Soil quality, management practices and sustainability of pineapple farms in Cavite, Philippines: Part 1. Soil quality

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ABSTRACT

Composite surface soil samples (0-10 and 10-20 cm depths) were collected from forty farms within four pineapple growing municipalities of Cavite, Philippines namely Indang, Alfonso, Tagaytay and Silang, in order to (1) diagnose and evaluate any soil nutritional and physical problems that may affect the productivity of pineapple farms in Cavite, and (2) recommend appropriate fertiliser application practices to alleviate any soil fertility constraints. Soils were analyzed for bulk density, aggregate stability, moisture content at saturation, field capacity, pH, total nitrogen (N), mineralizable N, organic C, extractable phosphorus, cation exchange capacity, exchangeable K, Ca, Mg and the micronutrients Cu, Fe, Mn and Zn. The topsoils contain little organic matter and have low levels of total N and extractable P but more than adequate levels of exchangeable K. Micronutrient levels of soils are sufficient in all of the pineapple farms. Most pineapple soils are already extremely acidic (pH below 4.5) as a result of long-term application of ammonium-based fertilizers. Soil qualities of relatively undisturbed sites are often better than those of soils long cropped to pineapple, implying the importance of fallowing. A trend towards declining topsoil pH was noted the longer the time farms were cropped to pineapple.

Key words: Soil quality, soil health, pineapple farming.

INTRODUCTION

Growing pineapple (*Ananas comosus* L.) is an important source of income for Cavite farmers in the Philippines. It is a cash crop of choice in the uplands because it tolerates acidic soils within the range of 4.5-6.5, has low phosphorus and calcium requirements, and is relatively drought-tolerant. However, the current status of soil fertility related problems of pineapple farms in the province is not known. Many pineapple farmers in Cavite are reportedly applying excessive amounts of nitrogen (Labios, 1999) way above the recommended rate for the crop (Cosico, 1991). This could result in higher production cost, soil acidification and potential environmental pollution. In the long-term, possible yield declines may be observed due to deficiency of some plant nutrients brought about by nutrient imbalances in the soil or due to deterioration of soil quality of the pineapple farms. Sadly, there had been no local study conducted about soil fertility related problems in these pineapple farms. Thus, it is important to diagnose any soil fertility or other soil management problems in pineapple production so that productivity can be raised and further sustained for this cash crop. A survey of soil qualities and soil management practices in Cavite pineapple farms is one important requirement in formulating a balanced fertilisation strategy.

Soil quality is the capacity of a specific kind of soil to function within natural or managed ecosystem boundaries to sustain plant and animal productivity, maintain or enhance water and air quality and support human health and habitation. The term is often used interchangeably with soil health. Changes in the capacity of soil to function are reflected in soil properties that change in response to management or climate (USDA, 2001). Soil quality indicators are important in focusing conservation efforts or maintaining and improving the condition of the soil and in evaluating soil management practices and techniques. Indicators are also important to relate soil quality to that of the other resources. It helps to determine trends in the health of soils and it can also serve as a guide in land

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management decisions (USDA, 2001). This study was conducted to assess the soil qualities of pineapple farms in four upland municipalities of Cavite namely Indang, Alfonso, Tagaytay City and Silang. Specifically, the study aimed to (1) diagnose and evaluate soil nutritional problems that may affect the productivity of pineapple farms in Cavite; (2) document and assess the fertilisation and soil management practices of pineapple farmers; and (3) recommend appropriate fertiliser management practices to alleviate any soil fertility constraints.

MATERIALS AND METHODS

Selection of farms

Topsoil samples (0-10 and 10-20 cm depths) from forty pineapple farms in upland Cavite (10 farms per municipality) were collected using an auger and composited into one sample per depth per farm. The farms are a subset of the sample farms studied by Dr. Alice T. Valerio of the College of Economics, Management and Development Studies (CEMDS), Cavite State University, Philippines (Valerio, 2002). Each farm selected has an area of at least 1000 m^2 devoted wholly to pineapple or where pineapple is an important crop in the farming system. Farmers who are engaged in planting pineapple for at least two years were the ones selected. Farmers were also asked about their current yields and the number of years they cropped their soil with pineapple. Where possible, composited topsoil samples were collected in nearby "undisturbed" sites. The undisturbed sites are those areas where soils are not cultivated and fertilized for a long period of time or a minimum of two years. These sites are usually woodlands, grasslands, abandoned coffee fields or vacant lots supporting a variety of weeds. Undisturbed sites were sampled as reference sites to compare soil qualities there with soil qualities in the cropped soils.

