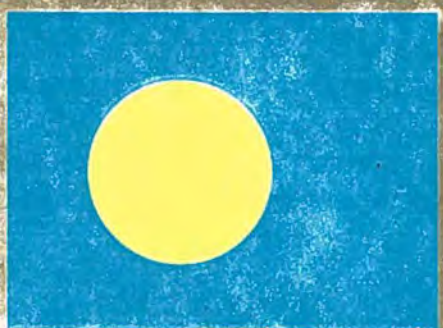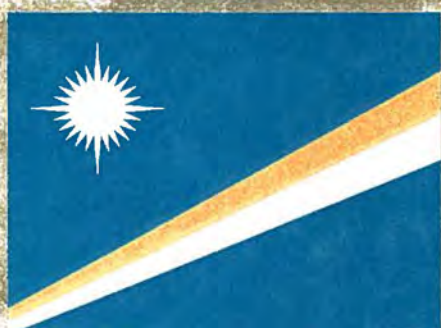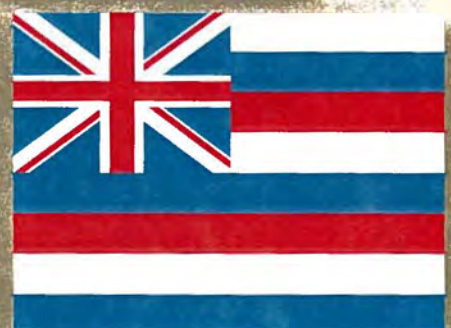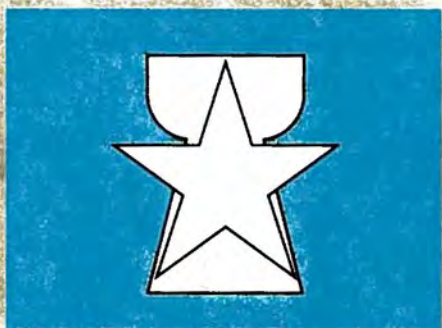# PROCEEDINGS OF THE WORKSHOP ON UTILIZATION OF SOIL AND PLANT ANALYSIS FOR SUSTAINABLE NUTRIENT MANAGEMENT IN THE AMERICAN PACIFIC
JANUARY 13 - 17, 1997

P.P. Motavalli, Editor
College of Agriculture and Life Sciences
University of Guam

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ACKNOWLEDGEMENTS

INTRODUCTION

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The development of effective plant nutrient management recommendation systems require an understanding of soil resources, plant response to inputs, the economics and cultural aspects of agricultural practices, and assessments of the environmental impacts of agricultural activities. In Micronesia, many of these key elements necessary for the development of nutrient management recommendation systems have either not been investigated or the information has not yet been widely disseminated. In addition, the large geographic distance among the islands of the American Pacific has hampered effective communication among scientists and extension agents and increased the difficulty of utilizing existing soil and plant testing facilities within the region.

The overall objective of the workshop is to increase regional communication and collaboration in developing sustainable plant nutrient management practices through increased use of soil and plant testing. Specific objectives of the workshop are:

1. To present information on soil resource evaluation and soil and plant testing.

2. To identify constraints to sustainable nutrient management in the region.

3. To promote regional collaboration in soil and plant testing and nutrient management.

Prior to the convening of the workshop, an initial survey was conducted among 15 invited participants from the American Pacific region including participants from Guam, the Northern Mariana Islands, Federated States of Micronesia, Palau, American Samoa, Hawaii, and the Marshall Islands. The survey determined the preferred dates for the workshop, the topics or information the participants would like to have presented, the list of suggested extension publications on soil and plant testing and nutrient management, the services a soil and plant testing laboratory could provide for their island, and suggested follow-up activities after the workshop would be over. Among the topics of interest to the participants were: soil and tissue sampling, quick and standard plant tissue tests for local crops, development of a standard nutrient trial for the region, interpretation of the soil survey, computer software for determining soil type and suitable plant species, field test kits, web pages for information on local soils, nutrient management in coralline/atoll soils, composting, nutrient requirements and toxicities of local crops, management and nutrient value of manures, water quality issues, Best Management Practices, soil test interpretation for intercropping systems, pesticide residue testing, soil test calibration, and acid soil management.

The schedule for the workshop has been divided into four principal sections: Soil Resources, Soil and Plant Testing, Plant Nutrient Management, and Future Collaboration. Regional representatives and growers in several important regional agricultural activities, such as farming, landscaping, and golf course maintenance, will also make presentations regarding plant nutrient management in their respective area. Presentations on regional fertilizer availability and Best Management Practices for plant nutrients will also be made.

Possible outcomes of the workshop include establishment of a regional nutrient management network, planned collaboration in regional research projects, development of regional extension publications, identification and support for regional centers for soil and plant testing, and review and revision of a nutrient recommendation computer program developed at the University of Hawaii. The organizers of the workshop also hope that this forum will provide sufficient information and time for discussion to allow for the initiation of a constructive regional dialog on sustainable plant nutrient management and soil and plant testing.

WORKSHOP SCHEDULE

MONDAY, JANUARY 13

Registration ....8:30 - 9:00 AM
Welcoming Address (J. Barcinas,
Dean of CALS, Univ. of Guam)..9:00 - 9:30 AM
Introduction to Soil and Plant
Testing (P. Motavalli, UOG) ....9:30 - 10:20 AM
Refreshment Break ....10:20 - 10:30AM
Soil Resources: Their Classification,
Mapping and Important
Characteristics (C. Smith, NRCS)....................................10:30 - 11:30 AM
Group Discussion ....11:30 - 12:00 AM
Lunch ....12:00 - 1:30 PM
Demonstration of Geographic
Information Systems (L. Heitz, UOG
and C. Smith, NRCS) ....1:30 - 3:20 PM
Refreshment Break ....3:20 - 3:30 PM
Methods of Sampling and Sample
Processing (R. Uchida, UH) ....3:30 - 4:30 PM
Group Discussion ....4:30 - 5:00 PM

TUESDAY, JANUARY 14

Announcements..8:15 - 8:30 AM
Procedures for Soil, Plant and Organic
Waste Testing (D. Vargo, ASCC) ....8:30 - 9:30 AM
Soil Quick Test Kits (F. Cruz, UOG) ....9:30 - 10:20 AM
Refreshment Break ....10:20 - 10:30 AM
Laboratory Demonstration
(P. Motavalli, UOG) ....10:30 - 12:00 AM
Lunch ....12:00 - 1:30 PM
Developing Plant Nutrient
Management Recommendations
(R. Yost, UH)..1:30 - 2:30 PM
Refreshment Break ....2:30 - 2:45 PM
Fertility Advice and Consulting Computer
System (FACS) (R. Yost, UH) ....2:45 - 4:00PM
Group Discussion..4:00 - 4:15PM
Social Dinner (Hyatt Regency Hotel)
Dinner Speaker: J. Perry, NRCS ....6:30 - 9:00 PM

WEDNESDAY, JANUARY 15

Plant Nutrient Management
in the American Pacific Island Reports:

Guam (F. Cruz, UOG) ....8:30 - 8:50 AM
Northern Marianas (A. Moore, NMC) ....8:50 - 9:10 AM
College of Micronesia
Palau (L. Ragus, PCC) ....9:10 - 9:30 AM
Marshall Islands (A. Kuniyuki, COM) ....9:30 - 9:50 AM
Pohnpei (J. Phillips, COM)...9:50 - 10:10 AM
Refreshment Break ....10:10 - 10:20 AM
Hawaii (S. Hill, UH) ....10:20 - 10:40 AM
American Samoa (A. Peters, ASCC).................................10:40 - 11:00 AM
Group Discussion ....11:00 - 11:30 AM
Lunch ....11:30 - 1:30 PM
Growers Reports:
Farmers (F. Quan, B. Watson, Guam) ....1:30 - 2:00 PM
Golf Courses (A. Couilliard, UOG) ....2:00 - 2:20 PM
Landscapers (S. DeBiasi, DeBiasis)....................................2:20 - 2:40 PM
Group Discussion ....2:40 - 3:10 PM
Refreshment Break ....3:10 - 3:30 PM
Fertilizer Availability in the American
Pacific (J. Flores, Brewer Environ.) ....3:30 - 3:50 PM
Best Management Practices for Plant
Nutrient Management (J. Kuhn, NRCS)..............................3:50 - 4:30 PM
Group Discussion ....4:30 - 5:00 PM

THURSDAY, JANUARY 16

Meet in front of Room AG127 .... 8:30 AM
Field Trip to Farms, Hotel and Golf Course
with Different Examples of Plant
Nutrient Management ....8:45 - 4:00 PM

FRIDAY, JANUARY 17

Announcements...8:15 - 8:30 AM
Group Discussion of Future
Collaboration for Soil and Plant
Testing in the American Pacific ....8:30 - 10:20 AM
Continue Discussion ....10:30 - 12:00 AM
Lunch ....12:00 - 1:30 PM
Summary and Future Agenda ....1:30 - 3:00 PM

INTRODUCTION TO SOIL AND PLANT TESTING IN THE AMERICAN PACIFIC REGION

Peter Motavalli
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College of Agriculture and Life Sciences
University of Guam

The importance of soil and plant testing in the Pacific Region has been underscored by the general fragility and observable finite nature of soil and freshwater resources in island environments. However, participation in soil and plant testing in the region has remained relatively low. **Among the many challenges facing the establishment of an effective soil and plant testing program in the region are:**

- Growers and extension agents are not convinced of the need or value of soil and plant testing.

- The lack of correlation and calibration information to develop plant nutrient recommendations.

- Soil and plant quarantine regulations can hamper sending samples to a regional soil and plant testing laboratory.

- Turn-around times for soil and plant analysis are too long to be useful for the grower.

- The high costs associated with maintaining a testing laboratory on a Pacific island.

- The growth of specialized testing needs (e.g. golf courses, nurseries, home gardens).

- Communication and collaboration among regional institutions responsible for agricultural extension and research are limited.

Despite these challenges, several advantages exist for establishing soil and plant testing in the region including:

- Insufficient or excessive use of fertilizers or manures can be avoided thereby reducing environmental pollution.

- Timely testing helps in management decisions on when and how much to amend soils to optimize plant growth.

- Effects of management practices can be observed over time.

- Profits can be increased by reducing costs for unnecessary fertilizer applications.

- Additional extension information regarding soil and plant management can be included in the soil and plant testing report and/or an extension agent can personally communicate the information to the grower. These avenues of communication help to establish a relationship between the grower and extension personnel for future information transfer.

The objectives of most soil and plant testing programs are:

- To provide information on soil characteristics (e.g. available plant nutrient) that will affect plant growth and crop yield.

- To recommend nutrient amendments (e.g. fertilizer and lime) when needed to improve soil fertility and profits for growers.

- To minimize the potential for environmental pollution.

The major steps in soil testing are: (1) soil sampling and processing, (2) soil analysis, and (3) interpretation and recommendation. For each of these steps to be successful, information is needed. For example, a knowledge of the field management history can indicate where soil samples should be taken. A knowledge of the soil series or other even more general classifications (e.g. acidic, neutral or alkaline soil) can assist in deciding the appropriate extractant for a sample and in interpreting soil test results. Information regarding the crop to be grown and yield goal can also help in determining appropriate fertilizer recommendations.

A common difficulty for many soil testing programs is the development and periodic updating of correlation and calibration information for the purpose of interpretation and recommendation. Correlation information relates soil test results with crop yield. An example of correlation information for soil test P is shown in Figure 1. Determination of a critical soil test P level allows for identification of low, medium and high soil test P ranges. Calibration information relates crop response to fertilizer applications under different soil test levels (Figure 2). From this information an optimum economic fertilizer application can be calculated. Development of correlation and calibration information is time-consuming and costly requiring multiple field trials at several sites over a number of years. Because of this time and cost, the soil testing programs at the University of Guam and the University of Hawaii have relied for years on experienced extension agents to interpret soil test results and make fertilizer recommendations. At the University of Guam, an additional reason for failure to develop correlation and calibration information has been the belief that an experienced extension agent can make better fertilizer recommendations than the more mathematical approach. The extension agent can take into account the grower's individual situation and management practices while a more general recommendation may fail to consider these factors. However, several drawbacks exist for this reliance on experienced extension agents including lack of uniformity in recommendations among extension agents, the additional delays in returning recommendations to growers, the questionable allocation of

extension resources, and the failure to establish or maintain an institutionally-based nutrient recommendation system which can continue after individual extension agents leave.

Bray in 1948 listed three criteria for a good soil test:

- The extractant should extract all or part of the available form of nutrients in soils with variable properties.

- The amount of nutrient extracted should be measured with reasonable accuracy and speed.

- The amount extracted should be correlated with the growth and response of each crop to the nutrient under various conditions.

A common misconception regarding soil testing is that the soil test result is a measure of the total amount of a plant nutrient element in the soil. As illustrated in Figure 3 for the soil phosphorus (P) cycle, essential plant nutrient elements may exist in many different forms in the soil many of which the plant cannot utilize. Therefore, the goal of a good soil test is to measure the amount of a plant nutrient which is available for plant uptake. In other words, the fraction of the plant nutrient element which is extracted and measured from the soil should correlate well with the amount of the plant nutrient which is taken up by the plant. Several chemical extractants are commonly used for extracting available soil P and the suitability of a particular extractant is often based on soil characteristics (Table 1).

Additional considerations in the selection of analytical methods and extractants is the speed with which results can be obtained and the accuracy of the results. Short turn-around times are critical in soil and plant testing because growers often need rapid response to make critical management decisions. In the Pacific region, further delays in turn-around times are imposed by the distances among islands and plant quarantine restrictions. Compromises in accuracy for speed are often made in the development of soil testing procedures. For example, a soil testing program may use volume as determined by a calibrated spoon instead of weight for measuring a soil for analysis. Despite these compromises in accuracy, a good soil testing program will vigorously pursue a program of quality control by use of check standards, blanks, and good analytical techniques.

A good illustration of the successes and problems a soil and plant testing program experiences in the Pacific region is the Soil and Plant Testing Laboratory at the University of Guam. As part of the Agricultural Experiment Station in the College of Agriculture and Life Sciences, the Laboratory has been offering soil testing services to Guam and the region of Micronesia for approximately 20 years. From 1984 to 1993 the Laboratory analyzed a total of 2,926 soil samples. The number of soil samples analyzed each year was relatively small ranging from 133 in 1988 to 444 in 1984 (Figure 4). Approximately 32% of the soil samples were submitted by farmers on Guam and 11.5% came from other islands in the region (Figure 5). The largest proportion of soil samples (42.6%) was submitted for research purposes. The Federated States of Micronesia (Pohnpei, Chuuk, Kosrae, and Yap) were the largest source of samples coming from outside Guam, accounting for 53.7 % of off-island samples (Figure 6). The major difficulties for the Laboratory have been in increasing public participation in soil and plant testing, in meeting the high cost of maintaining an analytical

laboratory on Guam, and in developing plant nutrient recommendations. The role of the Soil and Plant Testing Laboratory has slowly changed over the last 20 years with an increasing proportion of the soil samples coming from sectors, such as landscapers, golf courses and University of Guam researchers, with specialized needs for environmental testing. A current emphasis for the Laboratory is promoting plant tissue and organic waste testing.

The establishment of a successful regional soil and plant testing program in the American Pacific faces many challenges foremost of which is obtaining adequate funding and increasing participation in soil and plant testing. Since the region is undergoing a rapid rate of development, an important emphasis of the regional soil and plant testing program should be in providing testing capabilities for environmental monitoring. Initial efforts in establishing a regional soil and plant testing program may include:

- Increasing public awareness of the benefits of soil and plant testing.

- Creating closer links to regional soil and plant testing laboratories such as the laboratories at the University of Guam and the University of Hawaii.

- Conducting joint research related to soil and plant testing.

- Establishing an initial set of nutrient recommendations based on the experience of extension agents and other available information.

Table 1. Common soil P extractants

Extractant	Composition	Suitability
Bray P1	NH_4F+HCl	Acid soils, low to high CEC; Neutral, noncalcareous soils, low to moderate CEC
Mehlich 1	$HCl+H_2SO_4$	Sandy soils, acid, low CEC
Mehlich 3	NH_4F+NH_4NO+ $HOAc+HNO_3+$ $EDTA$	Wide range of soils
Olsen	$NaHCO_3$, pH 8.5	Neutral and alkaline soils

