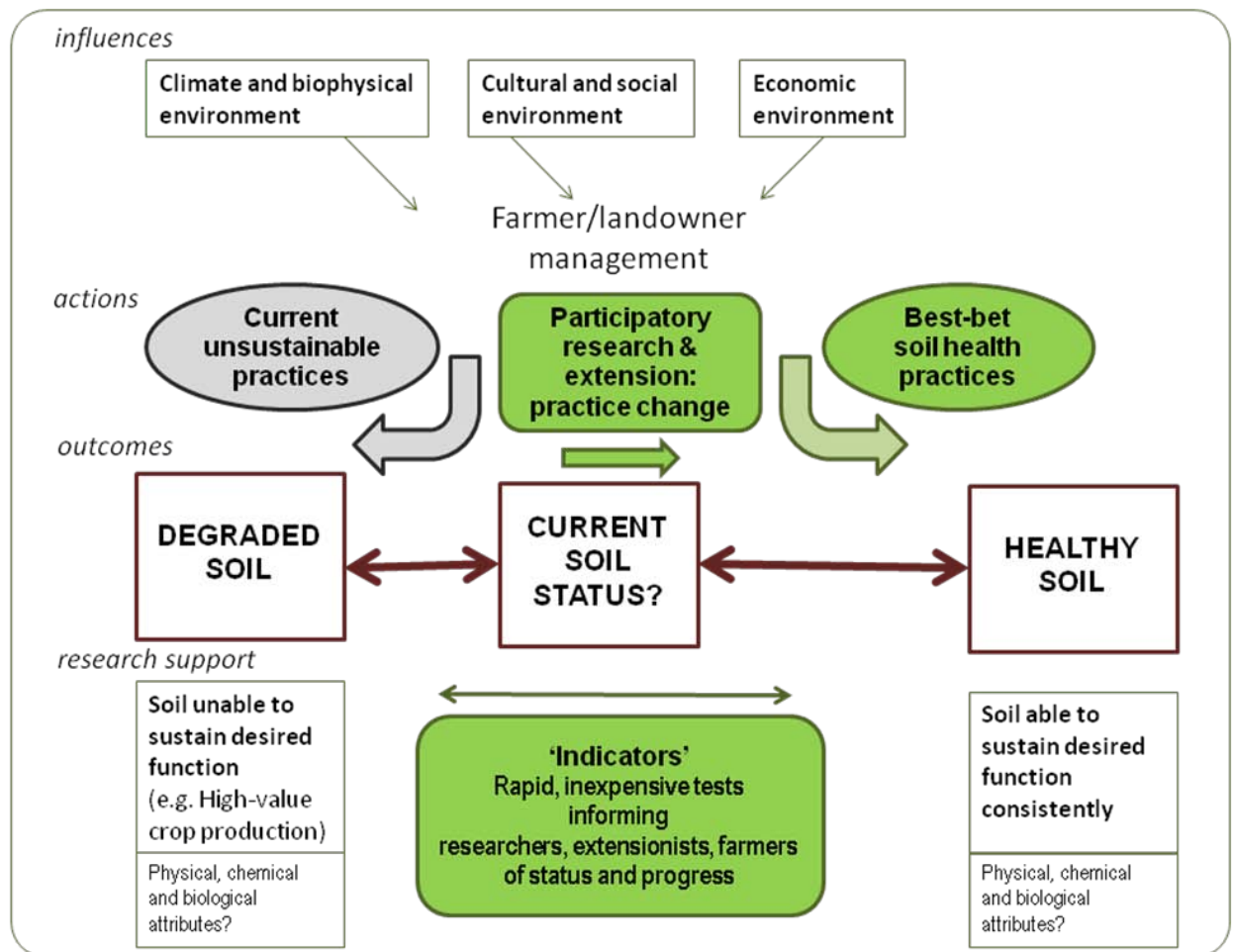


Figure 1. Concept for R&D interventions to improve soil health. Main project domain indicated by green shading.

4.2 Development of the ACIAR soil health project

Based on this rationale and the outline strategy developed during the course of the project workshop in Suva, as well as visits to potential pilot sites in Fiji, Samoa and Kiribati in July 2010 and November 2010, respectively, the proposal for PC/2009/003 on *Improving Soil Health in Support of Sustainable Development in the Pacific* (hereinafter "the Soil Health project") was substantially revised and submitted for external review on 23 November 2010. The proposal was reviewed by three eminent soil scientists with experience of working in the Pacific. All three agreed the project was within ACIAR's mandate of bringing Australia's research capacity to bear on problems of the developing countries and were generally supportive of the project. They did, however, suggest some areas where the project could be further strengthened and these suggestions were incorporated in the project document. This revision was submitted to ACIAR on 18 January 2011 for Small Group Review and further suggestions were made. These suggestions have again been incorporated in the revised project document (PC/2009/003) along with changes arising from the conclusions and recommendations of this SRA.

4.3 Contribution of soil health project to the Pacific strategy

The Soil Health project is expected to make a major contribution to the longer term strategy in the following areas:

- **Individual and institutional capacity building in soil health research**

One MSc student has already begun thesis research (on nematodes in banana production in Fiji) under the ACIAR-USP post-graduate scholarship scheme, in conjunction with the present SRA.