Collection and analyses of soil samples

Horticulturally important physical and chemical soil properties were measured using standard methods of analyses (Bureau of Soil and Water Management, 1988). Physical properties include bulk density by the core method, aggregate stability by the wet-sieving technique, field capacity, and moisture content at saturation. Chemical properties include total Kjeldahl N, potentially mineralizable N by anaerobic incubation (Anderson & Ingram, 1993), Bray-extractable P, exchangeable Ca and Mg by EDTA titration, exchangeable K by flame photometry, pH by the electrometric method, organic carbon by the modified Walkley-Black method and the micronutrients Cu, Fe, Mn and Zn by DTPA extraction. A Perkin Elmer A Analyst 100 atomic absorption spectrophotometer housed at the Laboratory Services Division of the Bureau of Soils and Water Management, Quezon City, Philippines, was used to measure the concentrations of micronutrients.

Slope steepness was measured in the field using an Abney hand level and clinometer, and the measurement expressed in percentage.

Data analysis

Means and the standard errors of soil properties were computed for the 0-10 cm and 10-20 cm depths. The weighted average values of soil properties for the 0-20 cm depth were also computed. To compare the soil quality status of the four towns, one-way analysis of variance was used. Mean separation was done using Duncan's Multiple Range Test (DMRT). A paired t-test was used to compare soil qualities in sites cropped to pineapple and in relatively undisturbed sites. Regression analysis was performed using the soil qualities in the cropped soils as predictors of yield. SPSS for Windows software was employed in all statistical analyses.

RESULTS AND DISCUSSION

Soil/land quality status of pineapple farms

Table 1 shows the mean soil physical qualities of the farms cropped to pineapple. Bulk density, aggregate stability, moisture content at saturation and field capacity were all within the range of values for normal soil physical properties (Hansen *et al.*, 1980). Almost all of the soil samples had stable aggregates when passed through a 0.25 mm sieve. More than 50 % of the soil weight was left after sieving under water. All soil samples are able to hold moisture greater than 50 % under saturated conditions. Field capacity of samples ranged from 15.1 %, where only a small amount of water in the soil can be available for plant use, to 56.7 %, where adequate amount of moisture can be used by the plants.

The slopes of the pineapple farms averaged 5 %. Slopes ranged from nearly level

(3 %) to steep (28 %). In nearly level farms, soil erosion is negligible but on steep slopes it is significant. The plow layer depth ranged from 15 to 33 cm. In general, a thick plow layer implies a good store of water and nutrients. However, in some sloping farms, the plow layer is no longer the topsoil or the A horizon but the subsoil or exposed volcanic tuff parent material which cannot store significant amounts of water and nutrients. Elevation of the farms ranged from 210 m above sea level (masl) in Silang to 615 masl in Tagaytay.

Table 2 shows the mean soil chemical qualities of the farms cropped to pineapple. The data indicate that the average values of soil properties are within the range of values normally encountered in soil analysis. Most values of soil chemical properties in the 0-10 cm depth are higher than in the 10-20 cm depth. What is striking in the pineapple soils is that they have pH already below what is considered to be extremely acidic (pH less than 4.5). This could be a result of the long-term use of ammonium-based fertilizers. These fertilizers are applied on the soil surface; thus, pH is lower in the topsoil. The topsoils contain little organic matter and have low levels of total N and extractable P but more than adequate levels of exchangeable K.

While total N is low, potentially mineralizable N is high, which implies that the soils are able to release inorganic N rather quickly. This characteristic is important in pineapple growing because fertiliser N applied is rapidly absorbed by the plant during the early growth stages (Kelly, 1993).

Micronutrient levels in the soils are also within the normal range. Micronutrients are usually higher in the 10-20 cm depth implying that these nutrients are taken up by plants in large quantity in the topsoil.

Critical values of selected soil parameters are given in Table 3. It shows that 77.5 % of the soil samples from the 0-10 cm depth are extremely acidic (below 4.5), while it is 62.5 % from the 10-20 cm depth, and 70 % from the weighted 0-20 cm depth. Pineapple can tolerate acidic soils, but as noted earlier, the low pH may lead to nutrient imbalances and poor nutrient absorption by plants that could result in poor yields in the long-term. One very important implication of this result is that if the farmer is thinking of shifting to other crops or would like to practice intercropping, the farmer's choice of crops will be limited to those species or varieties which are acid-tolerant (e.g. sugarcane, tea plant). Thus, some lime may need to be applied to the soil to allow other crops to grow successfully under the extremely acidic soil conditions. Regardless of depth, at least 70 % of the soils are deficient in nitrogen (<0.10 % N) due to low organic matter levels. This implies that since soil is deficient in N, high levels of N fertilizers will need to be applied to sustain production.