Figure 1. Correlation between soil test phosphorus (P) and relative yield.
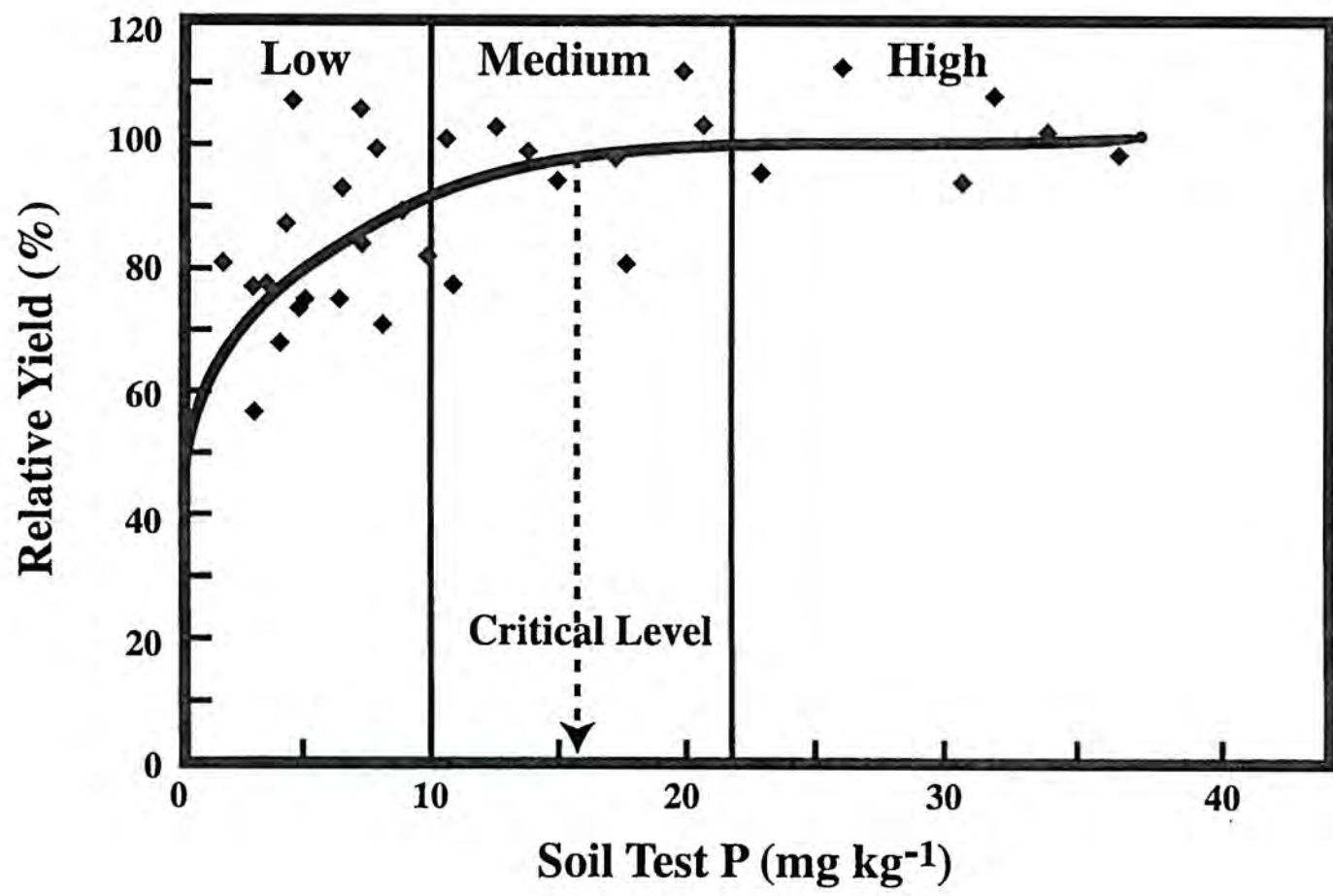
Figure 2. Calibration information for crop fertilizer response at different soil fertility levels.
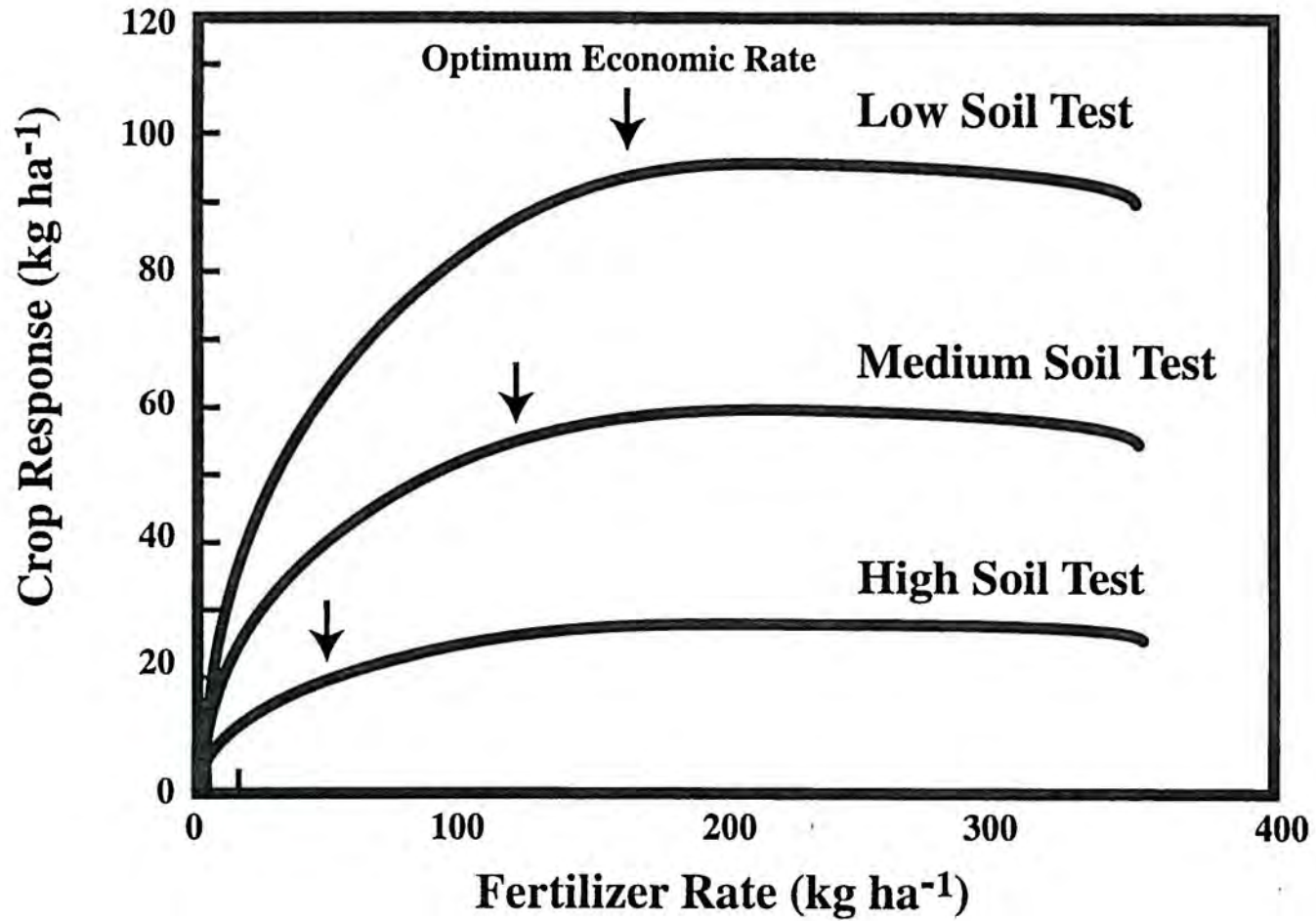
Figure 3. Soil phosphorus (P) cycle.
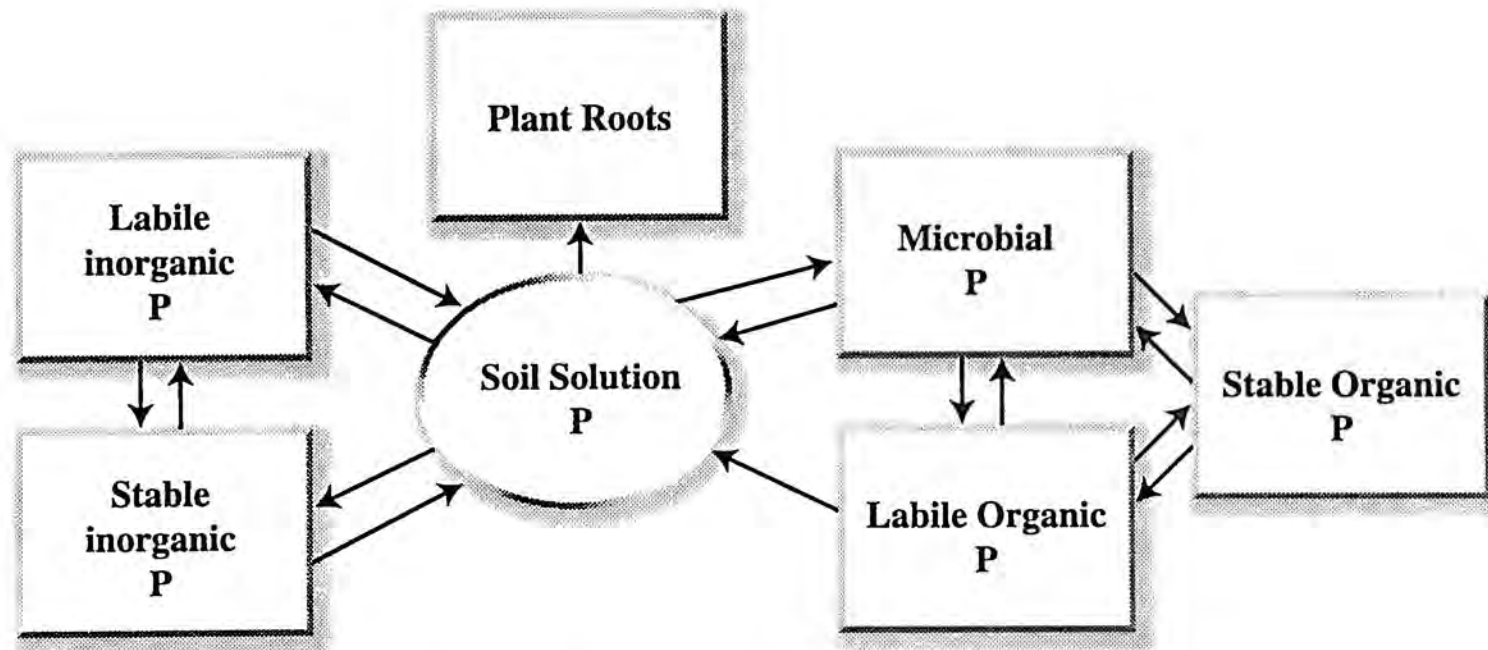
98 - 99% of soil P in primary and secondary minerals and OM
1 - 2% in microbial tissue
0.01% in soil solution

Figure 4. Number of soil samples processed each year at the University of Guam Soil and Plant Testing Laboratory
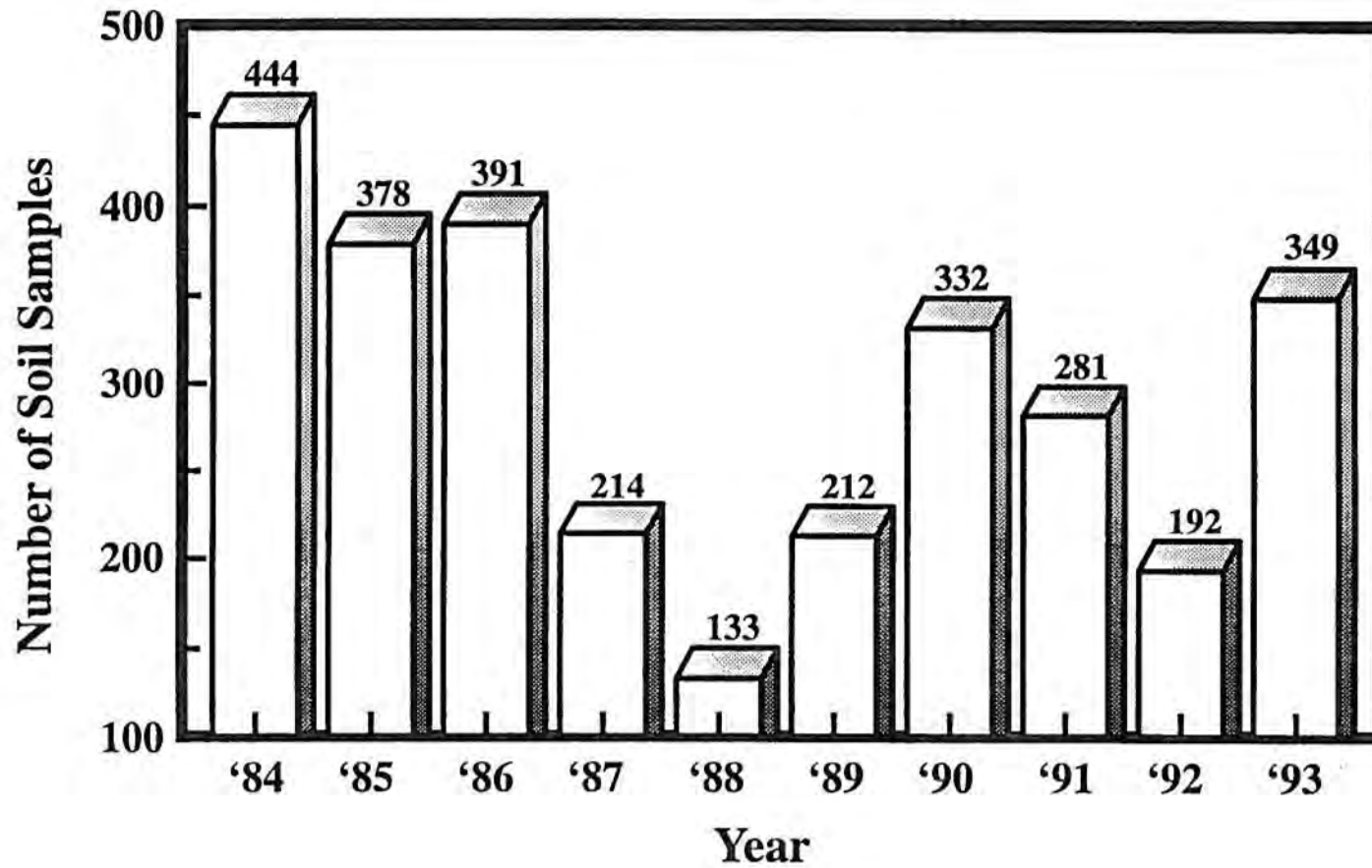
Figure 5. Source of soil samples submitted to the University of Guam Soil and Plant Testing Laboratory.

Landscapers
and nurseries 2.3%

Schools 0.6%

Golf Courses 9.7%

Government
Agencies 0.8%

Private
Companies 0.1%

Farmers 32.5%

Off-Island 11.5%

Research 42.6%
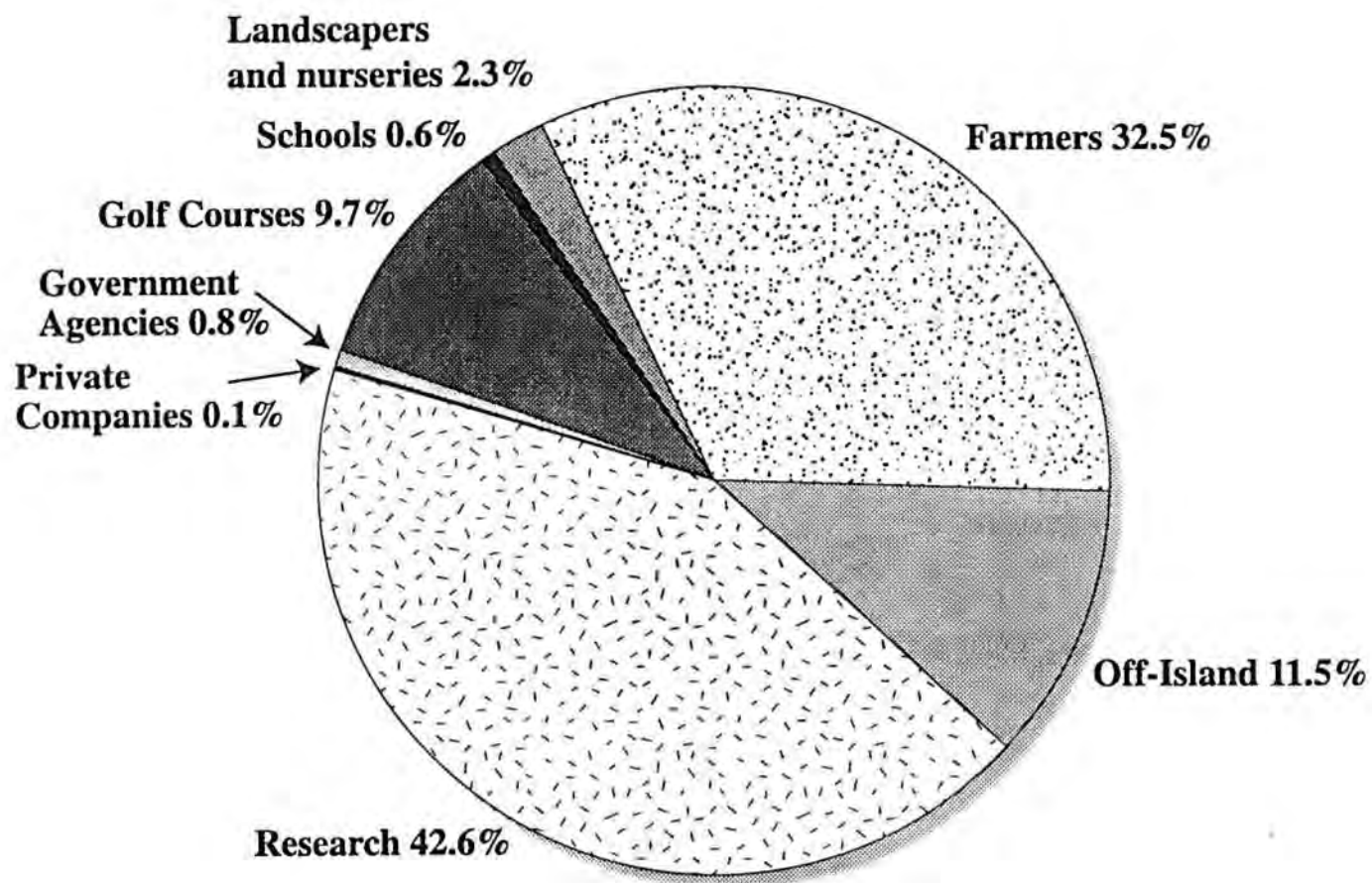
Figure 6. Off-island soil samples (1984 - 1993) tested at the University of Guam Soil and Plant Testing Laboratory.
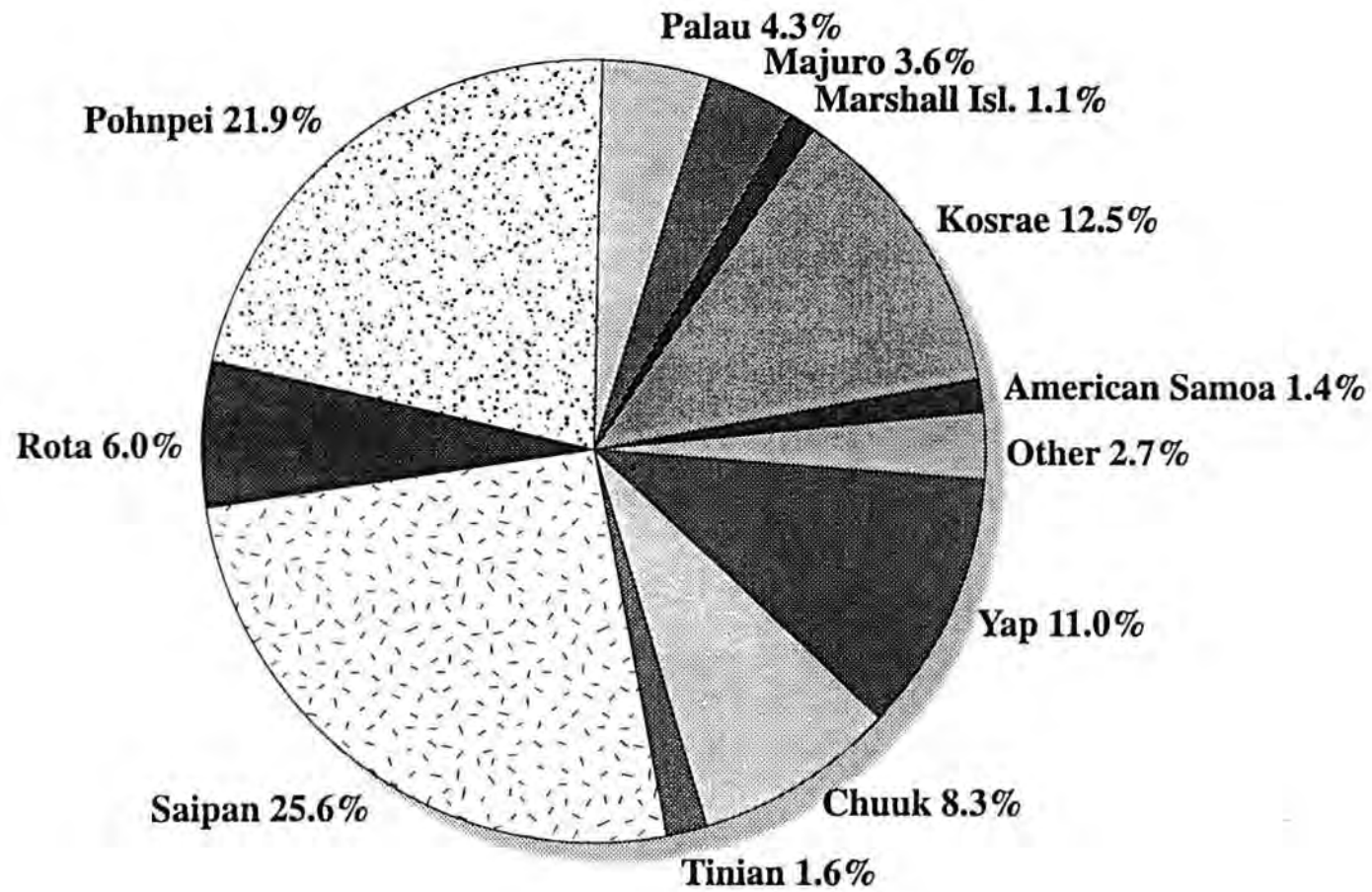
SELECTED FERTILITY-RELATED SOIL PROPERTIES FOR SOME SOILS OF AMERICAN SAMOA, THE CAROLINE ISLANDS AND GUAM

Christopher W. Smith
USDA NRCS
Honolulu, HI

Presented here are a few of the basic soil properties for some of the major soils in the American Pacific that are used for agricultural production. These properties and values are obtained from the National Soil Survey Laboratory database obtainable through the NRCS office in Guam or via internet through the USDA NRCS home page at http://www.usda.nrcs.gov.