At least two more students from the 2011 intake of the same scholarship scheme are already planning thesis research in conjunction with the soil health project and it is anticipated that a similar rate of involvement may well continue in subsequent years.

In the context of institutional capacity building at USP-Alafua, David Hunter is already an experienced soil scientist but will gain extra knowledge of biological aspects of soil health research through interaction with the DEEDI project team; other Faculty members (Tolo Iosefa, agronomist, and Rupeni Tamanikayiaroi, plant pathologist) will also gain hands-on experience of soil health approaches through participation in the project team. Together, this team, and their supporting technical staff, will represent considerable institutional capacity to promote soil health research among future intakes of post-graduate students at USP-School of Agriculture and mainstream the teaching of soil health concepts in agriculture at undergraduate level.

At SPC, the participation of Tony Gunua, Theme Leader for Crop Health in SPC's Land Resources Division and already an experienced plant pathologist with specific experience of soil-borne diseases, along with technical support staff, will help to ensure that soil health concepts and research methods become part of SPC's core capacity, with long-term spill-over benefits for other project development and training efforts in partner countries.

In Kiribati, the involvement in the Soil Health project of Toki Bakineti of the Centre of Excellence in Atoll Agriculture will help to ensure that soil health research approaches will be mainstreamed in the research and training agenda of the Centre, which is expected to grow substantially in coming years, with resulting spill-over in atoll partner countries.

At the national level, at Fiji-MPI, Mereia Fong has already gained a range of soil health research skills through participation in an earlier ACIAR project (PC/2004/049) on managing soil-borne pathogens of ginger, under the guidance of the present Australian team leader; the participation of Principal Research Officer, Poasa Nauluvula, and various technical support staff, in the Soil Health project will continue to build this institutional capacity.

- **Individual and institutional capacity building in participatory research and extension approaches to disseminating soil health concepts and practices**

At the national level, involvement of staff from Fiji-MPI, Samoa-MAF and Kiribati-MELAD, will provide them with first-hand experience of participatory research and extension approaches to promoting soil health, as well as immediate access to training materials designed for their specific cropping systems and environments.

Similar considerations apply at the regional level to SPC, USP-Alafua and the Centre of Excellence for Atoll Agriculture.

- **Strengthening of support services**

- diagnostic laboratory services

The soil chemistry laboratories at Fiji-MPI (Koronivia) and USP-Alafua were consulted during the current SRA and both will be involved in the soil health project as service providers and research partners. The project will provide the opportunity to improve facilities slightly at both laboratories with some purchases of small equipment and supplies relevant to soil health research. There will also be an opportunity to compare the results obtained from these national labs with data from analyses using more sophisticated equipment at James Cook University.

- biological support services (taxonomy/identification, diagnostic research)

Because of the diverse and hard-to-foresee nature of biological soil health problems, effective diagnostic support depends on establishing extensive informal networks of experts in specific research areas and taxa.

The DEEDI team offers specialist expertise in plant parasitic nematodes and their antagonists (other nematodes and microorganisms in 'suppressive' soils). Sampling and research undertaken with Fiji-MPI Koronivia research station has confirmed that parasitic nematodes, in particular *Pratylenchus coffeae* and *Meloidogyne* spp., have contributed to taro root damage observed in the field in Taveuni. The Australian team leader has also established effective links between Fiji (Koronivia) and Queensland (University of Queensland) for diagnosis of problems associated with *Pythium* spp. (under project PC/2004/049) which are also likely to be relevant to the new project.

For the Pacific region, SPC's Crop Health team plays a vital role both in conducting its own diagnostic research (as at present on pathogenicity of an organism affecting papaya, under project PC/2008/003) and in linking up with international laboratories providing various identification and diagnostic services. This role will be strengthened through the Soil Health project and through another ACIAR project under development, PC/2010/090 on *Strengthening Integrated Crop Management (ICM) research capacity in the Pacific Islands in support of sustainably intensified production of high-value crops*.

During this SRA, a previously unreported mealybug problem on taro in Taveuni was documented, leading to the identification of the organism as a *Paraputo* sp., morphologically intermediate between the previously described species *P. leverii* and *P. aracearum* (G.Watson, pers. comm.).

- **Communicating soil health challenges, opportunities and advances to decision-makers (at various levels)**

As noted above, soil health approaches already enjoy a level of support from senior decision-makers in the Pacific which is perhaps surprising given the limited adoption of soil health practices so far in evidence in the region. The project can nevertheless capitalise on this opening by documenting as case studies the experiences that will be gained at the soil health project pilot sites. Well documented examples of positive soil health impacts will help to encourage support for soil health work at the policy and planning level. The involvement of Emil Adam, theme leader for Information, Communication and Extension (ICE) at SPC, in the project will contribute significantly to this objective since SPC-ICE is a major provider of agricultural information support at all levels to governments and R&D organizations in the Pacific region.

The principal and immediate contribution of the ACIAR Soil Health project will be to test the effectiveness of an action-research and extension approach to solving acute problems in high-value Pacific cropping systems brought on by incautious intensification - as set out in Appendix 1 (strategy for systems in crisis) and in Figure 1, above.