Due to extreme acidity, most of the soils (>90 %) have low levels of extractable P but pineapple has a very low requirement for this nutrient. However, just like pH, low P values may not be tolerated by other crops in the farming system and P fertilisation and liming may also need to be practiced later on.

Despite the low pH level of pineapple soils, exchangeable Ca, Mg and K remain

Table 1. Status of soil/land physical qualities of 40 pineapple farms in upland Cavite.

Soil/land quality indicator	Minimum	Maximum	Mean	Standard deviation
Bulk density (g/cm^3)				
0-10 cm	0.87	1.42	1.16	0.16
10-20 cm	0.79	1.45	1.14	0.18
0-20 cm	0.85	1.15	1.15	0.15
Aggregate stability (%)				
0-20 cm	44.39	95.22	76.93	11.30
Saturation moisture content (%)				
0-20 cm	51.65	97.88	67.92	9.77
Field capacity moisture content (%)				
0-20 cm	15.23	56.72	38.01	8.32
Slope (%)	3	42	5.95	7.33
Plow layer (cm)	15	33	19.3	4.6
Elevation (m above sea level)	210	615	408	127

above the critical values considered low for these nutrients probably due to high cation exchange capacity of the soils (BSWM, 1990). With sufficient calcium, appearance of fruit abnormalities such as severe fasciations, joined multiple fruit and rounded (cannon balls) fruits are prevented. Adequate magnesium can prevent the occurrence of sun-bleached coloured leaves in pineapple crop. Soils with sufficient potassium can produce fruits with high sugar content and acid levels and with bright yellow flesh (Kelly, 1993).

Table 2. Status of soil chemical qualities of pineapple farms in upland Cavite.

Soil quality indicator	Minimum	Maximum	Mean	Standard deviation
pH				
0-10 cm	3.81	5.45	4.31	0.37
10-20 cm	3.91	5.43	4.41	0.35
0-20 cm*	3.86	5.44	4.37	0.36
Exchangeable K (cmol+/kg)				
0-10 cm	0.33	0.75	0.55	0.12
10-20 cm	0.39	0.75	0.58	0.11
0-20 cm	0.36	0.75	0.56	0.10
Exchangeable Ca (cmol+/kg)				
0-10 cm	12.10	18.50	15.06	1.60
10-20 cm	11.00	19.10	14.25	2.07
0-20 cm	11.60	18.00	14.66	1.62
Exchangeable Mg (cmol+/kg)				
0-10 cm	1.60	6.50	3.54	0.98
10-20 cm	1.80	5.80	3.64	1.05
0-20 cm	1.70	6.20	3.59	0.87
Extractable P (mg/kg)				
0-10 cm	1.0	26.6	6.1	4.8
10-20 cm	<0.1	10.3	4.4	2.7
0-20 cm	1.4	15.4	5.2	3.0
Organic Carbon (%)				
0-10 cm	<0.01	1.20	0.74	0.26
10-20 cm	0.37	3.19	0.82	0.44
0-20 cm	0.18	2.19	0.78	0.35
Total Nitrogen (%)				
0-10 cm	0.075	0.121	0.094	0.012
10-20 cm	0.069	0.180	0.089	0.018
0-20 cm	0.072	0.138	0.092	0.012
Mineralizable N (mg/kg)				
0-10 cm	5.48	82.47	38.90	16.34
10-20 cm	<0.01	56.31	29.91	11.37
0-20 cm	10.61	59.20	34.37	11.41
DTPA-extractable Cu (mg/kg)				
0-10 cm	0.09	9.38	2.89	2.24
10-20 cm	0.02	8.65	3.53	2.49
0-20 cm	0.07	9.02	3.21	2.25
DTPA-extractable Zn (mg/kg)				
0-10 cm	0.16	4.23	1.68	1.03
10-20 cm	0.35	4.88	1.84	1.06
0-20 cm	0.26	4.56	1.76	1.00
DTPA-extractable Mn (mg/kg)				
0-10 cm	14.12	118.42	49.45	26.92
10-20 cm	14.45	112.84	45.73	24.71
0-20 cm	14.29	114.83	47.59	24.72
DTPA-extractable Fe (mg/kg)				
0-10 cm	3.13	391.79	69.47	66.42
10-20 cm	4.61	361.06	74.58	66.54
0-20 cm	3.87	376.43	72.03	62.94

*Values for the 0-20 cm depth are averages of the 0-10 cm and 10-20 cm depths.