Base cations were determined by extraction with 1 N ammonium acetate, trivalent aluminum with 1 N KCl, and crystalline iron by citrate bicarbonate. General interpretive groupings of inherant soil fertility characteristics are by the use of the Soil Fertility Capability Classification (FCC) System.

American Samoa

Leafu soil series, 0-3 percent slopes, .17 K factor (erodibility index)

0-20 cm depth,   pH 6.3, 25 milli-equivalents/100g exchangeable calcium (Ca) and
                   magnesium (Mg)

20-50 cm,   pH 6.3, 25 Ca and Mg

Clayey soil texture in upper 20 cm, loamy in 20-50 cm layer, 4% or more iron (Fe) from crystalline oxides in upper layer, low potassium (K) reserves.

Pavaiai soil series, 6-50 percent slopes, .10 K Factor

0-20 cm depth,   pH 6.0, 16 Ca and Mg

20-50 cm   pH 6.2, 12 Ca and Mg

Clayey, 15% or more stones or boulders at surface, low K, 90% or more phosphorus (P) retention in the upper layer.

Guam

Akina soil series,   0-60 percent slopes, .20 K Factor

0-20 cm depth,   pH 5.0, (meq/100g) Ca and Mg: 7, K: 6*, aluminum (Al): 3.1, Fe: 10.4

20-50 cm,   pH 5.0, Ca and Mg: 4, K: 6*, Al: 4.2, Fe: 10.2

Clayey, ustic moisture regime (distinct wet and dry seasons), 10 to 60% Al saturation somewhere in the upper 50 cm, 4% or more Fe in the upper layer, low K (?)*.

* = K very high. The soil sample was taken from an agricultural experiment station. This soil is probably naturally K deficient.

Guam soil series, 0-15 percent slopes, .10 K Factor

0-20 cm depth,   pH 7.3, Ca and Mg: 38

20-50 cm   Hard Limestone

Clayey, 15-35% gravel or cobbles in the upper 50 cm or to a lithic contact.

Palau

Aimeliik soil series, 6-75 percent slopes, .17 K Factor

0-20 cm depth,   pH 5.1, Ca and Mg: 7.2, K: 0.6, Al: 1.9, Fe: 7.0
20-50 cm   pH 5.0, Ca and Mg: 0.5, K: 0.1, Al: 4.4, Fe: 8.0

Clayey, > 60% Al saturation, >4% Fe, low K.

Palau soil series, 6-75 slopes, .17 K Factor

0-20 cm depth,   pH 5.0, Ca and Mg: 0.7, K: 0.2, Al:5.5, Fe: 6.5
20-50 cm   pH 5.1, Ca and Mg: 0.2, K: 0.1, Al: 4.1, Fe: 7.0

Clayey, >60% Al saturation, >4% Fe , low K.

Babelthuap soil series, 2-75 percent slopes, .05 K Factor

0-20 cm depth,   pH 5.1, Ca and Mg: 0.3, K: 0.1, Al: 0.6, Fe: 8.8
20-50 cm   pH 5.3, Ca and Mg: 0.1, K: 0.1, Al: 1.8, Fe: 15.1

Clayey texture, >15% stones or boulders, >60% Al saturation, <4 meq/100g effective cation exchange capacity (ECEC) in the upper 20 cm, >4% Fe, low K.

Dechel soil series, 0-1 percent slopes, K factor not applicable

0-20 cm depth, pH 4.9, Ca and Mg: 5.2, K: 0, Al: 7.0
20-50 cm   pH 4.7, Ca and Mg: 5.2, K:0, Al: 5.7

Clayey, > 60% Al saturation, peraquic (wet) soil moisture regime, >4% Fe, low K.

Yap

Yap soil series, 0-30 percent slopes, .10 K Factor

0-50 cm depth   pH 5.7, Ca and Mg: 9.5

Clayey, >4% Fe, low K.

Weloy soil series, 2-75 pecent slopes, .10 K Factor

0-20 cm depths, pH 6.2, Ca and Mg: 13.6, K: 0.1, Fe: 5.1

20-50 cm   pH 6.1, Ca and Mg: 21.0*

Clayey, 15-35% gravel and cobbles, >4% Fe, low K.

* = Mg exceeds Ca. Some sites may have significant Ca/Mg ratio problems

Pohnpei

Dolen soil series, 6-100 percent slopes, .17 K Factor

0-20 cm depths, pH 6.2, Ca and Mg: 19, K: 0.1, Fe: 3.6

20-50 cm   pH 5.6, Ca and Mg: 8.9, Fe: 3.9

Clayey, 10-60% Al saturation, low K, >90% P retention*.

*Very high P fixing capacity, 4.8 meq Al, and pH 5.5 in layer below 50 cm.

Umpump soil series, 2-15 percent slopes, .15 K Factor

0-20 cm depth, pH 5.0, Ca and Mg: 3.1, K: 0.2, Al: 0.3, Fe: 13.6

20-50 cm   pH 5.6, Ca and Mg: 0.6, Fe: 16.1

Clayey, 15-35% gravel and cobble, <4 meq/100g soil ECEC, >4% Fe, low K.

Conclusions

1. Many soils have steep slopes and so clearing generates significant erosion hazard.

2. Most soils are highly weathered and have high to very high phosphorus fixation capacity.

3. Most have little ability to furnish potassium to the system.

4. Many are highly acid and may create aluminum toxicities for many types of crops. Liming rates are variable however.

5. Organic matter is easily lost and should be diligently maintained.

6. High rainfall throughout the year on most islands creates high nutrient leaching potential. Many soils also have low cation exchange capacities which aggravates this problem. Nutrients should be carefully managed: small frequent applications; liming and soil and plant testing should be frequent.

SAMPLING AND ANALYSIS OF SOILS AND PLANT TISSUES: HOW TO TAKE REPRESENTATIVE SAMPLES, HOW THE SAMPLES ARE TESTED

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College of Tropical Agriculture and Human Resources
University of Hawaii at Manoa

SOIL ANALYSIS:

Laboratory analyses are performed on small samples of soil taken from relatively large areas of land. If the sample does not truly represent the soil you intend to treat, all the precision of the analytical process is useless. Improperly collected samples not only make test results less informative than they might be, but the results also may lead to erroneous recommendations that reduce yields, waste money and resources, and pollute the environment.

Taking a representative soil sample

First, make a detailed map of your land. Divide your map into individual soil-test areas of a few (1-5) acres each. Label each area clearly on the map by using a combination of letters and numbers that make sense and thus are easy to remember. Each test area should consist of only one soil type or variation. Areas with different slope, color, drainage, texture, or management history should be sampled separately.

Samples should be one-inch cross-sections of the soil (called cores) taken to a specified depth, normally 0-4 inches for no-till fields or established pasture and turf and 0-8 inches for conventionally tilled fields (James and Wells 1990). For trees and fruit crops, two samples at different depths should be taken wherever possible: a surface sample from 0-8 inches and a sub soil sample from 8-24 inches. Each sample to be tested should be a thorough mix of 10-15 cores taken randomly or in a scientifically determined pattern. Although there are many sophisticated techniques (e.g., Kriging, strip sampling) to deal with variability in the field, a zigzag sampling pattern or a variant of it is often adequate for obtaining a reasonably representative soil sample (Sabbe and Marx 1987).

A soil "probe" is the professional's tool for collecting soil cores, but soil cores can be collected with a garden spade or trowel. Remove a shovelful of soil to the depth you wish to sample, then cut a one-inch section from the wall of the hole you have just dug. Place it in your mixing bucket. Care should be taken that an equal amount of soil is taken at each of the sampling sites, so that the resulting composite sample will represent all the sample sites equally.

Clean tools are essential for sampling soils. If specialized analyses are to be done, avoid brass, bronze, or galvanized tools, which may contaminate your samples with copper and zinc. Clean probes or shovels made of stainless steel are preferred. Mixing buckets should be durable but light (preferably made of plastic) and clean. A small amount of lime or fertilizer residue left in the bucket can severely distort your results. If analysis for boron is desired, the soil samples should not be stored in grocery (brown) paper bags, because such paper can release boron to the sample.

Collect soil samples two to three months before planting. In so doing, you will get your test results in plenty of time to plan your soil amendment and fertilization. Please be aware that you need to allow at least two weeks for the Agricultural Diagnostic Service Center to complete the analysis of your soils. Soils should be retested to confirm the effects of soil amendments applied. Subsequent tests of actively managed soils should be done to warn of nutrient buildup or depletion, perhaps once every two years or even more frequently, depending on the cropping activity.

Submitting samples and providing relevant information:

After properly collecting soil samples, they may be submitted to the University of Hawaii College of Tropical Agriculture and Human Resources (CTAHR) Agricultural Diagnostic Service Center (ADSC). Samples must be accompanied by an ADSC Soil Sample Information Form, which is available at the Cooperative Extension Service offices or at the ADSC. The more complete the information you provide, the better recommendations you will get. Because fertilizer and lime requirements vary with soils and crops, information about the soil's apparent density (heavy, light, or a'a land), the crop to be grown, and the soil's cropping and management history are important for making correct recommendations.

Soil testing

The ADSC provides all residents of Hawaii a reasonably affordable soil and plant tissue testing service. Routine analyses of soils and ornamental mixes include pH, salinity, extractable phosphorus (P), potassium (K), calcium (Ca), and magnesium (Mg). Soil organic carbon (organic matter), total nitrogen, extractable aluminum (Al), boron (B), and other micronutrients (e.g., zinc, manganese, copper) can be measured upon request. Detailed descriptions of the analytical procedures follow:

Soil Sample Preparation

Most soil samples are air dried and sieved through a 2-mm screen. Soils derived from volcanic ash (soils classified as Andisols) and soils being analyzed for ammonium (NH_4) are not air dried.

Soil pH

A soil sample weighing 30-50 grams (g) is placed in a waxed cup, and deionized water is added to make a saturated paste. The paste is equilibrated for one hour with occasional stirring. (Equilibration time is 1.5 hours for soilless mixes). pH is measured with a pH meter.

Soil salinity (electrical conductivity, EC)

A 50 g sample of soil is placed in a 100 ml disposable plastic cup; 50 ml of deionized water is added. The slurry is shaken on a reciprocating shaker for 45 minutes, then filtered. Electrical conductivity of the filtrate is read with a conductivity bridge.

Extractable phosphorus in soils with pH less than 7.0

The Modified Truog procedure (Ayres and Hagihara 1952) is used to extract phosphorus from acid (pH<7) soils. An extracting solution of 0.01 M H_2SO_4 (sulfuric acid) + 0.02 M $(NH_4)_2SO_4$ (ammonium sulfate) in a soil-to-solution ratio of 1:100 with 0.5 g of soil is shaken for 30 minutes.

Extractable phosphorus in soils with pH > 7.0

The Olsen method (Olsen et al. 1954, Olsen and Sommers 1982) is used to extract phosphorus from alkaline (pH>7) soils. An extracting solution of 0.5 M $NaHCO_3$ (sodium bicarbonate), pH 8.5, in a soil-to-solution ratio of 1:20 with 2.5 g of soil is shaken for 30 minutes.

In both the Olsen and Modified Truog methods, the slurry is filtered and phosphorus in the filtrate is measured colorimetrically using the Murphy-Riley method (Watanabe and Olsen 1965) on an autoanalyzer.

Extractable soil cations (Ca, K, Mg)

Ammonium acetate (1 M, pH 7.0) is used as the extracting solution with a soil-to-solution ratio of 1:20 with 2.5 g of soil shaken 10 minutes. Calcium (Ca), magnesium (Mg), and potassium (K) in the filtrate are measured with an atomic absorption spectrophotometer (AA).

Organic carbon

A modified version of the Walkley-Black method (Heanes 1984) is used to determine the organic carbon content of soils.

Total nitrogen

The micro-Kjeldahl method (Bremner and Mulvaney 1982) is used to determine total soil nitrogen.

Extractable aluminum

Aluminum extraction uses 50 ml of 1M KCl in a soil-to-solution ratio of 1:10 with 5 g of soil, shaken for 30 minutes. Aluminum in the filtrate is measured with an inductively coupled plasma spectrophotometer (ICP).

Extractable boron

Hot water is used to extract boron from 10 g of soil mixed with 20 ml water and boiled for 5 minutes. Boron in the filtrate is measured colorimetrically using the azomethine-H method (Wolf 1974, Mahler et al. 1984).

Extractable micronutrients

The DTPA method (Lindsay and Norvell 1978) is used to analyze concentrations of iron, zinc, manganese, and copper. A 10 g soil sample is mixed with 20 ml DTPA, then shaken for 2 hours before filtering. The micronutrients are measured with an AA spectrophotometer.

Soil test results and fertilizer recommendations

Within two to three weeks you should receive from the ADSC the result of your soil test along with fertilizer recommendations, if requested. The results for pH, P, K, Ca, and Mg are interpreted as either very low, low, sufficient, high, very high, or extremely high. Fertilizer recommedations provided include amounts of lime (given in lb/1000 ft^2 or tons/acre) and its estimated cost and fertilizer formulation options (for example, 21-0-0, 21-0-32, 10-30-10) and their amounts and costs.

PLANT TISSUE ANALYSIS:

As with soil analysis, sampling and sample preparation of plant tissues are often the weakest steps in the testing process. The sample should represent the overall plant population in the field, otherwise all the careful and usually costly analytical work is wasted.

Taking a representative plant tissue sample

Different plant species may require different tissue parts for meaningful sampling and interpretation. To ensure a representative sample, sample as many plants as practical. Generally, the youngest fully matured leaves on main branches or stems are sampled. They should be taken just prior to or at the onset of flowering.

Do not collect tissue that is covered with soil or dust. Do not collect from plants that are damaged by insects, mechanically injured, or diseased. Dead plants or senescent tissues should not be sampled. Also, sampling is not recommended when plants are under moisture or temperature stress.

Samples must be protected from dirt and fertilizer materials and should be placed in clean paper bags.

Plant tissue testing

Sample Preparation

Samples are cleaned, placed in a forced-air draft oven at 55 °C (or 70 °C in a gravity oven) for at least 12 hours, then ground to pass a 2-mm sieve with a Wiley mill. A 0.50-g sample is dry-ashed in a porcelain crucible for 4 to 6 hours at 560 °C in a muffle furnace. (If the ashing is judged incomplete, then the ash is cooled, dissolved in 1 M nitric acid, evaporated to dryness, then ashed again for 1 hour.) The residue is dissolved in 25 ml of 1 M hydrochloric acid.

Routine Plant Tissue Analyses

Analyses for P, K, Ca, Mg, Fe, Cu, Zn, Mn, Mo, Al, and Na are done on the ash solution, using an ICP spectrophotometer. Boron is measured by the Azomethine-H colorimetric method.

Total Nitrogen

A 0.250 g sample of dried, ground plant material is mixed with approximately 2 g of Na_2SO_4 and 7 ml of a digestion mixture of concentrated sulfuric acid, salicylic acid, and selenium. After a minimum of 2 hours, 3-4 drops of a sodium thiosulfate solution are added. The mixture is allowed to stand for 45 minutes, then 4 ml of 30% hydrogen peroxide is added. The mixture is then digested at 410 °C until a clear liquid is obtained (approximately 45 minutes). The liquid is cooled, then diluted with water. Nitrogen (NH_4) in this solution is measured colorimetrically by an auto-analyzer.

Special Plant Tissue Analyses By Request

Nitrate, sulfur, and silicon in plant tissues may be determined upon request.

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Soil Test Procedures for Soil Phosphorus

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Considering the difficulties associated with obtaining a representative soil sample, quantitative testing for available elements might be expected to be relatively straightforward with little opportunity for error, provided test procedures are followed correctly and conscientiously. This paper is meant to dispel any such feelings of complacency by disclosing some of the pitfalls in routine soil analysis. It draws upon the author's experience in establishing a soil testing laboratory in American Samoa between 1988 and 1990. It focuses on finding a satisfactory soil extractant for available phosphorus in volcanic soils formed under a hot, humid climate.

Developing a soil test for a given nutrient involves three steps:

1. selecting an extractant.
2. correlating the amount of nutrient extracted with the amount taken up by the crop.
3. calibrating the test value in terms of its effect on yield.

Constraints in time and resources may compel small soil testing facilities to adopt—at least initially—soil test procedures developed at established soil testing laboratories. Selection of a laboratory from which to copy procedures should be based on similarities in crops grown and soil types. For the latter, soil surveys can serve as a guide. Lacking these, the new facility might consider the five soil-forming factors (parent material, climate, vegetation, topography, and age).

Bias may play a deciding role in selecting laboratory procedures to follow. For example, American Samoa and Western Samoa grow the same crops using similar management practices on nearly identical soil types. Yet American Samoa uses soil testing procedures employed in Hawaii while Western Samoa follows procedures developed for New Zealand. A case in point is selection of a suitable soil extractant for available phosphorus.

Every soil testing procedure can be evaluated on the basis of three characteristics: reliability, applicability, and practicability. In general, we may accept any reasonable degree of reliability. Applicability to a wide range of soil types and practicability with respect to cost and time both assume greater importance when there are several competing procedures.

The complex nature of soil phosphorus and the failure of one well-defined chemical fraction to account for uptake by plants over a broad range of soil types have led to a proliferation of extraction solutions. An extractant should estimate the amount of phosphorus that can be solubilized over a typical growing season. Correlation studies determine which extractant is the most reliable index of the uptake of phosphorus by crops in the types of soils that the laboratory will be testing.