4.4 Soil Health project: research questions

The project was conceived as building on the lessons learned during an earlier project, *Development of Sustainable Agriculture in the Pacific (DSAP)*. This SPC-led project involved sixteen Pacific Island countries and had considerable success in introducing participatory research and extension approaches to diagnosing crop production problems and developing solutions that could be adopted at community level, including technologies for mitigation of declining soil fertility and erosion. While the process of diagnosis and capacity building conducted by DSAP has been well documented and there are anecdotal accounts of the adoption of technologies promoted by DSAP - such as the use of *Vetiver*

grass and the planting of multi-purpose agro-forestry trees - there is little quantitative documentation of the impacts of the project. For instance, only one study reported a highly positive return, in this case from the use of *Mucuna* (velvet bean) as a fallow rotation, suppressing weeds and adding organic matter and nutrients in squash production in Tonga. On the other hand, whether the adoption of DSAP soil improvement technologies really was weak or just poorly documented, the project appears to have had an effect in raising awareness of soil degradation issues and has left behind a widely distributed cadre of people interested in pursuing soil improvement work.

The present project therefore takes as its point of departure the proposition that:

- current problems (low productivity and quality; high incidences of soil-borne pests and diseases) in intensive production systems for high-value crops in the Pacific are primarily attributable to depletion of soil organic matter (leading in turn to a 'cascade' of secondary problems, such as: poor nutrient retention; loss of structure and poor water infiltration; a loss of microbial activity and, with that, a breakdown of biological services, including suppression of pathogenic organisms).

This leads us to pose two over-arching (and closely linked) research questions to be addressed by the soil health project:

1. Can tactics that decisively increase (or restore to previous levels) the amount of Carbon in the soil restore productivity and reverse this suite of problems?

2. Will growers who have access to

- soil improvement technologies that demonstrably increase productivity and
- evidence that these tactics are cost-effective (in terms of providing a positive return to effort);
- an understanding of soil health concepts and practices (provided by well-designed extension materials and well-trained extension staff); and
- tools (indicators) to measure the improvement in soil health status...

then adopt farm management practices that measurably improve soil health?

These propositions will be tested through the development of a 'package' of 'best-bet' tactics whose adoption (or not) will be advocated and tested in three pilot sites in the Pacific: taro production for export in Taveuni, Fiji; taro production in Upolu, Samoa; and vegetable in South Tarawa, Kiribati. A fourth pilot site, with banana growers in Queensland, who have already begun to adopt soil health practices, provides a foundation for this work.

A series of more specific research questions are addressed at the activity level:

Benchmarking:

- What is the current status of taro farm soils? (As judged by conventional physical, chemical and biological measures, on a continuum from degraded to healthy)

Diagnostic research (pest and disease problems):

- What is the relationship between soil organic matter (various kinds); abundance of, and damage attributable to, plant parasitic nematodes; root mealybugs; and root rots?
- Are additional tactics (e.g. management of mealybug-attendant ants) necessary to reduce pest incidence to acceptable levels?

Development and evaluation of indicators:

- Do results from indicators (i.e. simple, low-cost tests) correlate adequately with more complex/expensive conventional tests in describing current status of soil? (in context of deterioration towards degraded soil or improvement towards healthy soil - see schema)

Evaluation of best-bet soil improvement tactics:

- What are the impacts of the soil improvement tactics on:
 - a) soil physical, chemical and biological attributes? (as measured by conventional test)
 - b) crop yield and crop quality? (as measured by weight of marketable roots per plot or per plant, and rejection rate of roots)
- Do economic benefits (value of increased marketable yield) from soil improvement tactics cover costs (labour and other inputs) of carrying them out?
- How do farmers value/evaluate the benefits achieved and the costs of achieving them?

Capacity building among growers and intermediaries:

- Does the extension approach developed by the project increase the understanding of soil health concepts a) among extension service providers and b) growers?
- Following soil health 'training' (various kinds - 'soil schools', participatory soil healthy research...), are growers more likely to adopt soil health practices?

4.5 Aim, objectives and *modus operandi* of soil health project

Based on the previous analysis, the ACIAR project is designed to contribute to the broader development goal of improving the economic and environmental sustainability of intensive smallholder crop production in the Pacific Region. Its specific aim is to develop strategies for improving soil health in selected Pacific cropping systems. It has three objectives:

1. To elucidate crop production and related soil health problems at specific pilot sites and develop physical, chemical and biological indicators underpinning an integrated approach to improving soil management.
2. To evaluate 'best-bet' soil improvement practices for sustaining intensive Pacific crop production.
3. To increase the capacity of growers and their service providers to understand soil health concepts (including physical, chemical and biological processes) and apply them for sustained productivity.

The project will be centred around a participatory 'action research' approach to evaluate, on farmers' fields, the most appropriate strategies for improving soil health and sustainably increasing soil fertility; evaluation, by researchers and farmers, will involve measurements of crop yields and soil attributes (physical, chemical and biological), and assessment of costs and benefits of such actions. In parallel, the value of 'indicators' (i.e. provided by quick, inexpensive tests) to researchers, extension workers and growers will be assessed, as a means to assess current soil status and monitor progress towards soil health.