Most of the soils have sufficient levels of micronutrients. For copper, only 10 % of the soils in the 0-10 cm depth are below the critical value for Cu (0.2 mg/kg), and only 7.5 % in the 10-20 cm depth.

As regards zinc (Zn), 10 % of the soil samples, regardless of depth, are below the critical value of 0.5 mg/kg. Manganese (Mn) is sufficient since all of the soils are above the critical value (10 mg/kg). For iron (Fe), only

Table 3. Selected soil quality indicators, their critical values, number and frequency of farms below the critical values.

Soil quality	Number of samples	Critical value[1]	Number of farms below critical value	%
pH				
0-10 cm	40	4.5	31	77.5
10-20 cm	40		25	62.5
0-20 cm	40		28	70.0
Exchangeable K (cmol+/kg)				
0-10 cm	40	0.4	3	7.5
10-20 cm	40		3	7.5
0-20 cm	40		0	0
Exchangeable Ca (cmol+/kg)				
0-10 cm	40	0.5	0	0
10-20 cm	40		0	0
0-20 cm	40		0	0
Exchangeable Mg (cmol+/kg)				
0-10 cm	40	0.4	0	0
10-20 cm	40		0	0
0-20 cm	40		0	0
Extractable P (mg/kg)				
0-10 cm	40	10.0	37	92.5
10-20 cm	40		39	97.5
0-20 cm	40		37	92.5
Total N (%)				
0-10 cm	40	0.10	28	70
10-20 cm	40		36	90
0-20 cm	40		30	75
Potentially mineralizable N (mg/kg)				
0-10 cm	40	25.0	5	12.5
10-20 cm	40		6	15
0-20 cm	40		6	15
DTPA-extractable Cu (mg/kg)				
0-10 cm	40	0.2	4	10
10-20 cm	40		3	7.5
0-20 cm	40		4	10
DTPA-extractable Zn (mg/kg)				
0-10 cm	40	0.5	4	10
10-20 cm	40		4	10
0-20 cm	40		4	10
DTPA-extractable Mn (mg/kg)				
0-10 cm	40	10.0	0	0
10-20 cm	40		0	0
0-20 cm	40		0	0
DTPA-extractable Fe (mg/kg)				
0-10 cm	40	4.5	1	2.5
10-20 cm	40		0	0
0-20 cm	40		1	2.5

[1]Critical values of soil parameters except micronutrients were taken from Kelly (1993). Critical values for micronutrients were taken from BSWM (1988).

2.5 % of the soils (0-10 cm depth) are below the critical limit (4.5 mg/kg). Sufficient extractable Fe exists in the 10-20 cm depth.

Comparison of soil qualities in the four pineapple-growing towns

Table 4 shows the comparison of soil physical quality indicators in the four pineapple growing towns of Cavite. All soils have a bulk density within the range of 0.79 to 1.45 g/cm^3, which is below the critical value 1.5 g/cm^3. Soils with bulk density above this critical value can already restrict root growth (Donahue *et al.*, 1977). Bulk density of Indang soils is significantly lower than that of Alfonso soils. Lower bulk density can promote good aeration, drainage and root growth as pineapple cannot tolerate poorly drained soils. Tagaytay and Silang soils have bulk density comparable with the two towns. Moisture content at saturation and aggregate stability of soil samples from four towns did not differ significantly. Field capacity of Alfonso soils is significantly higher than the field capacity of the Indang, Tagaytay and Silang soils. Having a high field capacity is advantageous not only for pineapple crops but also to other rain-fed crops since the soil's water storage capacity is greater. There were no significant differences in the slopes of farms and the depth of the plow layer among all four towns. Tagaytay farms are located in the highest elevation, followed by Alfonso farms. Indang and Silang farms are located in relatively lower topographic positions.

Table 5 shows the comparison of soil chemical quality indicators in the four pineapple growing towns of Cavite. Topsoil (0 -10 cm) total N differed significantly between towns. Total nitrogen of soils in Alfonso and Silang are significantly higher than in Indang and Tagaytay. Significant differences were also observed in the potassium content of topsoil in cultivated areas. Indang soils have significantly lower exchangeable K than the Alfonso, Tagaytay, and Silang soils. In the 10-20 cm and 0-20 cm depths, Indang and Alfonso soils have significantly lower exchangeable K compared with Tagaytay and Silang soils.