Western Samoa (University of the South Pacific, Alafua Campus) uses the Truog procedure to extract soil phosphorus: $0.002 N H_2SO_4$, pH 3, 1:200 soil:extractant, 30 min shaking. American Samoa (American Samoa Community College, Land Grant Program) uses the modified Truog procedure: $0.02 N H_2SO_4$, pH 2, 1:100, 30 min. Both laboratories treat the extract to develop a phosphomolybdate blue compound and determine its concentration spectrophotometrically at 880 and 660 nm, respectively.

The practicability of each procedure is about the same. Both require 30 minutes of shaking, and though the Truog uses twice as much extractant, the acid concentration is ten-fold less. This translates to a negligible savings in sulfuric acid but perhaps a considerable reduction in waste disposal for the Truog procedure.

Their applicability can be assessed by how closely Samoan soils resemble those of New Zealand and Hawaii on which correlation studies were done for phosphorus. Short of a repetition of these studies using Samoan soils, a comparison of soil types from each island group should be the next most reliable way to accomplish this. This is based on the assumption that similar soil types have similar forms of phosphorus and, therefore, respond similarly to a particular extractant. Due to the difficulty of obtaining soil survey maps of Western Samoa and New Zealand, and to reconcile their soil classification scheme with that of the Soil Taxonomy system used in the United States, this assessment of applicability was not done.

Reliability can be subdivided into five important factors:

1. **reproducibility,** or the measure of the ability of different laboratories to check one another.
2. **reproducibility,** or **precision,** is the measure of the ability of a laboratory to check itself.
3. **accuracy,** or **systematic error,** that is, the difference between the test value and a true or accepted value.
4. **specificity,** or the ability of the procedure to measure what it is intended to measure.
5. **threshold,** or the smallest concentration that can be measured within a certain degree of confidence.

Which of these five factors is most important depends upon the purpose for which the test result will be used. For the soil testing laboratory, the primary purpose is generally to help provide a fertilizer recommendation to farmers. Accuracy, then, would seem to be of overriding importance. But the test result is just one aspect in making a fertilizer recommendation. Soil type, climate, crop requirements, management skill, yield goal, past performance, previous fertilizer history, and economics are applied as adjustments to make fertilizer recommendation less dependent on the soil test result, even though the objective of soil testing is to be able to predict a nutrient response independently of these other variables.

A more important aspect of the soil test result is monitoring the effects of fertilizer applications, cropping sequences, and cultural practices by performing the same laboratory test procedure and establishing sufficiency limits for each test result value. Here, repeatability must be good enough to detect when a significant difference occurs. Systematic error, as long as it is constant, is not important.

A rapid comparison of the two extractants was done on two soils with three replications each. The modified Truog procedure had slightly better repeatability as judged by the coefficients of variation, (cv) (Table 1).

I tried examining the reproducibility of these two methods by sending soil samples to Hawaii and to Western Samoa for testing. Unfortunately, the Western Samoa laboratory did not respond.

The University of Hawaii, using the modified Truog procedure, returned results of 169 and 101 ppm soil phosphorus for Soils A and B, respectively. These results were not unexpected. Much effort has gone into the study of irreducible differences that exist between supposedly identical measurements made in different laboratories that regulate food and drugs. Given the complex nature of soil, the reliability of test procedures may be limited to obtaining good repeatability. To achieve this, soil testing laboratories must continuously strive for good quality control.

Table 1. **Comparing the repeatability of the Truog and the modified Truog extractants for measuring soil phosphorus as ppm.**

Soil	avg. ± s (cv)	
	Truog	Modified Truog
A	8.9 ± 1.9 (21)	79.4 ± 15.4 (19)
B	16.6 ± 5.5 (33)	76.1 ± 19.1 (25)

Quick Tests for Plant and Soil Analysis

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The environmental impact of over-application of nitrogen (N) fertilizers and organic amendments has been a driving force behind the development of quick analytical tests. Environmental concerns include the harmful effects of high concentrations of nitrate (NO_3) in plant tissues and drinking water. The most immediate threat posed by the misapplication of N, excessive application, or improper timing, is the possible contamination of ground and surface waters with nitrates.

The goal in managing nitrogen (N) as a plant nutrient in agriculture is to optimize yield with minimal environmental impact. Of the three primary plant nutrients, nitrogen, phosphorus and potassium (NPK), N is used in the largest quantity by most vegetable crops. Nitrogen occurs in nature in various forms. Nitrogen is found in the atmosphere as N_2 gas, in soils in both organic and mineral forms and in organic form in plant and animal tissues. Nitrogen in the nitrate (NO_3) form is highly soluble and subject to leaching and run off from soils. Ingestion of high levels of NO_3, poses a human health risk, especially with children. The US Environmental Protection Agency has set 10 ppm nitrate-N as the maximum allowable limit in drinking water.

Factors that determine N management practices include:

1. N fertilizer is relatively inexpensive compared to other agricultural inputs;
2. Crops are able to absorb some excess N in a process called luxury consumption; and,
3. The solubility, plant availability and environmental threat posed by N fertilizers is related to the form of N and its solubility.

Although analytical testing procedures for soil and plant tissue are still considered standard methods, several problems exist with these procedures for N management. A common problem for many growers is that soil and plant testing laboratories take too long to get analytical results back to the grower to allow for timely management decisions. This problem of response time is especially a concern in the Pacific islands which are situated long distances from soil and plant testing laboratories. In addition, laboratory analysis can be expensive.

Portable home test kits are available from several manufacturers, which may alleviate the problem of turn-around time. Maintaining a fresh supply of reagents and keeping the equipment in top working order pose different but equally significant problems. Quick tests may provide a viable alternative especially if the tests are simple, well-calibrated for local conditions and crops, and easy to obtain and maintain.

Quick tests that have been developed for N include:

1. Nitrate sensitive test strips

2. Nitrate selective electrodes

3. Dual wavelength leaf reflectance meters

Nitrate Sensitive Test Strips

This test works through exposure of plant sap to strips coated with nitrate-sensitive dyes. Maximum color development of the test strips usually occurs in a prescribed time. A drawback to this method is that reading of the color and comparison to a standard is subjective. Therefore, results of this method only give a broad indication of N nutrition status.

Nitrate Selective Electrodes

This test uses an electrode which can detect nitrate and gives readings relative to standards with known concentrations of nitrate. Nitrate concentrations in parts per million (ppm) can be converted to nitrate nitrogen (NO_3-N) concentrations (ppm) by multiplying the nitrate concentration by 0.226. An example of this type of electrode is the Horiba 'Cardy' Meter. This meter has been used for nitrate analysis of plant sap and soil.

Dual Wavelength Leaf Reflectance Meters

These handheld units are used to measure the green color intensity of leaves. This intensity is related to the chlorophyll content of the leaf and possibly to N nutrition of the plant. As N becomes deficient in plants, chlorophyll content of the leaf is reduced. However, leaf color can also be dependent on several other factors including the cultivar, the growth stage, other nutrient deficiencies besides N, possible pest and disease damage, and light intensity. Changes in leaf color only become evident when deficiencies are severe. Slight changes in the nitrogen content of plant tissue do not result in immediate leaf color changes.

Considerations for Quick Tests

To be meaningful, the results of a quick test have to be compared to calibration information, which indicates if the nutrient concentration is deficient or adequate in the plant. The calibration information is usually appropriate for certain crops and if certain plant sampling methods are followed. Among the factors affecting the results from quick tests include the method used for plant sampling, the growth stage at which the plant is sampled, and the handling and preparation of samples.

Sampling

Since many of the quick tests analyze nitrate in plant sap, the time of day at which the plant is sampled can have an effect on test results. Nitrate in plant sap is rapidly converted to organic N when adequate light is available for photosynthesis. Sampling at a regular time, optimally between 8 AM and 2 PM, is important when nitrate content of plant tissue is used as an indicator of plant N status.

Another important consideration in any plant tissue sampling is standardization of the plant part that will be sampled. This plant part may vary according to the crop and the calibration information available. For many crops, the plant part most often sampled is the petiole or midrib of the youngest, fully expanded leaf.

The growth stage of the plant also influences N content. In general, young, vegetative growth has a higher N concentration compared to tissue of fully, matured plants in the reproductive stage. Another consideration for nitrate quick tests that analyze plant sap is the handling and preparation of plant samples. Plant samples collected in the field should be stored in plastic bags on ice to reduce transpiration and respiration losses before analysis. Plant sap should be extracted from plant samples within several hours of collection. Often the sap is extracted using a small press and tested immediately.

Table 1 compares nitrate-N sufficiency values and N requirements for cantaloupe from several references. As mentioned previously, ranges of nitrate-N sufficiency values in fresh sap decrease as the crop matures.

Table 1. Comparison of sufficiency values and N requirements for cantaloupes

Crop	Growth Stage	Sufficiency Values NO_3-N (ppm)		Approximate N Requirements (lbs/A/wk)
		Dry Tissue	Fresh Sap	
Cantaloupe (Hockmuth 1991)	First Blossom		1,000 - 2,000	21
	Fruits 2"		800 - 1,000	21
	First Harvest		700 - 800	14
Cantaloupe (Hartz 1994)	Vegetative Growth			5 - 10
	Early Flower	12,000 - 15,000	1,000 - 1,200	10 - 20
	Fruit Bulking	8,000 - 10,000	800 - 1,000	10 - 15
	First Harvest	4,000 - 6,000	700 - 800	5 - 10

For high value, drip-irrigated crops, quick tests can be used to determine when additional fertilizer is needed. These tests can be conducted frequently during the cropping cycle. Additional sampling methods for monitoring soil N status include suction lysimeters and soil core samples (0-30 cm depth) in the wetted zone.

The Horiba 'Cardy' nitrate meter can also be used to measure soil nitrate N. In general, the procedure recommended for this test involves:

1.   Sampling 15 - 20 soil cores which are then crumbled and mixed.

2.   Air-drying the crumbled soil within 24 hours.

3.   Addition and mixing of a liquid extractant with a measured volume of soil.

4.   Filtration of the extractant.

5.   Placement and measurement of the filtered extractant on the nitrate meter sensor.

Laboratory Demonstration of Soil and Plant Testing

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Objectives:

1. To demonstrate and discuss the benefits and disadvantages of soil and plant testing.

2. To demonstrate and discuss the methods used for the proper sampling of soils and plants.

3. To illustrate some concepts of soil and plant testing including selection of suitable extractants, compromises made for use of rapid analytical methods, and use of soil and plant quick test kits and portable meters.

Introduction:

The principal goal of **soil and plant testing** is to provide scientifically-based information on soil fertility and recommendations for nutrient or lime applications. These recommendations are given in order to **correct soil fertility** so that optimal crop yields can be achieved **without potential environmental pollution.** In this way, a grower can save on the cost of over-fertilization and also decrease the risk of environmental pollution. An additional requirement for soil and plant testing is that it be **quick and inexpensive.** Growers expect fast turn-around times on samples and are usually not willing to spend large amounts of money on testing. Soil and plant testing involves several steps including:

1. Proper sampling and processing methods: The principal steps of sampling and processing are to a) **obtain a representative sample** of a much larger area or larger number of plants, b) **avoid contamination** from other nutrient sources and c) keep records in order to identify sampling sites and compare results from previous sampling. Special care must be taken with **plant sampling** since **stage of growth, plant part sampled, type of plant** and the **number of plants sampled** can have an effect on the concentration of nutrients in plant tissue and in how representative the sample is of all plants in the field. Most laboratories **air-dry soil samples** and **oven-dry plant samples (at approximately 60 to 70 °C).** Drying helps to preserve samples by slowing down microbial activity, although some nutrient transformations may still occur during drying and storage. Once dried, soil and plant samples are normally ground and then passed through sieves to insure uniform particle size. This process helps to: a) well mix and homogenize individual samples so that smaller sample sizes are more representative and b) allow for greater chemical reactivity during extraction. The sampling guides which have been distributed give more specific information on proper sampling methods.

2. <u>Selecting appropriate analytical methods:</u> The major criterion for selecting analytical methods, especially the extractant to be used, is whether the amount of nutrient extracted correlates with nutrient availability for plant uptake. Note that plant tissue testing often provides more complete information than soil testing on nutrient deficiencies, especially for many of the micronutrients. However, a complete picture of nutrient availability is best obtained by taking both soil and plant samples.

3. <u>Calibration of soil test values and crop response:</u> An important step in interpreting analytical results is establishing **the relationship between soil test results and a plant characteristic such as yield.** These calibrations are usually established for the important crops and soil series in a given region through extensive field testing over many years. For most U.S. States, analytical results for each nutrient are grouped into fertility ranges such as **very low, low, optimum, high and very high categories.** Note that for many nutrients, results of soil and plant testing will not help to correct deficiencies experienced in the current growing season, but can be used as a guide for the subsequent season.

4. <u>Fertilizer recommendations:</u> Fertilizer recommendations are based on several criteria including the **analytical results for the soil sample, soil type, cropping history, previous fertilizer or organic amendments, crop to be grown and yield goal.** In addition, **calibration information, fertilizer response curves, and experience** all help the trained professional to provide accurate fertilizer recommendations. Many states have incorporated nutrient recommendations into computer programs. One danger with general fertilizer recommendations is that growers differ in the fertilizers they use, the method of fertilizer application, and timing of applications. These differences in management may also affect fertilizer efficiency and crop yields. Therefore, fertilizer recommendations should be used as a general guide and altered depending on local conditions and the grower's experience. Consultation with an extension agent who is familiar with the grower's situation can be helpful for determining an appropriate fertility program.

Demonstrations:

1. <u>Soil Organic Matter Tests</u>

This demonstration illustrates that: (1) sampling methods and sample processing can affect analytical testing results; (2) compromises in accuracy are made in soil analytical procedures to increase the speed of analysis and reduce costs; and (3) new analytical methods can increase the speed of analysis but may increase the costs of running a soil and plant testing laboratory.

Several methods exist for measuring soil organic matter including: (1) soil weight loss after destroying organic matter with heat or a strong chemical or (2) measurement of soil carbon. **Organic carbon** constitutes between 48 to 58% of soil organic matter, and therefore, is a good measure of the amount of soil organic matter. **Inorganic carbon,** such as found in $CaCO_3$, is also a component of soil. The sum of organic carbon and inorganic carbon is the **total carbon** in soil. Typically for measurement of soil organic matter, soil organic carbon is measured and soil organic matter estimated by multiplying the organic carbon result by 1.724.

Special care must be followed in preparing soil samples for organic carbon analysis because sample size is usually limited to between 100 to 200 mg. In order to insure that the sample is representative of the field from which was taken, the soil is ground fine enough to pass through a sieve with 0.5 mm openings.

One method to measure organic carbon is by use of heat. The **CHN (carbon, hydrogen and nitrogen) analyzer** heats samples to a high temperature (800 - 1000 °C) and drives off the carbon as CO_2 which is then measured using an infra-red gas analyzer or by gas chromatography. This instrument has the advantage of being able to measure carbon, nitrogen and possibly sulfur during the same analysis without the use of dangerous reagents. Problems with it include the high cost of the instrument and potential interference from inorganic carbon.

Another method which is commonly used is based on the reaction of $K_2Cr_2O_7$ and H_2SO_4 with organic carbon such that:

$$2 \ Cr_2O_7^{-2} + 3 \ C^0 + 16 \ H^+ \rightleftharpoons 4 \ Cr^{+3} + 3 \ CO_2 + 8 \ H_2O$$
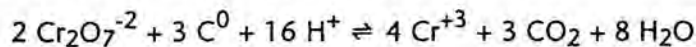
In this reaction the amount of $Cr_2O_7^{-2}$ reduced to Cr^{+3} depends on the quality of organic carbon which is present. Excess $Cr_2O_7^{-2}$ is then titrated with $FeSO_4 \bullet 7H_2O$ or $Fe(NH_4)_2(SO_4)_2 \bullet 6H_2O$ to a standard endpoint. Several methods utilize this chemical reaction and vary in their use of heating to insure complete oxidation of the organic carbon. The **Walkley-Black method** we will demonstrate today does not use supplemental heating and therefore only approximately 76% of the organic carbon is recovered. A correction factor of 1.3 is used to account for incomplete oxidation of the organic carbon. Problems with the dichromate-based methods include interferences from the presence of **chloride, ferrous iron and manganese oxides** and the difficulty of disposing of toxic chemicals generated using the method.

2. Comparison of Phosphorus (P) Extractants for Guam Soils

This demonstration illustrates: (1) the common colorimetric analytical procedure used for many soil testing procedures, and (2) the need for initial research in selection of extractants for soil testing procedures.

The major criterion for selecting analytical methods, especially the extractant to be used, is whether the amount of nutrient extracted correlates with nutrient availability for plant uptake. The amount of P in a water extract of soil may not relate to plant P uptake since plants extract more P from soil than just the amount contained in the soil solution at one time. Therefore, most soil and plant testing laboratories use extractants other than

water including **0.5M NaHCO₃, (also called the Olsen Test), 0.025M HCl + 0.03M NH₄F (also called the Bray No. 1 Test), and 0.05M HCl + 0.025M H₂SO₄ (also called the Mehlich No. 1 Test).** These extractants are suitable for different soil conditions and their use will vary from laboratory to laboratory. The attached table describes the characteristics and suitability of several P extractants. An additional table below provides a comparison of the amount of P extracted from two soils from Guam with different chemical characteristics. The University of Guam Soil and Plant Testing Laboratory uses the Olsen Test for P determination since this extractant works well in both neutral and calcareous soils.

Comparison of Soil P Extractants In Guam Soils

| Soil series | pH (1:1 water) | Clay | Organic carbon | Soil P Extractants | | |
				Mehlich 1	Bray P1	Olsen
		- % -	- % -	------------- mg kg⁻¹ -------------		
Guam series	7.6	17.6	5.0	0.1	0.0	0.4
Togcha series	4.9	65.4	2.3	5.3	15.2	0.5

3. Soil Texture

This demonstration will illustrate some errors introduced into a soil and plant testing procedure due to compromises in accuracy made to increase the speed of analysis and reduce costs.

Soil texture or the proportion of **sand, silt and clay** particles in a soil is an important property of soils since many of the physical (and chemical) characteristics of the soil are determined by soil texture. For example, an engineer may wish to determine if a certain soil is suitable as a base for a building foundation or a roadbed. In determining soil texture, **soil aggregates** must be physically and chemically broken up into their particle components. This process is known as **dispersion.** If aggregates are not adequately dispersed then the soil texture determined will overestimate the proportion of larger particles. In the method demonstrated today, dispersion is accomplished by using both a chemical dispersing agent (sodium hexametaphosphate or Calgon) and by physical mixing with a blender.

The method most commonly used for determining soil texture uses the fact that the rate at which soil particles settle in solution is determined primarily by the size of the particle. Large particles settle faster than smaller particles because smaller particles present more specific surface area. By measuring the density of the solution at different times using a **hydrometer,** we can determine the amount of particles in suspension. Density is affected by temperature so corrections must be made for temperature in density readings using the hydrometer.