To prepare for the action research, some further detailed consultation will be required with the farmer groups (in the context of a PRA) to select representative experimental plots and lead farmers. Discussions, literature reviews and direct observations undertaken during the SRA indicate that the over-riding priority for improving soil health is to increase

soil organic matter (in both taro export systems on volcanic soils and vegetable production in atoll soils). Identifying adequate sources of organic matter that can be accessed at reasonable cost, however, can be a major challenge in island environments; although some 'best-bet' materials and strategies have been provisionally identified in the course of the scoping study (see below), these will also need to be further refined in the course of initial farmer (and extension officer) consultations. These initial consultations will also provide an opportunity to benchmark current knowledge of, and attitudes towards, soil health. Finally, the 'action research' approach will provide the opportunity to carry out in parallel some diagnostic research on specific issues (such as the nematode damage, rots and mealybug infestations of taro noted during this SRA).

Some relevant extension materials are already available from existing work on soil health in banana systems in Queensland and other experiences elsewhere. However, extension materials and approaches will be refined during the project to provide growers and extension officers with both an understanding of soil health concepts and the practical means to monitor and improve soil health in their own context.

Expected outputs of the project are an enhanced understanding of the role soil biology plays in sustaining productivity, along with strategies and best practices for improving soil health in key cropping systems, and soundly-based indicators appropriate for monitoring the health status of soils by researchers, extension officers and smallholders. The capacity of farmer intermediaries to understand soil health concepts and to use participatory methods in support of helping farmers to improve soil health will be enhanced. An outcome of this capacity building will be that growers themselves are able to use soil health concepts and practices to sustainably improve the productivity of crops. An output of this part of the project will be a better understanding of the motivations and constraints of growers in adopting soil health practices.

Community-level impacts of the project will include more sustainable incomes from key commodities (taro, vegetables and bananas) with reduced environmental impacts from agriculture (including reduced clearing of forests due to improved taro yield), more efficient use of agricultural inputs, and reduced soil erosion. In Kiribati, food security and improved nutrition will be fostered by developing more resilient and sustainable vegetable production systems.

5 Characterization of pilot sites and identification of practices to restore soil health

Following the decision (above) to focus on pilot sites in Fiji and Samoa (taro, grown on weathered basalt soils), Kiribati (vegetables in a coral atoll environment) and Australia (banana on an alluvial plain), the SRA team began the PRA process (in the Pacific island sites), to diagnose the soil constraints faced by land holders, their current management and information systems and barriers to adoption of improved soil health practices. The team made a preliminary selection of soil physical, chemical and biological indicators (at different levels of sophistication for different stakeholders) that can be used in developing soil health management strategies. These will need to be further developed and evaluated in the course of the soil health project. An initial selection of 'best-bet' soil improvement and management tactics was also made at each site but these will need to be further refined and validated in formal PRAs during the early stages of the project. An initial review of information packages and extension techniques available was undertaken but these will need to be modified and further developed in the course of the project to assist growers and their intermediaries to develop sustainable soil health management practices for tropical crops in the Pacific region.

5.1 Selection of partners and agreement on strategy

The PRA has largely been completed for Taveuni, but there is a need for further engagement of taro growers and peri-urban communities in Samoa and Kiribati, respectively. Soil samples will be taken to set a benchmark of physical, chemical and biological soil properties and to evaluate the characteristics of the production system currently being used.

The selection of lead farmers and experimental plots will be done with the project team working closely with regional government extension teams to implement a locally acceptable and participative strategy. The aim would be to involve the local farming community as much as practically possible in the selection process.

In Fiji, the local Ministry of Primary Industries (MPI) extension team in Taveuni will conduct community meetings allowing the farming community to select likely pilot site farmers by vote, and, as is the way in these communities, other farmers would then be involved in preparation, planting and maintenance of the sites.

In Samoa, an initial community and environment assessment will be needed to determine the most efficient and acceptable approach for pilot site selection to enable maximum diffusion of site results. However, the farmer network established by the Taro Improvement Program provides an advanced starting point with well-established communication in place, along with mapping of sites and some characterization of farmers' holdings and crops. Staff from the University of the South Pacific (USP-Alafua) and the Ministry of Agriculture and Fisheries (MAF) will facilitate these discussions.

In Kiribati, the process would be conducted by extension staff from the Centre of Excellence for Atoll Agriculture. Candidates for participatory research and training will be selected at a community meeting following pre-meeting awareness activities by the extension staff. Initially sites will be restricted initially to the peri-urban regions of South Tarawa, with possible extension to other Tarawa and outer island sites later. In addition to working with spatially representative communities, groups to be targeted will include youth groups and the Women's Federation who have a centre in South Tarawa. Local extension staff will advertise the experimental sites with regional communities and conduct regular field days at these sites.

5.2 Development of soil health Indicators

An objective of the project is to identify key physical, chemical and biological soil health indicators that are linked to the major soil constraints identified in the course of the PRA. Such indicators must be suitable for use by smallholder growers and their intermediaries in the Pacific to monitor progress. The aim would be to develop indicators at different levels of sophistication from simple qualitative tests for use by growers, to tests that could be conducted by service providers (or, in some cases farmers themselves) after training, through to emerging techniques that could serve as useful research tools. In particular, low-cost methodologies for measuring soil health (such as soil biochemical test) are being developed by DEEDI, which would allow a continuation of the measurements beyond the life of the project by service providers in the Pacific. However, these techniques require validation and refinement for different laboratories and calibration against current methods.

Physical indicators would include characteristics such as texture, bulk density, infiltration and aggregate stability. The tests would be conducted on samples collected from farms.

Chemical indicators would form part of a standard nutrient test that are commercially available, or from government/university laboratories in the Pacific, and would include extractable nutrients, organic C, pH, CEC. Special attention will be needed to identifying tests that can be conducted reliably and at an affordable price by service providers in Pacific countries.

Biological indicators would need to be selected that are sensitive to management changes and that are relevant to soil functions, such as disease suppression or nutrient recycling. The biological indicators could be selected from biochemical tests such as labile C, fluorescein diacetate (FDA), β -glucosidase; bioindicators such as weeds, earthworms, insects and analysis of nematode community diversity and structure; and molecular tests such as T-RFLP (terminal restriction fragment length polymorphism) to better characterize microbial communities.

A suitable foundation is provided by the Cornell University Soil Health Test (CUSHT) which includes a range of tests that have been found to be:

- reasonably priced,
- require minimal infrastructure to perform the tests,
- identify constraints in specific soil processes that go beyond nutrient deficiencies,
- provide practical management strategies specifically targeted at the soil constraints,
- allow farmers to monitor their soils over time and develop responsive strategies prior to degradation occurring and
- are easy to interpret.

This approach has already been found to have merit in the context of Australian banana and vegetable industries and will be modified for use in the Pacific.

5.3 'Best-Bet' management practices (Objective 2)

'Best-bet' management practices for cropping systems that overcome identified soil constraints and improve soil, economic and environmental indicators will be developed and tested on farmers' fields through participatory 'action research'.

Studies will be conducted initially at pilot sites with crops and soil types common to the region (i.e. taro on weathered basalt slopes in Fiji and Samoa; and vegetables on a coral atoll in Kiribati) but will ultimately lead to applications in a wider range of sites and farming systems. One site in Australia, alluvial plains, using the banana industry as model, will also be used as a contrast to the Pacific situation. In Australia a site for the 'best bet' management practices will be established using practices such as minimal tillage, cover crops and retention of crop residues to prevent the decline in soil health indicators and promote improved agronomic characteristics of bananas. Furthermore, banana growers will be engaged to establish some or all of the components of the best-bet management practices on their farms, which will be monitored for changes in soil health indicators over the life of the project.

Cropping systems and areas for the pilot studies have been identified during the SRA but exact sites will need to be determined in consultation with local communities. The treatments to be evaluated at the sites will be determined during the PRA in consultation with smallholders to ensure that they are practical and they are conceived as demonstration activities requiring community input into planning and planting. A key activity will be to review the organic residues available (both green manure and composts) and their characteristics and costs. The management strategies evaluated will aim to increase the economic and environmental sustainability of crop production and land management.

Treatments provisionally identified for further research in a taro farming system are:

- management of residues from fallow and weeding (generated by herbicides or hoeing)
- *Mucuna* green manure cover crop (supplemented or not with inorganic fertiliser); this is the main focus of existing MPI/TTT/SPC trials and therefore accessible for monitoring using the project's indicator toolkit but may not need to be incorporated as specific treatments in the project's own on-farm research
- residues from multipurpose trees/shrubs (*Gliricidia*, *Inga* etc) grown on field margins, and used as a top dressing or shredded and incorporated
- 'cocopeat' from grinding of low-density coconut wood (available as a by-product of coconut replanting operations or milling of cocowood products)
- biochar from low density coconut wood chips or other organic matter (e.g. coppicing of *Gliricidia*, *Inga* etc).

Treatments provisionally identified for further research in atoll vegetable systems are:

- residues from weeding and fallen leaves (breadfruit etc) as mulch/top dressing, in trench before planting or composted
- residues from multipurpose trees/shrubs (*Gliricidia*, *Inga* etc) grown on property boundaries and applied as a top dressing or shredded and incorporated
- domestic/urban organic waste, shredded and/or composted.
- seaweed collected on shores (and suitably leached to reduce salt).

Measurements of physical, chemical and biological indicators will take place at the pilot sites and changes in soil properties documented. Erosion control will also be an important factor in the development of best management practices, particularly in the Australian context (since Pacific agriculture already tends to involve minimum tillage). This information will also be used to determine the sensitivity of the indicators to soil management practices. It will also be used to demonstrate the holistic interactions which occur in soil health management.

Some simple Cost Benefit Analysis (CBA) will also be used in the evaluation of 'best-bet' options. For instance, we would want to know:

- what is the economic cost to the farmer, measured in terms of reduced productivity or smaller sized taro corms (and the reject rates by the market), of poor soil health? and
- are the extra inputs (labour/organic matter) required to maintain good soil health, justified by an increase in productivity and therefore financial reward? i.e. is the additional financial return greater than the cost of the additional inputs (time and money)?