We can then determine the %clay by making hydrometer readings after approximately 7 hours. However, our standard method (the Bouyoucos method) calls for a reading after 2 hours in order to allow for rapid determination of texture in a soil and plant testing laboratory. Reading the hydrometer too early tends to overestimate the calculated proportion of clay.

4. Soil and Plant Quick Test Kits

This demonstration will illustrate the use of several soil and plant quick test kits and their advantages and disadvantages. Kits for each regional land-grant institution have been prepared for use and testing during and after the demonstration.

Improving technology and the need for rapid soil and plant testing results has stimulated an interest in the use of **soil and plant quick test kits.** These kits often have the advantages of being **portable** and **simple to use** so they can be taken into the field to aid in rapid management decisions. With the relative isolation of many of the islands and atolls in the Pacific region these tests have potential to overcome the long turn-around time if samples were sent to a regional soil and plant testing laboratory. Extensive research has been conducted on several quick test procedures including the use of **portable chlorophyll meters and measurement of nitrate in soil or plant sap** as measures of plant nitrogen nutrition. Disadvantages of these tests include: (1) other factors such as type of plant variety, plant disease, sample handling, and time of sampling can affect results, (2) lack of calibration information for local crops, (3) dependence on a single supplier for new reagents and replacement parts, and (4) with improper storage many of the reagents can become ineffective.

How Fertilizer Recommendations are Made in the Fertilizer Advice and Consulting System (FACS) Software

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(excerpts from the Hawaii Soil Fertility Manual, 1997)

Diagnoses and recommendations:

"Recommendation," as used here, means advice from a soil or crop specialist to those deciding how much of, what form of, and when to apply a fertilizer to a soil to benefit growth of a plant or crop. Recommendations of fertilizers and soil amendments should consider the interactions of all the factors discussed in this manual, including the soil, the crop, the climate, the beneficial effects of soil organisms such as rhizobia and mycorrhizal fungi, and the harmful effects of plant diseases, insects, and nematodes.

The relations among these factors affecting plant growth are dynamic and complex. Any of them can become growth-limiting at any time, necessitating a specific remedy to permit the crop to achieve its genetic potential. The major tasks of the diagnosis and recommendation effort are to (1) identify growth-limiting (or yield-limiting) factors and (2) suggest economical, environmentally sound, and practical management alternatives.

In the process of modifying the amounts of nutrients in the soil, fertilizer applications have broad effects on the existing soil physical, chemical, and biological properties. Careful consideration of these impacts is needed, because unanticipated effects can limit plant growth and yield.

For example, achieving sufficiency of phosphorus (P) is not solely a question of increasing the amount of "available" P (see table 1). If the soil has been fumigated and the crop is one that is highly dependent on symbiotic associations with soil fungi (AM, or arbuscular mycorrhizal fungi), the crop will not obtain sufficient P even when soil analyses show high levels of extractable P, or when large amounts of P fertilizer have been added. In such cases, the most practical solution is to ensure that the crop is adequately colonized by AM. Similarly, even adequate AM colonization of the plant roots will not ensure good yields if nematode infestation is severe. These examples illustrate how all parts of the soil-plant system are potentially growth-limiting. Consequently, a critical part of plant nutrient management is noticing sub-optimal plant performance, identifying the cause(s), and devising a remedy.

Table 1. "Available" and "Extractable" nutrients:

Available nutrients: those nutrients that plants can absorb.

Extractable nutrients: are those nutrients that are removed from the soil and measured during laboratory analyses. The extractant solutions may remove more or less of a nutrient than is actually available to a plant, so measurements of extractable nutrients are only a "best guess" of the levels of nutrient that a plant's roots can absorb.

In the overall diagnosis process that leads to a recommendation, individual soil and plant tissue samples are just part of the evidence that must be considered. It is a common misconception that the soil analysis or the plant tissue analysis is the only diagnostic information that really matters. Equally important is the "background" information about the soil and plant conditions asked for on the form filled out for samples submitted to the University of Hawaii College of Tropical Agriculture and Human Resources (CTAHR) Agricultural Diagnostic Service Center. The more complete the description of the system, the better informed will be the diagnosis. The greater the detail provided, the more likely the expert will successfully make the correct diagnosis.

Because of the complexity of plant growth systems and the frequent uniqueness of growth environments, useful nutrient management strategies usually combine scientific principles with site-specific data and observations, seasoned with personal experience of the specific plant and production system (Table 2). But there are some useful similarities among effective nutrient management plans. One such similarity is that nutrient recommendations are often developed in two steps:

Diagnosis: Are yields or quality substandard?
If so, what is the cause?
If the cause is nutritional, is it due to deficiency or to excessive (possibly toxic) levels of the nutrient?

Recommendation: How much of, what form of, and when to apply a fertilizer to a soil to benefit growth of a plant or crop.

Table 2. Keys to diagnosing soil nutrient problems.

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1. Recognize the problem. Be alert to signs of abnormal plant growth and declines in yield or product quality.

2. Measure the situation. Keep good records of inputs, growth conditions, and yields. Monitor soil nutrient levels and other soil factors affecting plant growth such as soil pH, salinity, and moisture tension. Monitor the crop's nutrient content.

3. Consult knowledgeable people before problems become severe.

The preliminary diagnosis may begin with the grower observing an abnormal condi--tion, or suspecting that growth is sub-optimal. This leads to taking soil and/or plant tissue samples for analysis.

The next stage of diagnosis, after obtaining the analysis results, involves identifying potentially harmful soil conditions, or nutrient levels that are insufficient, excessive, or somehow out of balance. This stage requires some scientific knowledge of soils and plants and is often based on data from prior experiments with the specific types of soils and plants involved.

The recommendation (or what to do to correct the problem) often requires considerable knowledge of how soil-plant systems operate. People who grow plants as a hobby or a business often are very good observers of the condition of their crops. With some scientific training and the help of literature on the subject, they may be able to proceed through the diagnosis process and, based on their own experience, they may be able to develop their own strategies to correct the problem observed. However, we strongly suggest that consulting with professional experts on soils and plants is of value and can help to avoid mistakes.

Diverse kinds of information can contribute to a diagnosis by pointing to nutrient deficiencies or excesses and suggesting which nutrient is involved. These general indications include:

* visual symptoms of a deficiency
* yield reductions
* cropping history
* previous experience with the specific soil or soil family

More specific information about the crop and the soil-nutrient system is required to arrive at a recommendation to remedy the condition.

Diagnosis is the "front line" in nutrient management. If no one suspects a deficiency or an excess, then it is likely that the problem will go undetected and production will suffer. For this reason, we think it is important that all those involved in plant, soil, and nutrient management should be aware of the principles of diagnosis. Especially, those in the field who are closest to the production system on a day-to-day basis should know about some aspects of the diagnostic process. The tools of diagnosis are discussed in the following paragraphs.

Visual symptoms can suggest the presence of nutrient deficiencies but can be misleading. Similar symptoms may not mean the same thing in all plants or all situations. Often, only a special combination of circumstances results in a distinctive color. Often, plants are deficient in a nutrient or nutrients but do not show symptoms. Even the presence of symptoms, however, is not definitive evidence of deficiency. Many causes, including disease, insect, and pesticide damage, can mimic nutritional deficiency symptoms. Soil and plant analyses are usually required to confirm that symptoms have a nutritional cause.

Tissue analysis, the total nutrient content of a plant tissue, can be a precise tool for nutrient diagnosis. The particular tissue chosen is usually the one that is the best indicator of the plant's overall nutrient status. With corn, for example, the leaf just below the ear, sampled when the ear is silking, has been found to be most effective in diagnosing nutrient conditions that can result in yield changes. In some other crops, the "indicator" or "index" tissue is the youngest leaf that has most recently reached full size. Suitable indicator tissues must be identified for each crop by carefully controlled experiments.

Nutrient dilution is another factor that can lead to misinterpretation of tissue analysis data. Nutrient contents are expressed as concentration, an amount of nutrient per unit weight of plant tissue. However, if the plant's accumulation of a nutrient lags behind its rate of growth (increase in weight), then the concentration of that nutrient in the tissue will decrease. Conversely, if nutrient acquisition continues but the plant weight does not increase, the nutrient concentration can increase. These conditions confuse the identification of the growth-limiting factor and complicate diagnoses. Such complications emphasize the need to consider several lines of evidence when diagnosing plant nutrient deficiencies.

Sap analysis is another type of tissue analysis routinely used for some crops. Rather than measuring the nutrient content of the entire tissue, it measures the nutrient content of the plant's sap, or the juice readily squeezed from an indicator tissue. Sap analysis has become more widely used with the development of relatively inexpensive, portable instruments that measure certain plant nutrients in their ionic forms, such as measuring sap nitrate (NO_3) as an indicator of plant nitrogen (N) content. Sap analysis can be quickly done in the field and repeated during the growth of the crop. Easy though it may be to get a measurement with these portable instruments, the interpretation of the results is subject to complications. Localized correlation and calibration experiments are needed to accurately predict responses to fertilizer input recommendations derived from diagnostic interpretations based on sap analysis.

Soil analysis provides information about the potential of a growth medium (field soil or prepared potting mix) to provide the nutrients required for plant growth. Routine soil (or plant media) nutrient analysis commonly measures extractable calcium (Ca), magnesium (Mg), potassium (K), and phosphorus (P). In special cases, soils are analyzed for aluminum (Al), for nitrogen as total N, ammoniacal N (NH_4^+-N), or nitrate N, and for micronutrients, most often including boron (B), copper (Cu), manganese (Mn), and zinc (Zn). Based on knowledge of the particular soil's characteristics in relation to supplying nutrients, levels of extractable nutrients are interpreted to arrive at estimations of total amounts of nutrients available to a crop in that soil. These levels are in turn compared to "critical" levels considered adequate for the crop to be grown; critical levels are established by planned experiments, and often by compiling results of many planned experiments.

Soil analysis data is often most useful when combined with plant tissue analysis data. The combination of soil and tissue analyses, considered in light of site-specific information about the soil-plant system, is our most powerful tool in diagnosing plant growth problems.

A reliable soil analysis requires a sample that is truly representative of the soil or medium in which the plant is grown. Getting a representative sample requires thoughtful observation of the area being sampled and careful sampling procedure.

Soil analyses are not definitive - they can mislead. For example, the soil K level may be high, but the plant may be deficient in K because of soil compaction, nematode infestation, or other factors that limit nutrient absorption.

Cultural practices that affect soil salinity levels, organic matter content, tilth, aeration, and other soil conditions should be considered in nutrient diagnoses and interpretations. These conditions influence nutrient sufficiency when they affect nutrient transformations in the soil or nutrient transport through the soil, into the plant, and within the plant. This nutrient absorption pathway is extremely complex. It begins with various types of movement and chemical transformation as nutrients migrate from soil minerals or organic matter into the soil solution. Encountering plant roots, the nutrients are further influenced by the root rhizosphere. At the root surface, they enter the plant by being transported across a plant membrane. Within the plant, the nutrients move in the xylem to sites of growth, where they are synthesized into plant material.

This complex process is subject to influence by many factors. For example, water stress rapidly affects uptake of most nutrients. After a few days of wilting, plants can display the same yellowing of lower leaves associated with nitrogen deficiency. Phosphorus absorption by plants is strongly reduced by water stress; conversely, phosphorus deficiency leads to wilting.

Timing of nutrient applications in relation to plant tissue sample collection can be critical to obtaining a meaningful plant sample. There is a time gap after fertilizer application before the "flush" of nutrient uptake and the resulting growth response in the plant have occurred. This may be several weeks for herbaceous plants and a year or more for established tree crops.

Nutrient ratios are sometimes helpful in interpreting soil analysis data. For example, plants' sulfur nutrition is affected by their nitrogen content, so an unusual N/S ratio can signal imbalances. High soil potassium (K) levels can induce magnesium (Mg) deficiency, so the K/Mg ratio in the soil should be considered before assuming that soil Mg levels are adequate.

Other factors in addition to nutrient levels can affect interpretations of nutrient conditions. Applications of fungicides and fumigants to control harmful organisms can eliminate the beneficial AM fungi. Many plants are strongly dependent on AM fungi for help in taking up phosphorus, and plant growth will be limited when the fungi are killed.

Recommendations:

Once a nutrient deficiency is diagnosed, a recommendation can be developed for an action to correct the situation. We have described a diagnostic approach that assembles a wide range of information from various sources. Recommendations, in contrast, are developed by narrowing the approach to focus on the particular problem: What is wrong with the usual nutrient supply system? Among other factors it requires a "calibrated" soil test (see Table 3).

Table 3. "Calibrating" soil tests:

Calibration: A soil test is calibrated in a two-step process:

1. Identify the level of each nutrient that is adequate for good growth of the crop.
2. Determine how much fertilizer is needed to increase soil test values to the level of adequacy for the nutrient and the crop.

The results of each of these steps vary with the soil type. For example, depending on the soil, the amount of phosphorus needed as fertilizer may range from 2 to 50 times the actual increase in soil-test P that will result from the fertilizer application.

Calibration research is expensive to conduct, and because of the numerous diversified crops grown in Hawaii and the many different types of soils found in the state, development of calibration data has been limited. Therefore, field testing by growers cooperating with researchers is presently one of the few practical ways to obtain calibration data.

A frequent answer is that there is a simple deficiency—the available "pool" of a certain nutrient or group of nutrients in the soil is too small. Just as frequently, however, factors other than limited quantity have restricted the supply of the particular nutrient. In this latter case, solving the deficiency is not always merely a question of adding more nutrient as fertilizer. In fact, most growers have already tried this remedy before asking for help.

As we have described above, many factors can affect the adequacy of nutrient supply. In developing recommendations, specialists from other disciplines often must be consulted to confirm the diagnosis. These specialists include plant pathologists, entomologists, horticulturists, and plant physiologists.

Correcting soil nutrient deficiencies:

Soil nutrients can be grouped in three general categories:

(1) Nutrients that react extensively with the soil:

* phosphorus (P)
* potassium (K)
* calcium (Ca) and magnesium (Mg) as supplied in limestone

Management of these nutrients is largely concerned with their amounts in the soil, which are managed by determining how much nutrient is necessary for good growth (the critical level of the nutrient) and how much fertilizer nutrient is required to bring the soil or media to the necessary level. Soil test calibration determines for a particular crop and soil how much fertilizer is required to bring the soil test level to the level necessary for good growth.

(2) Nutrients that react relatively little with the soil and the need for which, consequently, is determined largely by plant demand; examples are nitrogen (N) and, in some soils, potassium (K).

(3) Nutrients that are required in small amounts and which can easily be either deficient or toxic, such as zinc (Zn), manganese (Mn), iron (Fe), boron (B), molybdenum (Mo), and copper (Cu).

The power to improve crop management using information obtained from a methodical program of nutrient monitoring was recognized several decades ago by Harry F. Clements and incorporated into his crop log system for sugarcane production. Today, similar techniques are applied in monitoring the nutrient status of many crops—for example, macadamia.

To improve the accuracy of fertilizer recommendations, farm managers should keep records of their fertilization program and crops' responses to it. A good soil fertility management record would consist of:

* soil and plant tissue analyses at the beginning of the fertilization cycle
* measurements of crop yields
* records of fertilizer inputs (amounts and times) associated with the crop yields
* soil and plant tissue analyses after the cropping cycle

These data permit estimation of the nutrient additions and removals and the resulting deficits or surpluses. After several years, such records will reveal trends in nutrient status that have resulted from the fertilization program. In addition, records of applications of other agricultural chemicals to the crops may be useful in the diagnosis of problems that occur. Monitoring nutrients in this way provides useful management information.

Regulations affecting agriculture are becoming more stringent when it comes to impacts of agricultural practices on the environment. Already, on-farm use of certain agricultural chemicals, such as pesticides, must be recorded to ensure that "best management" guidelines are being followed and that applications are done properly. In the future, records on use of fertilizers may also be required to help state and federal regulatory agencies protect the environment. Farmers who use sound record-keeping and nutrient management practices to improve their profitability will be better prepared to comply with and meet the standards of any new regulations on agricultural chemicals.

CTAHR Agricultural Diagnostic Service Center:

In recent years, CTAHR's Agricultural Diagnostic Service Center and Department of Agronomy and Soil Science have focused much effort on transforming and improving the soil and plant tissue analysis service. The specific objectives of this effort have been to improve the handling and analysis of soil and plant tissue samples by accomplishing the following objectives:

1. Change sample analysis procedures to more quantitative methods that have better supporting research (in the form of correlation and calibration studies from other areas).

2. Shorten the time between soil sample submission and delivery of diagnostic and recommendation results to clients.

3. Provide farmers with an acceptable alternative to U.S. mainland laboratories, which often give recommendations that are irrelevant to Hawaii conditions.

4. Develop, confirm, and standardize recommendations appropriate for Hawaii conditions.

5. Improve the diagnosis and recommendation process by making it clearer to all the parties involved (clients, extension agents, and extension specialists and their supporting departments).

6. Provide supporting information (such as is contained in this manual) to assist agents in explaining and interpreting diagnoses and recommendations.

7. Promote interactive communication and facilitate information feedback from the parties involved to the ADSC Nutrient Management Working Group that would permit the group to correct faulty diagnoses and recommendations and implement more appropriate new procedures.

8. Develop a computerized system that would reduce the amount of time required by the specialist to generate quality recommendations.

These changes have resulted in more samples being received by the ADSC and increased awareness of nutrient management by specialists, extension agents, and their clients.

Fertilizer Advice and Consulting System:

The last step in the preceeding list of objectives is a crucial one. It has led to the development of the Fertilizer Advice and Consulting System (FACS). This involved organizing the information that is already available on Hawaii's soils and crops. Also, it attempts to automate the process of comparing new information about a specific situation with the existing body of knowledge.

FACS is a computer program developed using an "expert systems" knowledge-capture strategy. Computers cannot mimic all of the human decision-making process, but they can store much of the information that experts need to make decisions, and they can make that information available to others. They can also do some of the preliminary analysis of the information by duplicating some of the considerations that an expert would apply to a problem.

The goal of soil and plant tissue analysis is to improve nutrient management for increased productivity and economic benefit and decreased negative effects on the environment, if not to improve the environment in some ways. The analysis is used to identify nutrient mismatches between crop, soil, and farmer needs and develop recommendations that correct the mismatches.

An example of the type of information FACS uses for diagnosis is that contained in the fact sheet developed by the Nutrient Management Working Group (Tamimi et al., 1994, Agronomy and Soil Science Fact Sheet no. 3). The fact sheet gives broad target ranges of soil pH, phosphorus, potassium, calcium, magnesium, and salinity that have been established for certain crops in Hawaii.

Wherever possible, FACS uses local data to interpret foliar analysis results, but at the present time the program is largely based on the plant nutrition book by Jones et al. (1991). The sufficiency ranges given in the Tamimi et al. (1994) fact sheet have been expanded in FACS to five categories of suggested interpretations for both soil and plant analysis: very low, low, sufficient, high, and very high. These ranges correspond to specific interpretations and actions. For example, if sample values were interpreted in the "very low" or "very high" ranges, it indicates that a change in the nutrient management program is needed, not just the addition of more or less nutrient.