There will be some soil management techniques that might prove more labour intensive (i.e. producing composts and incorporating into the soil) and others that might be relatively easier (using weedy fallows), and therefore time/cost effective. These might not produce the very best results in terms of soil health, but may be more likely to be taken up by farmers because of their effectiveness from a CBA perspective. These issues will be explored and will inform best and most appropriate practice.

A more complete evaluation of the cocopeat vs. biochar options may be appropriate in Taveuni, in view of the substantial capital investment that these processes imply. This could include the evaluation of the 'carbon footprint' of these processes (in view of the fuel and machinery required to prepare the biomass) and exploration of the possibility of selling energy (biogas or electricity) produced as by-products of pyrolysis, to offset costs and increase the economic sustainability of these options.

In Australia current practices include both monoculture of banana and rotation with other crops. Evaluations of 'best-bets' could involve comparing:

- replanting bananas immediately versus leaving a fallow period;
- minimum-tillage versus full knock-down cultivation; and
- rebuilding the beds using a companion crop versus bare soil in the plant crop.

The expected outcomes in Australia are expected to include increased use of fallow crops to build soil organic carbon, reduced mechanical cultivation and increased use of intercropping with companion grasses to reduce erosion and reduce soil degradation.

5.4 Enhancing capacity to apply soil health concepts (Objective 3)

This objective involves developing a system that allows landholders to receive information, increase their knowledge of soil health management and apply this knowledge for greater productivity and sustainability. Different information packages and delivery protocols will be tested at pilot scale in the soil health project to give growers an opportunity to determine the best means of receiving information to meet their needs. This should accelerate adoption and increase the knowledge of smallholders.

Training of landholders, farm advisors and agricultural service providers will take place at pilot scale within the project (and more broadly as an outcome, and as part of the impact pathway of the project) to build the capacity of the agricultural community to adopt and understand soil health practices. It will allow the information from soil health testing to be interpreted and extended through local communication networks.

Over the course of the project, it will be important to develop a longer-term communication strategy that will help landholders to receive information more efficiently and increase their knowledge of soil health management. Such a strategy will guide the research-and-development efforts of their service providers. A strategy will include promoting to growers the value of improved soil health (by explaining and/or demonstrating the benefits to be expected), identification of soil health constraints on their land, identification of management practices that may be able to overcome soil constraints and identification of the appropriate indicators to monitor changes in soil health properties.

The ultimate intended beneficiaries of this project will be smallholders, who will be provided with communication and information resources targeted to meet their needs. However, this will be achieved at least in part by building the capacity of industry service providers to use appropriate educational strategies, to ensure that they have access to reliable information and to strengthen their information networks. It is anticipated that information packages will be made available based on formats from previous projects for banana and vegetable growers, but the culturally most appropriate methods for communicating information and building knowledge will also be pursued within the project. The information will be updated and re-focused to ensure its relevance to growers in the Pacific islands and in a format that will facilitate uptake and adoption.

6 Impacts and adoption pathways

The impacts of this SRA will be mainly via the improved design of project PC/2009/003 which is expected to have economic and social impacts through sustainable improvements in the productivity of the taro export industry and vegetable production (Pacific islands) and banana industry (Australia), with improved and more secure livelihoods of those communities dependent on them, and reduced negative environmental impacts.

Initial products of this SRA include:

- Consensus- and evidence-based selection of pilot sites to be used for further soil-health research (where evident soil-related problems provide an 'entry point' to engage with farmers on soil health issues and an incentive for farmers to change their current practices, combined with the availability of appropriate capacity among R&D partners to undertake this work);
- Preliminary diagnosis of the problems affecting these targeted 'systems in crisis' in the Pacific islands (export taro and peri-urban vegetables), confirming that they are soil related and characterised by critically low soil carbon levels (taro and vegetables), and high incidence of damage by nematodes (taro);
- Identification of a previously unreported problem caused by root mealybugs (*Paraputo* sp., probably *leveri*), associated with under-size and mis-shapen taro roots in Taveuni, Fiji (Figure 2);
- Establishment of appropriate partnerships (involving research, extension and farmer organizations) to sustain the proposed research; and
- Consensus on the research strategy to be used, as embodied in a revised proposal for the 'soil health' project (PC/2009/003) which has the support of all partners.



Photos: Jennifer Cobon, DEEDI

Figure 2. Mealybug infestation on taro in Taveuni

a) mealybug-infested corms (left) are smaller and often mis-shapen



b) close-up of corm showing mealybug (*Paraputo* sp.) infestation

7 Conclusions and recommendations

This SRA enabled the soil health project team to come together and discuss the project under development (PC/2009/003) and specifically to clarify the conceptual basis of the project, the cropping systems and pilot sites to be targeted, the research questions to be addressed, and the methods to be used during the course of the project.