Our current interpretations reflect a substantial change in the philosophy of nutrient management. No longer is excess fertilizer applied considered "money in the bank" or nutrient "insurance." Rather, it is wasteful, environmentally harmful, and could be the focus of regulatory action in the future.

Developing FACS has involved the use of logic, which is intended to make the diagnosis and recommendation process clear and open to scientific critique. FACS has also been developed to help its users learn principles of nutrient management. This knowledge can

empower growers to improve their nutrient management programs by understanding the value of information used in diagnoses. They can also be more knowledgeable when implementing the recommendations for correcting crop, soil, and management mismatches.

If diagnosis identifies nutrient deficiencies or excesses, FACS proposes a recommendation. Often, nutrient deficiencies are found, because our tropical soils are highly weathered. The process by which recommendations are developed depends on the client. For example, recommendations for homeowners stress convenience and environmental concerns in the selection and application of nutrients, while recommendations for a rancher may focus more on productivity, economic, and environmental factors. The general sequence used in FACS for developing recommendations is as follows:

Soils and soil series are grouped into three broad categories based on bulk density: heavy soils (bulk density 1 g/cc), light soils (bulk density 0.5 g/cc), and a'a lava soils.

The crop to be grown will determine the target pH range, and the yield goal will determine the probable nitrogen demand.

If needed, a recommendation for soil pH adjustment is determined to meet the crop needs, depending on acidity and alkalinity factors. In locations where rainfall is adequate for crop growth, soil acidity is often a problem. Buffer curves are used to calculate lime requirement, considering whether the limiting factor is Ca or Mg deficiency, Mn toxicity, Al toxicity, or extreme pH.

The phosphorus requirement is determined. Target soil levels (Fact Sheet no. 3) are identified, and broad buffer coefficients (the change in extractable P per unit of applied phosphorus) are used for the three soil categories.

The potassium need is considered using a similar calculation procedure (target minus actual divided by the buffer coefficient).

Critical levels of calcium and magnesium are considered, and also the ratio of Ca to Mg. Based on the initial levels and the expected changes due to lime and phosphorus applications, predicted levels are compared with minimum levels and, if they are still inadequate, additional nutrient applications are recommended.

Micronutrients are added as a "blanket" application when foliar analysis indicates deficiency.

The development of the Fertilizer Advice and Consulting System is in progress. As more accurate and precise information becomes available, FACS will be improved. Continued review of literature and accumulation of local experience is necessary to improve recommendations. FACS also must be thoroughly tested by Cooperative Extension Service agents and specialists. Most likely the present prototype will be revised several times. The goal is to develop a "self-correcting" system that incorporates input from growers, researchers, extension agents, extension specialists, and the ADSC while moving cooperatively toward improved and proactive management of nutrients in Hawaii's agricultural and natural ecosystems.

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Plant Nutrient Management on Guam

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The goals of plant nutrient management on Guam are: 1) to increase awareness of the environmental impacts of nutrient applications, and 2) to increase profitability for growers. The goals are achieved through the development and promotion of nutrient management methods suitable for the environmental, economic, and social conditions of Guam. The major plant nutrient sources currently available on the island include manufactured fertilizers and organic materials, such as animal manure, food processing wastes, and plant materials. A common problem limiting the use of organic sources, is their sporadic availability and high cost of transportation.

Soil organic matter management is an important part of sustainable agricultural production. The goal of sustainable management is to increase or maintain soil organic matter levels. Among the animal residues available on Guam are hog waste, fish processing waste, and sewage sludge. Use of hog waste has been hampered by the difficulty of handling the material since most hog producers add large amounts of wash water to the waste. Hog farmers lack adequate waste storage and transport facilities. In addition, recommendations for appropriate application rates of hog waste have not been developed for the environmental conditions of Guam. Fear of potential pollution from hog farm sites and land applications of hog waste, especially in areas overlying the Northern Guam aquifer, has also attracted additional regulatory scrutiny.

Fish scraps produced during fish processing is a plant nutrient source that has not been adequately exploited, despite the relatively large amounts of this waste produced on the island. Factors restricting use of this material include the need for further processing before land application, the lack of recommended rates of land application, and environmental regulations.

Sewage sludge is also an under-utilized organic source of nutrients on Guam. Current sewage treatment plants on Guam only have primary treatment of sewage, which results in relatively high risks while handling the solid product. Further processing to reduce potential human health risks, such as composting, heating and grinding, may be required and have not been fully explored. In addition, recommended application rates for sewage sludge have not been developed. Further use of this product must also overcome the social stigma attached to handling human waste.

A wide assortment of plant residues are also available on Guam for land application. Wood and paper waste products compose a large proportion of the waste stream. These products generally require additional processing to improve their suitability for land appli-

cation. Appropriate application rates and management for these types of waste products have not been widely studied on Guam. Negative attitudes among the public for using these types of waste products as soil amendments must also be overcome.

Use of green manures and cover crops has been actively promoted by several government agencies on Guam including the Natural Resources Conservation Service and researchers of the College of Agriculture and Life Sciences. Initial focus has been on testing appropriate plant material for Guam and the region. Availability of selected plant materials is critical for the adoption of green manures and cover crops as standard practices. Management systems using these practices must include careful timing and planning to avoid competition for resources between the green manure or cover crops and the crop plant.

The major fertilizer nutrients used on Guam are nitrogen (N), phosphorus (P) and potassium (K). The primary management components of these plant nutrients are the available sources of nutrients, timing of application, and placement of fertilizers. Generally, P and K are applied in a granular form preplant or at planting. Often up to half of the N is applied along with the P and K. Nitrogen and to some degree, K, are increasingly being applied in small multiple doses through fertigation. Applying nutrients in small doses can closely match crop needs and can reduce the risk of run-off and leaching due to unpredictable events of heavy rainfall.

Commonwealth of the Northern Marianas Soils

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Roughly 70% of all the soils on Saipan, Tinian and Rota can be found on limestone plateaus. They are comprised of clay loams or clay, generally shallow, and slightly to moderately sloped.

Most of the farming and grazing in the CNMI is done on these soils. These soils also provide the watershed for most of the Commonwealth water supplies. Aquifers are recharged by water infiltrating through the porous limestone of these plateaus. Herein lies our main concern regarding nonpoint pollution in the CNMI, i.e., nitrate and pesticide contamination of the water supplies of Tinian and Rota from farming activities. We are not as concerned with the water quality on Saipan due to high chloride concentrations which make it undrinkable.

In the past, the few soil samples requested by farmers were collected by land grant personnel and shipped off to the University of Hawaii or the University of Guam for analysis, sometimes taking months for a reply. Due to this time lag, most farmers rely on extension agents' knowledge and recommendations regarding soil types and nutrients needed for their specific crops. Any improvement in the time lag for a soil analysis would significantly improve our farmers' decision making.

In the near future, land grant personnel will begin to take soil, water and plant tissues samples to test for pesticide residues. These samples will be taken on a periodic basis to determine any trends, if any. Our main concern here is in the Marpo Valley on Tinian and the Sabana on Rota. In both cases, farmers are leasing prime farmland situated on the main watershed for their respective islands. Over-reliance on fertilizers and pesticides has the potential to pollute these important aquifers.

Soil Nutrient Management in Palau

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Palau In Perspective:

Palau, located in the Western Pacific, consists of more than 200 islands with a combined area of 43,830 hectares. It has 16 states run by elected and by traditional leaders. Palau has a hot and humid climate. Average annual rainfall is 370 cm per year. The rainy months of July to January produce 30 cm of rain per month. In the driest months of February to April, rainfall averages 21 cm per month. Average air temperature is 27 °C. Relative humidity is 82% on the average.

Agriculture, tourism and marine resources are the backbone of the Palauan economy. The goal for agriculture of the national development plan from 1995-1999 is to develop market-oriented sustainable agriculture geared towards self-sufficiency, exports, and import substitution. At present, there are two major types of producers: subsistence and commercial. Subsistence farmers focus on cassava, taro, sweet potato, banana and coconut. There exist 15 commercial farms that grow vegetables and are mostly located on the biggest island of Babeldaob. Areas cultivated by this last group range from 0.4 to 4 hectares (1 to 10 acres) operated and managed by foreigners dominated by the Taiwanese and Chinese.

Soils In Palau:

According to Smith (1983), there are 10 soil orders and twenty soil series in Palau. Their potentials and limitations for crop production, woodland management and productivity, recreational development, building site development, sanitary facilities, construction materials, water management; and physical, chemical and engineering properties were identified by Smith (1983). Palau has five soil formations as listed below:

Soils on bottom lands: very deep, poorly-drained, found in valley and coastal areas.
Soils on marine terraces: very deep, poorly to moderately drained.
Soils on volcanic slopes: very deep, well-drained, found on uplands and hills.
Soils on limestone: shallow, well-drained, on uplands and coral islands.
Soils that formed in coral sand: very deep, excessively-drained, sloping soils, on beach areas.

Palau's largest islands are volcanic and are composed of basalt and andesite. Some islands are of limestone formation. Two of them are platform and reef islands, while one is a coral reef.

Soil Nutrient Management Practices:

The majority of the farmers in Palau still employ traditional sustainable practices that are labor-intensive and rarely dependent on energy and chemical-intensive technologies. The usual traditional way of planting crops is accompanied by the addition of organic matter. The soil is dug and set aside. Compost and other green plant materials like leaves, twigs and grasses are added then covered with a small amount of loose soil. Crops are planted and some organic materials and sometimes ash are added. Then the mound is built. Unless the quality of the growing media declines, this process is not repeated until another cycle of planting.

Among traditional crops in Palau, taro has at least six identifiable systems of production. These are the paddy-like culture (mesei), damp or wet planting (dechel), garden or farm (sers), terracing on sloping land, slash and burn following a fallow, and a hybrid of mesei and dechel. In all cases, organic matter is added in the holes dug for the plants.

However, commercial farms use commercial fertilizers, usually in combination with compost and animal manures. Poultry manure is sold at $5 per 25 pound bag by the local poultry owners. Those with piggeries use hog wastes in which the solids are added to the compost. Liquid effluents are watered to plants.

In general, these are the different ways that traditional and commercial farmers sustain the soils in Palau for crop production:

1. Fertilization:

Traditional farmers rarely apply commercial fertilizer in subsistence crops. They believe that commercial fertilizers change the texture and taste of their produce.

Farmers engaged in vegetable crop production usually use commercial fertilizer like complete, ammonium sulfate and urea. The amounts and frequency of application for these fertilizers are variable and are not recorded. Application varies from mixing with soil at planting time, sidedressing of mature plants or applying on the soil surface where crops are planted. For home gardens, foliar fertilizer like Miracle Gro is also used.

2. Organic matter maintenance:

Some farm wastes such as dried leaves, stems, branches, sawdust and manure are used in maintaining the organic matter of the soil.

   a. Use of manure: Hog solid wastes and chicken manure are mixed with fresh or dried plant residues for compost making. Liquid manure from hogs are usually kept in septic tanks. The liquid is used to fertilize vegetables, root crops or fruit trees.

   b. Crop rotation: In some farms, farmers plant common legumes like yard-long bean after which another crop like cucumber will follow.

   c. Composting: This is a common practice throughout Palau. Plant residues are not

usually burned but are kept to decompose at one corner of the backyard or farm. Others prefer using black trash bags for decomposing leaves of plants and/or grasses. Some add manure to the pile of plant residues. These are usually applied to the plants after they are partially decomposed by mixing with the soil where the plants will be grown. Lime is sometimes added with the compost or placed on top of the soil surface after planting crops.

d. "Green manuring" is the practice of incorporating any green or fresh plants or parts to the soil at planting time. For instance, to maintain the fertility of a taro patch measuring 3.6 m by 3.6 m (12 ft X 12 ft), 24 kg (about 28 bundles of available grasses like elephant or Johnson grasses) are added to the patch to maintain adequate soil fertility. In the second year, only 6 kg (7 bundles) of grasses are required.

e. Use of droppings of bats and sea birds as fertilizer: These materials are usually found on the Rock Islands. Only a few farmers utilize them due to cumbersome handling from the caves to the farms. The source of materials is far away and a boat is needed to get them.

f. Fallowing of a farm for 1 to 4 years, depending on available area tilled by the farmer. The bigger the farm, the longer is the resting period for the land before planting crops.

g. Use of fish washings for small home gardens.

h. Use of lime and ashes. Twelve kg of ash are mixed with 341 g of lime. The mixture is spread in soil and turned in and left for five days before planting taro. This practice is being used by traditional farmers to control corm rot of taro.

3. Prevention of soil erosion:

This is accomplished by minimum tillage, planting nitrogen-fixing trees on sloping areas or ridges and use of viney, crawling plants like sweet potato and squashes.

4. Amending soil structure:

For clayey soils, commercial farms mostly managed by the Chinese buy commercial top soil and steer manure to improve the workability of the soil and its fertility. Again, the quantities used are not established yet.

Role of Soil and Plant Testing in Sustainable Agriculture Production:

In general, farmers in Palau can be further assisted in improving the sustainability of their lands by:

1. Determining present soil nutrients of representative soil samples from 20 Palauan soil series.

2. Determining nutrient composition of compost made up of different materials such as grasses, banana leaves, chicken manure, etc.

3. Providing decomposition rates for tropical plants and animal wastes used in composting.

4. Providing information about amounts of lime to be added in each Palauan soil series.

5. Providing information about amounts of compost to be added by soil series.

6. Providing information about changes in soil properties affecting soil nutrient availability and plant utilization of these nutrients.

Recommendations:

The development and implementation of a regional collaborative project comparing traditional and modern farm practices in terms of sustainable crop production may be appropriate at this time when most islands still have existing traditional farmers amidst the predominance of modern producers in progressive places. Standard plant and soil data need to be collected at cooperators' sites. The soil nutrient management practices for one crop commonly grown in the region may simplify comparison of results by location.

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Soil Analysis: Marshall Islands

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An appropriate descriptor symbol for atoll soils is the letter "S" representing: 1) **Severe,** 2) **Same,** 3) **Shallow,** 4) **Seven,** 5) **Six,** 6) **Sand** and 7) **Salt.**

The United States Department of Agriculture Soil Conservation Service, in cooperation with the Department of Interior, Office of the High Commissioner, during the Trust Territory of the Pacific Islands era in 1979, conducted a soil survey of several atolls in what has become the Republic of the Marshall Islands.

Severe is the most common descriptor used in the multiple tables characterizing conditions for recreational development to water management. The reason for this becomes clear when one considers the process of atoll evolution.

Atolls are formed on reef structures that began as fringe reefs attached to volcanic islands. Over the course of millions of years, the volcanic island erodes away separating the shoreline from the former attached fringe reef creating a barrier reef. Eventually, the entire volcanic island erodes away completely leaving behind a lagoon in the center surrounded by the barrier reef. The volcanic rock continues to erode while coral continues to build on its water-insoluble platform. Evidence for this "Darwin's Subsidence" process comes from drilling cores to discover the depth at which volcanic bedrock can be found underneath the solid coral and how many years ago the living coral initiated its growth as a fringe reef structure. Volcanic bedrock is found under more than 4000 feet of solid coral and the first coral structure was deposited about 50 million years ago. Since we know that coral can only grow within 150 feet of the surface, constrained by light intensity and temperature requirements, the first coral deposits must have been within this range of the surface. To find them now greater than 4000 feet beneath the surface requires continued erosion of the volcanic bedrock from beneath the coral platform, a rise in sea level, or both.

What is known is that atoll soils are approximately 3,500 years old, a relatively young geological and soil age. This corresponds to the post-glacial xerothermic period when the sea level was approximately 6.5 feet above the current level. At that time, the world entered another glacial period locking surface water into the polar ice caps, thereby gradually lowering the sea level to its current depth. This process exposed the reef platforms allowing coraline deposits to accumulate which are mainly calcium and magnesium carbonates, a calcareous base of sand and gravel. Accumulation of this nature creates a rather flat topography. The climate of the Marshall Islands is uniformly of high temperature throughout the year causing rapid decomposition of the organic matter deposited by the few types of plants capable of growing in these **severe** conditions, limiting the accumulation of humus. Hence, the major factors (parent material, climate, biological activity, relief and time) affecting soil formation have produced a soil that is **same over time and location.**

Atoll soils are **same** also because atoll formation produces a **shallow soil zone** above the coral reef bedrock. The **shallow soil zone** limits the creation of diverse soil horizons as does the narrowness of the reef platforms upon which the accumulations deposit, resulting in only **seven types** of soil map units. The general Marshall Islands atoll soil composition consists of 50% cobbly loamy sand, 30% rubble and 20% ngedebus. The **shallow soil zone** is also constrained by having a **six foot average land height** above sea level that is composed mostly of **sand.** The atoll soils are "AC" soils with a very **shallow** "A1" horizon of incorporated organic matter, a narrow "A3" transitional horizon leading directly into the "C" horizon of unaltered material of gravel, rubble and **sand.** At such a low average elevation and narrow width, persistent winds spray **salt** over the surface. In addition, periodic storms and typhoons cause considerable rejuvenation of the developing soil, destroying large zones that were planted for subsistence agriculture. These factors contribute to the **severe** classification descriptor and reduce or setback the rate of soil development, leaving the conditions very much the **same** over time.

Other factors contribute to the **severe** classification. The gravel and sand are very porous with high drainage and resultant low available water capacity. The calcareous soil is poor in cation exchange because very little clay is present so this process is conducted by the scarce organic matter present. Nitrogen, phosphorus and potassium, the major plant nutrients, are in low supply; the calcareous limestone nature of the soil creates a highly alkaline condition between pH 8.0 and 8.4 resulting in the unavailability of iron, manganese and zinc to plants along with the fact that these elements and copper are also found in short supply. The ground water is often saline and the activity of soil microorganisms is limited.

Anthropological evidence suggests that Marshallese arrived between 2,000 to 3,000 years ago. At that time, birds were present and could have contributed guano as a source of phosphorus. Trench excavations find the presence of bird bones only during the initial period of colonization by the Marshallese settlers, an indication that the early settlers depleted the bird populations and the birds ceased to be significant inhabitants. Such a finding may explain the current phosphorus deficiency in the Marshall Islands soils.

Nitrogen, phosphorus, potassium, iron, manganese, zinc and copper need to be increased. The highly alkaline and almost entirely limestone nature of the calcareous soil must be considered in attempting to lower the pH to allow iron, manganese and zinc to be available for plant uptake, or alternatives must be introduced such as appropriate chelators (ethylenediamine di-o-hydroxyphenyl acetate, EDDHA, for iron chelation in alkaline soils for example), foliar application or slow-release formulations along with intensive buffering. Compost application must take into account appropriate starting material to achieve suitable mineralization in terms of rates and composition. Composting must also negotiate high soil porosity and temperatures which lead to rapid leaching and organic matter decomposition, reducing humus accumulation.

Currently, there is an expressed desire to avoid the use of chemical fertilizers which may have been a result of overuse. Instead, recommendations call for the use of copra, chicken manure and wood ash. While there is no question about the added nutrient benefits in terms of the nitrogen from the copra and chicken manure, and the potassium from the wood ash, there is a need to examine these amendments in terms of sustainability. Not

many atolls in the Marshall Islands have chickens in sufficient quantities to be able to collect the manure for soil amendment. Majuro is the source of chicken manure that is used in large quantities. When taking into account manure purchase, labor, trucking, shipping and bag costs to collect, bag and deliver the chicken manure, the cost is $16.50 per bag. Copra is gathered in many of the outer atolls, then shipped to Majuro where it is subjected to similar costs as the chicken manure in terms of copra purchase, labor, trucking, shipping and bag costs. The cost of using copra is $9.90 per bag. As a result, the cost to apply a single application of this amendment using 2 bags of copra plus a bag of chicken manure for soil in a single trench that is approximately 30 feet long is $36.30. This quickly places such soil amendment activities out of reach for most Marshallese who are involved in subsistence practices. Furthermore, whether these amendments add back fully all of the necessary nutrients that are deficient in atolls soils remains to be analyzed.

It becomes apparent that a systematic approach is necessary in order to understand factors such as atoll soil phosphorus buffer coefficients; the extent of nutrient deficiencies and availability due to the high soil pH; the ability to reduce this pH in a sustainable manner; the types of atoll plants such as legumes which are rapid growing and can routinely be used in composting; the rate of mineralization of prospective composting choices; the ability to alter the soil porosity for water availability. When these factors are better understood, recommendations for atoll soil amendments will be more reliable, providing the opportunity to include another "S" descriptor: 8) **Sustainable,** and to modify 1) **Severe** and 2) **Same** for the soil zones to be used for agriculture.

Nutrient Management in Pohnpei

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Soil nutrient management practices in all the islands in the Federated States of Micronesia (FSM) generally are based on traditional knowledge where special consideration is given to the ecosystem. In all the islands, most of the agriculture is for subsistence purposes. Use of organic material is perhaps the most utilized practice in nutrient managment everywhere. Even with the use of chemical fertilizers as NPK or the single elements to complement the increased development pressures for a cash economy, emphasis is still with the use of such organic material. The most frequent practice now is to combine both chemical fertilizers and organic matter. Farmers are using compost, decayed plant materials, chicken manures as well as mulching, green manuring, and the use of the nitrogen-fixing, Acacia and Flemengia.

The use of chemical fertilizers is strictly for cash or commercial production. Such fertilizers are available through the government Office of Agriculture and Forestry and from a number of importers. Types of fertilizers available include 80 lbs bags of complete and single elements, foliar spray fertilizer in small quantities, and certain types of liquid-type fertilizers.

Farmers could purchase fertilizers in small quantities, therefore there is no need for any storage capacity at the farms. There are a few larger operations with more than one acre farming area. These farms, however, have storage facility.

Chicken manure is readily available at poultry farms. These are sold for a dollar a sack (80 lb feed bag). There is a chipper machine at the Agriculture Station. With that equipment, by-products of broiler processing (intestines, feathers, and shanks) are mixed with chipped plant materials and grasses.

A newly introduced composting practice is being placed in the field by the office of the U.S. Natural Resources Conservation Service (NRCS). This is called "basket compost". A 3 foot diameter meshwire fencing is strategically placed in the field or in the backyard over a hole about 1 and 1/2 ft diameter and 2 feet deep. Grasses, leaves and pig manure or chicken manure are placed in the enclosure up to the height of the meshwire, which is about 18 inches tall. Vegetable crops are planted surrounding the perimeter. It took only a few months for the formation of a rich soil in the hole. The plan is to eventually plant yam in the hole.

Island Report: Hawaii

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Introduction:

The purpose of this report is to provide some information about the status of fertility management in Hawaii, not in an exhaustive manner, but with the purpose of explaining how our knowledge and equipment may be of assistance to other Agricultural Development in the American Pacific Project (ADAP)-affiliated institutions.

With that in mind I touch only briefly on the soil and agronomic context of our work with fertility recommendations. I discuss at greater length how recommendations are made, what are the weaknesses in our recommendation system, and what we have learned so far, using a sub-set of sample data contained in the data base component of our new system.

Soil environment:

All soil orders are represented in Hawaii (Table 1), making this state an excellent natural soil science laboratory. However, this diversity is somewhat illusory, as most agricultural soils have volcanic rock or ash substrates, and most important soils are slightly to severely acid. One critical example of the kind of problems we face in making fertility recommendations is phosphorus. Phosphorus fixation, or sorption onto soil particles, varies considerably, from almost none in histic (organic) soils to severe in highly weathered mineral soils, and especially in volcanic ash soils.

Table 1: Hawaii soil orders, percent of total land area.

Soil Order	Percent	Notes
Inceptisol	24	Mostly volcanic ash soils - acid (new order: Andisols)
Histosol	14	A'a land (vegetated lava flows).
Oxisol	5	Acid soil.
Mollisol	4	Neutral pH, low rainfall areas.
Ultisol	3	Very acid soil.
Aridisol	1	Desert soils, neutral or alkaline.
Entisol	1	Includes coralline sand derived soil - alkaline.
Vertisol	1	Often steep, very unstable - neutral to alkaline.
Spodosol	1	Largely limited to Alakai Swamp, Kauai.
Alfisol	0.1	Slightly acid soil.
Miscellaneous	46	Nonarable, unvegetated lava flows, etc.

Source: R. Warwick Armstrong (ed.), Atlas of Hawaii, 1984.

Economic environment:

According to a recent local newspaper article (Hawaii Tribune-Herald, 1997), the number of on-farm workers has declined from 13,000 in 1991 to 11,000 in 1994, with about 4,800 farms in existence in 1994. Employment includes work taking up an average of 15 or more hours a week, paid or unpaid. Farms are any agricultural enterprise with gross receipts greater than $1,000 per year. Agriculture provided one work space out of 15 overall in the state in 1994 (Hawaii Tribune-Herald, 1997). Adding processing, packaging, and other downstream activities, the total employment climbs to 38,000 (Tribune-Herald, 1997). At a rough guess, agriculture is about tied with military expenditures for a distant second place behind tourism, in terms of overall economic importance to the state.

Hawaii has a tremendous diversity of commercial products (Table 2). Forest, marine, livestock, and aquaculture products are not included in this table. Another feature of Hawaii agriculture is that there is, if anything, a negative correlation between the size of an industry and the number of farms. Farm size varies from a few that are some of the largest in the United States, to many that are basically backyard-and-weekend operations. The diversity of both products and farm size also makes Hawaii a tremendous natural laboratory for studying farm management issues.

Table 2: A profile of Hawaii agriculture in 1994.

Crop	Sales $	Number of farms
SUGAR	160,100,000	24
PINEAPPLE	78,105,000	15
FLOWERS and NURSERY	67,894,000	660
VEGETABLES and MELONS	36,105,000	480
MACADAMIA NUTS	35,535,000	650
OTHER FRUITS	23,611,000	836
COFFEE	10,400,000	550*
FIELD CROPS	10,158,000	585
TARO	2,806,000	180

* based on an informal source, for 1996 (Coffee Times, a trade/advertising publication of coffee growers and processors of Kona, Hawaii).

From Statistics of Hawaiian Agriculture 1994. Hawaii Department of Agriculture and US Department of Agriculture.

Agricultural Diagnostic Center

The Agricultural Diagnostic Center (ADSC) is a unit of the College of Tropical Agriculture and Human Resources, University of Hawaii at Manoa. It provides analytical, diagnostic, and recommendation services to students and researchers, extension specialists, private research organizations or other agencies, all commercial operations, and the general public (home gardeners and landscapers).

Table 3 shows one measure of the relative importance of the many functions the ADSC performs. Costs vary according to sample type and analysis specifications. Revenue sources reported here do not include salaries, paid from state general funds via the university.

Table 3: Revenue sources in fiscal year 1996.

Source	Revenue $	percent of total
plant disease analysis	7,900	7
feed/forage analysis	13,950	13
insect identification	760	1
soil analysis	24,740	23
tissue analysis	25,675	24
water analysis	7,370	7
*CTAHR support	28,815	25
total	$109,210	100

*earmarked funds distributed by the college to pay for analyses used in research and education. Source: Ray Uchida, 1996.

Perhaps the most frequent source of criticism by clients is sample turn-around time, which has been as long as two months. In the past year or so, turn-around time has improved somewhat, partly through the hiring of new staff, and partly through the development of the automated Fertility Advice and Consulting System (FACS).

Costs of using the ADSC are low compared to mainland competitors, but that is balanced against faster and more reliable turn-around times. The ADSC has a quality advantage in that local knowledge is used in its interpretations of sample results, information mainland labs do not use. For that reason, there is some unwillingness at the college to surrender the sample analysis business to the private sector.

There is some pressure to raise rates, but the current ADSC director, Ray Uchida, feels sample processing time should be improved more before raising rates could be justified to the public. The long-term goal is to get sample processing time down to five days for tissue analyses, and two weeks for soil analyses.

The technical improvements needed to reach this goal include the installation of analytical equipment suitable for a system where only one analysis run is needed for either soil or tissue analyses. For soil, phosphorus analysis uses the modified Truog extraction method, and ammonium acetate is used to extract potassium, calcium, and magnesium. These two extractions would have to be exchanged for the Mehlich extraction method to use the new system. This means collecting correlation data in order to convert sample value interpretations. Only the most important soil series in Hawaii could be covered in a realistic time frame.

FACS:

Recommendations are now primarily made from FACS (Fertility Advice and Consulting System). One of the goals of FACS is to bring the ability to make sample analysis based recommendations to extension agents, using county extension office copies of FACS software, connected to the ADSC by an e-mail system. This would also make reporting sample analyses much faster than mail, and much cheaper than fax. There have been three extension agent training sessions on using FACS, and making recommendations on the basis of sample analyses, since 1993.

The recommendations are made using a data base of local crops and soils and their nutrient sufficiency ranges, locally available commercial materials and their cost, and algorithms to compute recommendations from sample results. Recommendations for application of major nutrients (nitrogen, phosphorus, and potassium) and lime come in the form of so many pounds per acre of a particular fertilizer or soil amendment. A fertilizer is chosen on the basis of the most economical single formulation that meets the minimum recommended application rate for each of the major nutrients.

Database concerns:

While every soil map unit in the state of Hawaii (as determined by the USDA Natural Resource Conservation Service - NRCS) is included in the FACS data base, there is not enough correlation data available to exploit the wealth of information collected by the NRCS for each mapping unit. Returning to the previous example, to estimate levels of phosphorus sorption in local soils, all Hawaii soils are lumped into three soil 'types', as opposed to the hundreds of soil mapping units that have been delineated.

There is also a lack of basic data on nitrogen use efficiency, buffer coefficients for lime and potassium, leaching rates (particularly of nitrate-nitrogen), and fertilizer response calibrations for local soils.

As of now the soil data base is limited to the state of Hawaii. We neither have data for soils from other Pacific islands, nor do we have a formal procedure for extrapolating our local knowledge to make recommendations based on sample results for soils outside of Hawaii.

The FACS system at present also does not adequately serve alternative nutrient management strategies. Implicit in the logic of the FACS system is that the grower will buy all of his nutrients in a bag. For clients interested in lower-cost or more environmentally friendly nutrient management systems, FACS still has little to offer.

Thanks to the FACS system, it is now possible to collate, organize, and make status reports on sample analyses and information provided on sample submittal forms. At this time, there is no budget for this work, so the informational potential of this data has not been adequately evaluated.

FACS database:

Table 4 displays what is to my knowledge the first attempt to organize sample information contained in the FACS data base and test its usefulness in learning about the ADSC's clients and their problems. Due to time constraints, a very small subset of the data available was used. No attempt was made to make use of time of sample submittal as a variable, because there is not yet a long enough time frame within the FACS data base to allow for such an analysis. My interpretation of this selected data set is that there is some evidence of potassium deficiencies, there is some reason for concern about nutrient management in coffee plantations, and we need to list more crops in the FACS data base, to cut down on the number of 'other crop' designations (Table 4).

Table 4: FACS data base example, soil test results for A'a lands, 1996.

Field size (acres)	Crop to be grown	pH	Phosphorus	Potassium	Calcium	Magnesium
1.00	Avocado	OK	High	Very Low	Sufficient	Very Low
1.50	Avocado	High	Low	Very Low	High	High
1.50	Avocado	OK	High	High	High	High
3.00	Avocado	High	High	Low	High	High
0.02	Coffee	OK	Very Low	Sufficient	High	High
0.02	Coffee	Low	High	Sufficient	Sufficient	Low
0.02	Coffee	Low	Low	Very Low	Sufficient	Low
0.02	Coffee	High	High	High	High	High

Only samples with completed forms for soil type, field size, and crop to be grown were selected for this study. As not every grower in Hawaii submits samples to the ADSC, and many who do submit samples do not supply all the requested information, this study is a non-random selection from the population of Hawaii growers. For that reason, definite conclusions cannot be made directly from this study about nutrient management or soil nutrient status in the soil type discussed here.

To keep this example to a reasonable size, only data from soil samples submitted over a four-month period in 1996 are included. The data set is further reduced to only those from the 'a'a lands, or Histisols, mostly located in Hawaii county. In its natural state, this soil type has a thin and uneven layer of organic material overlaying poorly weathered lava rock. After clearing and years of cultivation, there may be little soil of any kind left. Although marginal in appearance, this land can support valuable perennial crops if sufficient nutrients are applied, thanks to a beneficial climate.

Table 5: Descriptive statistics for field size

minimum = 0 acres	mean = 3 acres
first quartile = 0.2 acres	standard deviation = 6 acres
median = 1.2 acres	coefficient of variation = 200%
third quartile = 3.0 acres	
maximum = 30 acres	

Field size is obviously skewed toward smaller fields, with a median of 1 and a maximum of 30. A coefficient of variability of 200% (standard deviation divided by the mean) supports my conclusion that field size is not normally distributed. This pattern of many small fields and a few relatively large ones holds within the major crop types as well, meaning that in this data set there is no crop associated with large fields, nor any crop particularly associated with small fields.

Table 6: Overall soil sample status for each crop

Number of samples by crop	pH	Phosphorus	Potassium	Calcium	Magnesium
avocado = 4					
coffee = 21	low	variable	variable	variable	variable
lettuce = 1					
macadamia = 10	high	high	variable	high	high
other crops = 33	high	variable	very low	variable	variable
vegetables = 2					
total = 71 samples					

For crop type, 'other crops' could be any number of things, so it would not be surprising to observe a wide variability in sufficiency levels of major nutrients, nor would such variability necessarily indicate poor nutrient management. That would have to be confirmed on an individual crop basis, with plant samples and observation of plant distress symptoms. For a specific crop, such as coffee or macadamia, one would expect fairly uniform nutrient levels, indicating some consensus has formed on what is the 'right' level for a nutrient, and also indicating some effort over recent years to attain that level. Wide variability in sufficiency levels could be the result of diverse micro-environments and cultivar differences in soil nutrient requirements. Or it could indicate disarray in or disinterest in nutrient management for that crop. Again, plant tissue sampling and observations of distress symptoms are necessary to confirm nutrient management problems. Crop types with fewer than 10 submittals were not characterized due to their small sample size.

Table 7: Number of samples falling into a given sufficiency range

Sufficiency range	pH	Phosphorus	Potassium	Calcium	Magnesium
Very high	3	4	0	1	2
high	23	38	15	37	29
sufficient	19	4	9	20	5
low	21	9	9	3	15
very low	5	16	38	10	20

The small number of samples in the 'very high' category shows there is little soil sample evidence that over-application of fertilizers or lime is a widespread problem among these a'a-land farms. The large numbers falling into the 'very low' category, especially for potassium, indicates the possibility that under-application, and loss of crop yield or crop quality due to nutrient deficiencies, may be a widespread problem in this soil type.

Conclusion:

Agriculture in Hawaii is unique to itself in some ways, and more similar to the continental United States than to its sister island groups in other ways. On the other hand, its crops, soils, and climate mark it as very much a part of the Pacific Basin.

The differences mean that technologies developed in Hawaii, such as the FACS nutrient management recommendation system, cannot be mechanically applied elsewhere, nor can samples sent to the ADSC from outside of Hawaii be mechanically plugged into our system. However, some of those differences, including a relatively large research and extension infrastructure, enable us to make a unique contribution to a regional nutrient management network. The similarities in such factors as crops and soil types should enable us to successfully incorporate into our system information from the other island entities in the American Pacific.

ADAP institutions desiring to use the testing facilities at the Universities of Hawaii and Guam need to understand the capabilities and weaknesses of these facilities. This is critical both to helping us improve our services to other institutions, and to their correctly interpreting and using the sample test results that we send back.

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Island Report for American Samoa

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Though farmers in American Samoa recognize the benefits of chemical fertilizers, relatively few use them because:

1. Unless subsidized, the cost of commercial fertilizer is beyond the means of most farmers.
2. Both subsidized and unsubsidized supplies are of limited selection and of uncertain availability.
3. High humidity and temperatures severely limit the shelf-life of fertilizers and their containers.
4. High rainfall results in considerable leaching of water-soluble fertilizers.
5. Their use is not cost-effective on traditional crops of taro, banana, and coconut.
6. Many farmers lack the equipment or the knowledge to adequately calibrate applications.
7. Their use exacerbates the serious weed problem.
8. They are unwilling to pay for soil and plant testing needed to make the most effective and efficient use of commercial fertilizers.

Composts and green manures are also rarely used because:

1. Neither is a traditional practice, and Samoan growers are very conservative and resistant to change.
2. Composts are thought to serve as breeding sites of the rhinoceros beetle, a coconut pest.
3. Steep slopes and small farm sizes make mechanization impractical.
4. Few farmers own livestock as a source of manure.
5. The price of chicken manure from the few poultry farms has risen to compete with commercial fertilizers.

As a consequence:

1. Commercial fertilizers or chicken manure are used primarily for vegetable production, since these are the principal cash crops.
2. Farmers rely upon and take pride in the natural high fertility of their volcanic soils.
3. Farms are patterned on an agroforestry system with considerable intercropping of a diverse selection of crops grown non-intensively.

Nutrient Management in Turfgrass

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Plant nutritional requirements for optimum growth are not well understood in turfgrass science. In comparison to other crops, there is no yield to measure the turfgrass response to a certain management practice. Turfgrass performance is evaluated in terms of quality, which represents a subjective feature. Practical experience combined with favorable environmental conditions used to be successful to the turf grower. Today, however, the demand for finer turf and the severe stresses from closer cuts and intensive play often require a higher level of cultural expertise including nutrient management.

Turfgrass nutrient management is influenced by turfgrass requirements, the level of desired turfgrass quality, the level of nutrients in the soil, the intensity of the site used, and the environmental conditions. There are specific turfgrass nutrient management problems encountered in Guam that are linked to the heavy use of the site and the environmental conditions.

Golf courses on Guam are constantly under play due to a twelve month growing period. The year-round play results in heavy traffic and severe stress to the plant community. Adequate fertilization programs have to be developed to assure desired visual quality under such growing conditions.

The climatic conditions of Guam also play an important role in the nutrient management of golf courses. High precipitation combined with warm days and nights shorten the life span of nutrients in the soil. Moreover, the drastic differences in precipitation during the wet and dry seasons affect turfgrass management. Higher precipitation in the wet season will tend to leach nutrients more than during the dry season. Concerns of golf courses polluting the aquifer in the northern part of the island have been raised. Golf courses are pressured to use slow-release nitrogen to reduce the leaching of nitrates.