The SRA involved communication and consultation at different levels and in different ways in order to get acceptance for the proposal at an organizational level, and always with an eye on farming communities where the work will be carried out and eventually adopted. It was important to carefully articulate the purpose of the project and seek the input from our Pacific partners before we could be sure of their support. In Kiribati and Samoa, where we are at an earlier stage of project design and implementation, we had to start by seeking support from institutional management before meeting with local growers and industry/community leaders. In Taveuni the project's message has already been accepted by R&D leaders and we were able to engage directly with the local taro producers, initiating the PRA and action-research process. We were thus able to gain good insights into the soil health issues and were able to start devising 'best-bet' strategies with some confidence.

7.1 Conclusions

The consultations and field visits undertaken during the SRA have led the research team to conclude that soil fertility and soil health issues are indeed at the root of the production problems observed in the target systems in the Pacific islands. Yields and quality of produce are low and deteriorating while soils, both under repeated taro and vegetable production, are very low in organic matter; meanwhile there is evidence that quality problems are associated with high levels of pests and plant pathogens (especially plant parasitic nematodes), suggesting that these soils have substantially lost their biologically suppressive function (provided in a healthy soil by a diversity of non-pathogenic soil microorganisms).

This situation leads the team to postulate that management tactics that decisively increase soil organic matter will lead to an improvement in physical, chemical and biological attributes of soils in the target systems (and especially the suppression of damaging soil-borne pathogens), leading in turn to improvements in productivity and quality.

Growers do have access to conventional soil chemical analysis, via local or international providers, but are currently making very little or no use of such services, probably due to what is perceived as their high cost. They are currently unaware of and/or do not have access to biological tests.

The team therefore postulates that quick, low-cost indicators, providing information on the status of soils would be useful to growers extension workers and researchers, to complement the information available from conventional soil analyses.

Farmers in the pilot sites were found to have an awareness of basic soil fertility issues (especially lack of macronutrients and the use of fertilizers) and were often aware of advice to use compost and to adopt other 'sustainable agriculture' practices. Usually they were unaware, however, of soil health concepts (such as the impact of soil-borne pathogens and the link between quality problems, plant disease and poor soil health).

The team therefore postulates (also based on experience in the banana industry in Queensland) that using suitable educational strategies to increase the understanding of soil health concepts, among growers and their service providers, will help to encourage growers to test and adopt soil improvement practices.

The cost of fertilizer and the work involved in implementing 'sustainable agriculture' practices was often cited as a reason for not adopting their use.

The team therefore postulates that demonstrations of the cost-effectiveness of soil health practices (especially using participatory approaches that allow farmers to make their own evaluation of tactics, alongside formal data gathering by researchers) will be vital in encouraging further testing and adoption of these practices by farmers.

These postulates are incorporated as researchable hypotheses in the revised project proposal. In view of the large number of variables involved (including both bio-physical and socio-economic factors) and the complexity of their potential interactions, a classical one- or two-variable experimental approach to exploring these hypotheses is not feasible. The team therefore concludes that an 'action-research' model, in which 'best-bet packages' of measures are tested on farm by researchers and growers working closely together (and, if necessary, the strategies are refined in an iterative process) is the most appropriate for tackling these issues.

7.2 Recommendations

Based on a project workshop in Suva and visits to potential pilot sites in Fiji, Samoa and Kiribati in July 2010 and November 2010, respectively, including extensive discussion with potential partners, the SRA team recommends that:

- the soil health project be viewed as part of a longer term strategy for strengthening soil health R&D in the Pacific, which will be integrated into the core agenda of SPC and its R&D partners, as well as the curriculum of USP;
- project research should be focused on four pilot sites (taro for export in Fiji and Samoa; peri-urban vegetable production in Kiribati; and dessert bananas in Australia), with the possibility of extending the project's approach to other related systems (banana in Fiji and Samoa; red papaya and ginger in Fiji etc.) through collaboration with other projects and postgraduate student thesis projects;
- a participatory 'action-research' model is the most appropriate approach to problem-solving in these systems, allowing on-farm trialling of 'best-bet' soil improvement approaches, while more formal/detailed research is pursued in parallel to answer specific research questions;
- extension efforts should focus on increasing the understanding of soil health concepts among growers and service providers, to enable them first to evaluate the soil health practices on offer and subsequently to adapt and adopt those most appropriate to their individual needs;
- the project proposal should be revised to reflect the conclusions and recommendations of this SRA; and
- the project needs to follow on from the SRA in the shortest possible time to maintain the project's momentum and support from our Pacific partners.

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9 Appendixes

9.1 Draft outline of a Soil Health R&D Strategy for the Pacific Islands

The purpose of a 'soil health R&D strategy for the Pacific Islands' is to underpin the agricultural development of the region by ensuring that the productivity of key cropping systems can be sustainably increased, while conserving the natural resource base and ecosystem services upon which agriculture depends.

Current intensification efforts are failing because they offer economic incentives to increase crop production, without providing growers and other stakeholders with the knowledge, technologies and incentives that will allow them to do so sustainably. Although the concepts and practical principles of soil health are well established and their effectiveness has been demonstrated at least at pilot scale in the Pacific islands, adoption of soil health practices by growers and land-holders has so far been limited.

The **soil health strategy** takes as its starting point that the principles of soil health are **scientifically established** (so basic research is not required) and that there is some **policy support** for efforts to improve soil health at the level of senior decision-makers, such as the Heads of Agriculture and Forestry Services (so this is not a major constraint that needs to be addressed with high priority). However, there is a need for various **enabling and supportive actions** that will allow soil health concepts and practices to be **mainstreamed** and become the prevailing paradigm in agricultural policy and planning, research, extension and production.

These enabling actions include:

- adaptive research to
 - identify soil health approaches that are most appropriate to local circumstances
 - evaluate and adapt technologies that are cost-effective under prevailing circumstances
 - select or develop indicators that offer researchers, extension workers and farmers a cost-effective means to monitor current soil status and progress towards adequate soil health
 - evaluate and adapt extension approaches that enable farmers to understand soil health concepts and adopt soil health practices
- Individual and institutional capacity building in soil research
- Individual and institutional capacity building in participatory research and extension approaches to disseminating soil health concepts and practices
- Strengthening of support services
 - diagnostic laboratory services
 - biological support services (taxonomy/identification, diagnostic research)
- Communicating soil health challenges, opportunities and advances to decision-makers (at various levels)

Specific/local strategy for 'systems in crisis'

- I. Diagnosis of crop production and soil health problems
 - a. Preliminary 'on-the-spot' diagnosis (by soil researchers, in consultation with extension workers and farmers): assess colour, texture and structure of soils (and their local variation - e.g. due to erosion, waterlogging etc); assess 'crop health' (yield, quality of product, any visual symptoms of deficiencies); assess specific pest and disease problems (are these soil-related or attributable to other causes - poor crop hygiene, contaminated planting material, invasive species etc.)
 - b. Conventional laboratory-based diagnosis of physical and chemical attributes (by researchers)
 - i. Local/national laboratory testing for major nutrients, physical attributes
 - ii. Comprehensive/detailed tests - reduced set of samples sent to regional/international labs for GLC analysis of all elements, including trace elements
 - iii. Comparison of data (from i and ii) with published data (if any) of expected values, optima for target crop etc.
 - c. Conventional laboratory-based testing of biological attributes (by researchers)
 - i. Identification of pests (insects, nematodes, molluscs...) and pathogenic organisms (fungi and bacteria), if necessary including molecular studies for strain identification etc.
 - ii. Experimentation, if necessary, to investigate whether organisms (if new strains/species or poorly known) are pathogenic and/or damaging
 - d. Indicator-based diagnosis (by researchers, with extension workers and farmers)
 - i. Apply limited number of tests (physical, biological and chemical) available in 'soil health toolbox'
 - ii. Compare with results of conventional tests to see whether major problems are successfully detected
 - e. Evaluation of the resources available for soil improvement (by researchers, extension workers and farmers). This will include consideration of both technologies (purchased fertilisers, organic amendments, green manure cover crops, agroforestry etc) and specific materials (e.g. among organic amendments: animal manure, cocopeat, sugarcane waste etc.); evaluation will include consideration of cost/availability, expected value for soil improvement and, if necessary, specific tests to confirm characteristics.
 - f. Synthesis of analysis and recommendations. (by researchers, extension workers and farmers). Assembling the best available evidence from diagnostic tests, the key problems are identified and prioritized, and strategies devised to address them.

(N.B. This is an iterative and evolving process. The process is 'iterative' in the sense that preliminary recommendations can be made and some work on improving soil health can begin on the basis of the preliminary diagnosis; the problem-solving strategy may need to be modified as results from detailed tests

become available - for instance if lab tests indicate a specific micro-nutrient deficiency, appropriate fertilizer can be added; if a disease problem is shown to be seed-borne, then clean planting material will become an important supplementary tactic. The process is expected to evolve as the 'indicators' are shown to be effective, less conventional/formal testing will be needed. As Pacific soils and cropping systems become better known, less diagnostic research will be needed)

II. Evaluation of 'best-bet' soil improvement tactics

- a. Participatory planning (by researchers, extension workers, farmers) of 'best-bets' to be tested and how to test them (who? where? when? and evaluation methods?)
- b. Evaluation of effectiveness of best-bet tactics through:
 - i. effects on yields and quality (reject rates)
 - ii. effects on conventional soil fertility measures
 - iii. effects on soil health indicators
 - iv. cost-benefit analysis
- c. Synthesis of results (across evaluation methods) and recommendations

(N.B. This is also an iterative and evolving process. The results of each growing season's trials will feed into the design of the next season's, resulting in improving or refining of the 'best bet' tactics and modification or abandoning of those that are ineffective. Results will also be fed into the education/extension effort, below)

III. Promoting adoption of soil health practices

- a. Develop capacity-building plan for farmers and farmer intermediaries
- b. Develop training materials for farmers and trainers
- c. Conduct training-of-trainers and support farmer training
- d. Develop longer-term capacity-building and awareness-raising strategy

(N.B. This is also an iterative and evolving process. Initially, training materials will focus on principles of soil health while crop-specific materials will be based on modified materials previously used by DSAP in the Pacific islands and for the banana industry in Australia, as well as the results of the preliminary problem analysis. As the project builds its own experiences of improving soil health in taro and vegetable systems, training materials will be improved and targeted more accurately to the local production systems and context, as well as capturing the results of the best-bet evaluations of soil health improvement tactics).