Guam also has significant soil pH differences that affect the availability of nutrients. The northern part of the island is mostly covered with high pH soils due to the presence of calcium carbonate. Low pH soils, influenced by the volcanic soil of the mountains, are mainly found in the southern part of the island. These extremes in soil pH affect the nutrient availability to plants. Aluminum, for example, will become toxic to plants at low pH while phosphorus is unavailable at low and very high soil pH.

This presentation gave an overview of some specific nutrient management problems encountered on Guam golf courses. Unfortunately, golf course managers are still unsure as to what represents a good nutrient management plan for their courses. With the coming of additional golf courses on Guam and in the Pacific Rim, there is a need for a better understanding of turfgrass nutritional management.

Best Management Practices for Nutrient Management

Jacob Kuhn
Resource Conservationist
Natural Resources Conservation Service

Before one can talk about Best Management practices for nutrient management, we need to understand why it is important. Agriculture is still one of the largest land uses in the world and some countries are much more proficient at producing food crops than others. Crop production can vary from very intensive and extensive to minimal soil disturbance and little inputs. The application of nutrients generally introduces an additional energy source to the ecosystem.

The environment is constantly changing. Forests are being transformed through succession; prairie and savanna areas are maintained by naturally occurring fires; and lakes undergo phases of eutrophication. As humans disturb these ecosystems, the balance is no longer natural. The addition of excess nutrient into natural waters promotes eutrophication, a natural aging process of increased plants and less open water. Algae growth increases causing shading of deeper dwelling organisms such as grass or invertebrate, and ultimately sedimentation. Excess nitrogen in the form of nitrates can leach into groundwater sources and eventually render the water unfit for human consumption.

Phosphorus and Nitrogen

Before we look at ways to manage nutrients and minimize their impacts to the natural environment, we should look at some basic properties of nitrogen and phosphorus and how they interact in the tropical environment of our area. Both nitrogen and phosphorus exist in several chemical forms in the soil but not all forms are readily available to the crop. The cycling or transformation of these nutrients from one chemical form to another explain the gains and losses of each nutrient.

Generally, phosphorus undergoes chemical processes in tropical soils, which render it unavailable to plants over time. Due to this chemical interaction, phosphorus is tightly held by the soil. Because of this, phosphorus transport to surface waters is generally associated with soil erosion although some soluble phosphorus can be carried way from the top few inches of the soil in surface run-off. Nitrogen on the other hand, is very mobile after a short period of time in the soil. In soils with poor drainage and low permeability, nitrogen can be readily carried off-site in surface run-off. In soils with moderate to well permeability and moderate to well drainage, the nitrogen is readily leached into the soil and below the root zone. Ultimately, it can end up in groundwater sources and in some cases, migrate out with excess flow to the ocean.

Nutrient Management

In general, nutrient management can best be accomplished using two different approaches: limiting the quantity applied or increasing the efficiency of use of nutrients; and increasing the retention of nutrients in the crop field. These techniques are part of agriculture management techniques called Best Management Practices (BMPs) These practices are intended to reduce or eliminate losses of nonpoint source pollutants. The following BMPs have been proven to be effective at minimizing losses of both nitrogen and phosphorus.

Proper Application Rates - Nutrients should be applied based on realistic yield goals and crop requirements, and the capacity of the soil for crop production. Application rates should be based on soil test and account for all nutrient sources.

Appropriate Timing of Nutrient Application - Nitrogen applications should correspond to when the crop needs the nutrient, which varies with growth stages. Split applications allow for better utilization before excesses are leached. Avoid early or late application. Take into account crop growth stage when selecting the form to be applied.

Appropriate Application Method and Placement - Band fertilizers instead of broadcasting for row crops. Incorporate surface applications of all sources to minimize losses, (where appropriate with tillage operations). Use fertigation to apply frequent but low rates for better crop use.

Soil and Tissue Testing - Test the soil to establish residue levels and overcome soil nutrient limits such as pH or phosphorus availability. Apply nutrients as recommended. Test crop tissue to establish crop needs and apply foliar sprays.

Reduced Tillage Practices - Limit tillage practices when practical. Reducing soil disturbance reduces erosion on sloping land. Selecting tillage practices should include evaluating soil properties, climate, farming system, and land use at the edge of the field.

Crop Rotations - Legumes in rotation may reduce nitrogen fertilization needs. Include sod crops in the rotation to improve soil structure and reduce erosion. Include high residue producing crops and cover crops in a rotation to improve soil organic matter and crop residue. Organic matter helps hold nutrients for future crop use and crop residues on the soil reduce soil erosion.

Cover Crops - Plant cover crops after harvest to use leftover nutrients in the soil. Some cover crops are legumes and may reduce nitrogen fertilizer requirements. Cover crops also improve soil organic matter.

Pond - A permanent water impoundment traps sediments and associated attached phosphorus. Nitrogen is decreased though volatilization and denitrification.

Critical Area Planting - Remove excessively eroding crop areas from production and estab-

lish permanent grasses. This reduces sediment-transported nutrients.

Contour Farming - Field tillage operations are performed on the contour of the land to slow run-off and significantly reduce erosion. Reduces run-off losses of nutrients.

Stripcropping - Alternate strips of row crops with close growing or sod-forming crops. Alternate crops and planting dates. Crops are planted on the contour or across the pre-dominate slope. Reduces soil erosion and surface run-off.

Grass Filter Strip - Establish a permanent grass strip at the base of the slope of a field to trap sediment from surface run-off and increase infiltration.

Terrace - Cut channel and berm along the contour of a field, at regular intervals, to reduce slope length and intercept run-off. Increases infiltration and significantly reduces soil erosion. Can be constructed to allow crops to be planted along the top and sides of the terrace, or narrowed and stabilized with rock or grass.

Diversion - Grass channel and low berm across the slope that diverts excess water away from cropped areas to undisturbed grass or forest areas. Reduces erosion potential on protected fields.

Grass Waterway - A permanent sod channel to collect and convey concentrated surface run-off. Reduces erosion in concentrated flow areas, traps sediment, and increases infiltration.

Sediment Control Basin - An earthen basin to collect and store run-off and accompanying sediment.

Irrigation Water Management - Calibrate irrigation systems. Apply irrigation water based on soil moisture measurement. The irrigation system must allow for even distribution of water. Irrigation scheduling should take into account rainfall and soil water-holding capacity.

Outline of Final Group Discussion

Regional Cooperation for Soil and Plant Testing

-Hawaii and Guam for regional soil testing

-Institutionalized: Agreements
        Investment in resources

-Improve turn-around time

Needs of Each Institution

Commonwealth of the Northern Marianas Islands:

1. Tissue analysis for extension agents.
2. No ability currently to make recommendations.

Palau:

1. Don't have capability to analyze soil & plant.
2. No info on nutrient recommendation for each soil series and management.
3. Don't have way of crediting organic amendments.
4. Need help with soil nutrient management.
5. Translate management recommendations into local language.

Pohnpei:

1. Same as other islands.
2. Need nutrient recommendations for different islands.
3. Soil and plant testing needed for small and backyard farming.
4. Need to know what is going on in other islands of region.

Marshall Islands:

1. Need focus on research for nutrient management to fill in information gaps.
2. Promote regional collaboration because more chance of funding.
3. Promote soil and plant testing.

American Samoa:

1. Same as other islands.
2. Will be having new soil and plant testing lab.

Hawaii:

1. Need more improvement in nutrient recommendations - correlations coefficents (P & lime) utilization of organic materials, other crops.
2. Many samples going out of state for analysis - private labs.
3. Environmental impact of recommendations.
4. Feedback on recommendations.

Natural Resources Conservation Service:

1. More info on nutrient composition of local soil amendments (organic).
2. Provide more awareness of soil series.
3. Soil information available in Pedon database of National Laboratory in Lincoln, Nebraska.
4. Base nutrient trials and recommendations on similar soils in region.

Guam:

1. Very low participation in soil and plant testing because
   a. lack of information
   b. sending samples off-island for testing .
   c. poor reliability, long turn-around time

2. Relying on extension agents experience
   a. need for info to be institutionalized - written down
   b. need for initial laboratory research for correlation and calibration
   c. history - analyzed or its not right form

3. Growing importance of specialized testing and recommendation needs

Forms of Communication for Institutions in Region:

1. Newsletter
2. Discussion Group
3. Webpage
   a. interactive
   b. printed out
   c. electronic form
4. Other
   Time slot set aside for PEACESAT tele conference on regular basis
   - free
   - deal with specifics

Items for Follow-Up from Workshop:

1. Web Page

ADAP Nutrient Management Pacific Islands
Sustainable Nutrient Management Network

Table of Contents:
*Contact list of participants
*Proceedings

*Nutrient & Sampling Information - Exist
                                   NRCS
*Discussion forum
*Soil & Plant Results Database
   a. Guam
   b. UH
*Lincoln, Pedon Data Base
*Phosphate and Potash Institute link
*Local crops
   a. range of yields under different management
   b. Sufficiency levels
   c. management suggestions
   d. horticultural properties
*Nutrient and toxicity symptoms
*Lab charges and services.

2. Extension

   a. Document real-life success stories of using soil and plant testing and nutrient management.
      i.   Regional demonstrations with selected farmers using soil and plant testing.
   b. How to manuals
      i.   soil
      ii.   plant
      iii. composting
      iv. quick-test kits
      v.   how to use results for improving nutrient management - interpretation and recommendations.
   c. Designing fertilizer trials for soil testing - every crop and soil type.
   d. Decision support system (FACS)
     - database
     - decision support
   e. Compost and organic amendments
     - more emphasis on nutrient value

Adaptation of the Nutrient Recommendation Program (FACS) for the Region

Program needs to be changed to be flexible and open-ended

    a. crops
    b. soils
    c. written in accessible computer language: delphi,
        access or paradox data base

-2 to 3 weeks after workshop participants in Workshop may provide a written evaluation of FACS

-CNMI will depend on UOG for program
-Fertilizer based on P needs rather than N.
-Additional information from client
    a. profession
    b. real address
        linked with GPS for each farmer

Minimum data needed for FACS

a. Soils
      series
      buffer coeefficients (research)
             P, lime
                    aglime
                    coralline
                    limestone

b. Crops

Future Proposals

1. Extension publication on organic amendments

    a. Time
    b. Printing, layout, materials

2. Regional project:
    a. regional research and demonstration on soil & plant quick text kits
    b. demonstration of soil & plant testing
    c. Calibration and Adaptation of FACS

Possible funding sources: SARE, ADAP, TSTAR Tropical Research Program, Sharing costs among land grants.

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Appendix B.
Workshop Post Evaluation
Questionnaire and Results

The following workshop evaluation is designed to give the organizers of the workshop some feedback on any problems or positive aspects of the workshop you experienced. Thanks for your help.

Name of your Institutional Affiliation:_____
                    City, State, Country:_____

1.   Did the workshop meet your expectations?
      (Circle one)   Yes   No

      Please explain why or why not:_____
      _____

2.   The presentations in the workshop were:

      a.   too simple
      b.   just right
      c.   somewhat informative
      d.   very informative

      Explain why:_____
      _____

3.   What topics were not covered in the workshop which you
      would like to see addressed in a future regional workshop?
      _____
      _____
      _____

4.   The discussion sessions were:

      a.   failures
      b.   less than productive

c. productive
d. very productive

Explain why:_____

_____

5. The laboratory demonstrations were:

a. too simple
b. just right
c. somewhat hard to understand
d. really hard to understand

Explain why:_____

_____

6. The field trip was:

a. poorly organized
b. just right
c. somewhat informative
d. very informative

Explain why:_____

_____

7. (For off-island participants) My hotel accomodations on Guam and other living arrangements during the workshop were:

a. inadequate
b. less than adequate
c. adequate
d. very good

Explain why:_____

_____

8. Please provide a list of short-term and long-term future regional collaborative projects or activities you might suggest to follow-up after the workshop.

Short-term:_____
_____
_____

Long-term:_____
_____
_____

9. Please list any additional comments you would like to make regarding the Workshop.

_____
_____
_____
_____

Q1	Did Workshop meet expectations?	Q2	The presentations in workshop were
Yes	Sampling for each island covered	e	Most target audience needed nuts and bolts-GIS was too esoteric
Yes	Explained importance & reasons needed to provide proper nutrient management	d	Opportunity to learn agri. situation and problems on other islands
Yes	Basic inf., which in needed in this area		
Yes	—	b	—
Yes	I came expecting to learn a lot and I did	b,d	There was a good range in presentations and overall they were good
No	Not enough time was devoted to islands other than Guam and HI	b	The presenters were communicating in a very clear manner. Handouts were helpful
Yes	Sharing of inf. and experience was very valuable	c	a better mix of disciplines agronomists, economists
Yes	I learned a lot about soil testing and its application to plant performance	d	Learned about computer software
Yes	Provided inf. on regional nutrient managment	d	found out which institutions can provide testing and inf..
Yes	—	b,d	adequately presented-Speakers were very knowledgeable in their areas
Yes	Participants were experienced in the region	d	—
Yes	I learned a lot and had some issues clarified	c	Speakers were very accommodating
Yes	Collegial contact, rec. commonalties-circumstances, inf. on strategies	d	—
		d	excellent cross section

Yes = 12
No = 1

a = 0		a:	too simple
b = 4		b:	just right
c = 2		c:	somewhat informative
d = 8		d:	very informative
e = 1		e:	all of the above
NR = 0		NR:	no response

What topics were not covered...

*Once data base is built and correlated, the inf. should be shared

*How to interpret soil and plant tissue data and make recommendations

*—

*How to do on farm trials to verify test results recommendations

*Nutrient recommendation Program (regional).

*Guidelines on making fert. recommendations, regional similarities in fert. requirements.

*Knowledge level of extension agents so varied difficult to cover everyone's experience level

*List of major testing labs and costs for services

*I think all topics were covered clearly.

*Build smaller discussion groups aimed at particular problem areas.

*The farmer/participants were not given group time.

*Some discussions on new soil classification and reference materials.

*Would like to see nuts and bolts on making recommendations with practical problem solving

Q4 The discussion sessions were...

b   Too structured and strained with little opportunity for getting at knowledge gaps

c   People were able to relate their situation and question the presenters

b   I prefer less discussion and more depth

c   They allowed for further exploration of the topics presented

c   The discussions were very productive due to participants expressing good opinions

c   Time was provided

c   Important issues relevant to all of us are being identified

c   We are in the process of defining and improving the ADAP project

c   Discussion provides a forum for participants to share ideas

c   Some discussions were omitted, sometimes its better to pose a few questions to focus the discussion

c   I liked the active participation by audience

c   Sometimes people are too tired

d   excellent inf., good practical examples excellent networking

a = 0	a:	failures
b = 2	b:	less than productive
c = 10	c:	productive
d = 1	d:	very productive
NR = 0	NR:	no response

Q5 The lab. demonstrations were...

b —
b Easy to understand-needed more demos on P, K, Ca, Mg, analysis
b I would have enjoyed a lot more
b —
b Demos were straight forward and clear
b more time could have been devoted to quick tests
b presenters did their jobs
b introduced the process without having to get into specifics
c Some were too technical for me to understand

b —
b very simple and well explained
c —
b would have liked a "hands-on" exercise

a = 0	a:	too simple
b = 11	b:	just right
c = 2	c:	somewhat hard to understand
d = 0	d:	really hard to understand
NR = 0	NR:	no response

Q6 The field trip was

d good cross section of uses
d It showed how soil and plant analysis can be used as tools to plan operation
c I missed half of it because I got separated from the group.
c,d —
d both farmers and landscaper/golf course know their jobs very well
b —
c challenges fared by landscapers/golf courses were identified
d it was great to see the variety of conditions & concerns and see how they are being addressed
d It allows me to see the practical side of nutrient management
d very nice
c the golf course tour was very good
b —
d excellent!

a = 0	a:	poorly organized
b = 2	b:	just right
c = 4	c:	somewhat informative
d = 8	d:	very informative
NR = 0	NR:	no response

Q7 Rate your hotel accom.

c   cheap but clean

d   hotel was excellent and well situated to restuarants

— —

— —

c   No problem

d   Good rate-good location-confusion with the tax

d   room was clean, comfortable, affordable when partic. are pooled

c   easy access to amenities

d   nice, clean, convenient,well planned

d   comfortable, good price, quite adequate

c   good

d   very good facility including cost

d   excellent clean cheap spacious

a = 0	a:	inadequate
b = 0	b:	less than adequate
c = 4	c:	adequate
d = 7	d:	very good
NR = 2	NR:	no response

Short term projects

*Liming and P curve developments

*Determine common elements and prioritize research needs

*__

*__

*Soil and Plant testing procedure

*Take soil tests and conduct nutrient trials for islands

*Information exchange meetings, workshops conferences

*Develop BB/email contact for quarterly updates fill in information gaps

*Regional publication

*Develop coefficients to predict lime, P, K, requirements, improve communications fill in inf. gaps

*__

*__

*__

Long term projects

*Network newsletter of nutrient tests on regular basis

*Conduct nutritional trials to establ. data and interpret

*__

*__

*Regional nutrient management network

*how to make recommendations

*Research project, comm. network, publications, training regional recommendations for soil amendments on major plant/crops in region

*Regional trial or Demonstration

*Communication

*Prioritize research gaps

*__

*Exchange of ideas

*prepare grant proposal for region

*__

Additional comments

*___

*Thanks to coordinators and participants for sharing inf.

*___

*I expected to get training in making recommendations from soil testing results

*Everything was organized very well

*Mostly focused on Guam-needed to know the minimum requirements for doing testing and trials on other islands

*Prompt follow-up for the recommendations agreed upon by the participants has to be done

*Need successful cases for using soil/plant testing, how much more research is needed to gather basic inf. in region

*___

*___

*___

*Would have liked the inf. and agenda before arriving on GU.

*Served to fill in information/networking void, conducted effectively excellent planning

Q10 What affect will this workshop have on you

a	back to my usual work in Honolulu
d	relating how my present work and be applied to other Pacific islands
—	—
d	Allowed me to join colleagues from the region to work on common issues
d	Learned a lot can now see the importance of testing as well as extension agent experience
—	Impact yet to be seen-lack of resources are a problem
d	Specific projects collaborations with the U of H scientists were crystallized
d	We'll take advantage of the soil/plant testing to give us an understanding of the conditions and interactions in Marshalls
d	Will improve my productivity in relation to nutrient management, it has increased my knowledge on soil and plant analysis
c	—
—	—
d	I sense this will have a great impact on what I do in Agriculture
d	need regional diagnostic fac. closer to us, met key personnel on GU and HI, learned how to improve my own diagnostic services A huge Si Yus Masse to Val and Frank for their enormous, excellent, and efficient effort in providing the support. Thanks everyone!

a = 1		a:	no impact
b = 0		b:	little impact
c = 1		c:	fair impact
d = 8		d:	great impact
NR = 3		NR:	no response

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