In the 10-20 cm depth and 0-20 cm depth, exchangeable Ca is lowest in Silang soils compared with the other three towns where exchangeable Ca levels are comparable. Exchangeable Mg of Tagaytay and Silang soils (10-20 cm depth) are significantly higher than the exchangeable Mg of Indang and Alfonso soils. In the 0-20 cm depth, Silang soils have higher exchangeable Mg than Indang and Alfonso soils.

There were no significant differences in organic C, pH, extractable P and potentially mineralizable N in soils of the four towns.

Regardless of depth, levels of Fe, Cu, and Zn did not differ significantly among towns. The Mn levels of Alfonso and Tagaytay soils are significantly higher than the Mn levels of Indang and Silang soils.

Fertilizer recommendations for the four towns

Ammonium sulfate and urea are nitro-

Table 4. Mean soil physical quality indicators in the four pineapple growing municipalities of Cavite.

Soil quality indicator[1]	Indang	Alfonso	Tagaytay	Silang
Bulk density (g/cm^3)				
0-10 cm	1.05b	1.24a	1.14ab	1.17ab
10-20 cm	1.01b	1.20a	1.16ab	1.17ab
0-20 cm	1.03b	1.22a	1.15ab	1.17a
Aggregate stability (%)				
0-20 cm	79.52a	74.83a	75.87a	77.50a
Moisture content at saturation (%)				
0-20 cm	66.78a	73.76a	65.51a	65.64a
Field capacity moisture content (%)				
0-20 cm	34.21b	48.07a	35.47b	34.29b
Slope (%)	3.80a	4.40a	8.30a	7.30a
Depth of Plow Layer (cm)	17..2a	19.0a	19.9a	21.12a
Elevation (masl)	300.5c	490.5b	562.5a	329.5c

[1]Within a row, means with a common letter are not significantly different at the 5% level by DMRT.

Table 5. Mean soil chemical quality indicators in the four pineapple growing municipalities of Cavite.

Soil quality indicator[1]	Indang	Alfonso	Tagaytay	Silang
pH				
0-10 cm	4.36a	4.28a	4.40a	4.24a
10-20 cm	4.40a	4.27a	4.50a	4.34a
0-20 cm	4.38a	4.28a	4.46a	4.05a
Exchangeable K (cmol+/kg)				
0-10 cm	0.45b	0.51ab	0.60a	0.59a
10-20 cm	0.58ab	0.51b	0.64a	0.61ab
0-20 cm	0.51b	0.51b	0.63a	0.60a
Exchangeable Ca (cmol+/kg)				
0-10 cm	15.88a	15.21a	14.73a	14.44a
10-20 cm	15.66a	14.58a	14.50a	12.25b
0-20 cm	15.77a	14.89a	14.61ab	13.35b
Magnesium (cmol+/kg)				
0-10 cm	3.24a	3.19a	3.68a	4.07a
10-20 cm	3.15b	2.86b	4.03a	4.51a
0-20 cm	3.19bc	3.02c	3.85ab	4.29a
Extractable P (mg/kg)				
0-10 cm	6.63a	6.13a	5.52a	6.46a
10-20 cm	4.13a	4.16a	4.29a	4.83a
0-20 cm	5.38a	5.15a	4.81a	5.65a
Organic Carbon (%)				
0-10 cm	0.67a	1.00a	0.66a	0.76a
10-20 cm	0.71a	0.70a	0.89a	0.77a
0-20 cm	0.87a	0.70a	0.75a	0.85a
Total N (%)				
0-10 cm	0.084b	0.100a	0.091b	0.104a
10-20 cm	0.089a	0.091a	0.086a	0.090a
0-20 cm	0.087a	0.096a	0.092a	0.096a
Potentially mineralizable N (mg/kg)				
0-10 cm	36.87a	39.94a	40.29a	38.51a
10-20 cm	28.39a	33.86a	26.48a	30.59a
0-20 cm	32.63a	36.90a	38.53a	34.55a
DTPA-extractable Cu (mg/kg)				
0-10 cm	3.42a	2.69a	1.92a	3.52a
10-20 cm	4.01a	3.45a	2.81a	3.85a
0-20 cm	3.71a	3.06a	2.36a	3.68a
DTPA-extractable Zn (mg/kg)				
0-10 cm	1.64a	1.73a	1.30a	2.04a
10-20 cm	1.89a	1.78a	1.78a	1.92a
0-20 cm	4.31a	5.14a	5.68a	5.04a
DTPA-extractable Mn (mg/kg)				
0-10 cm	67.21a	34.62b	33.13b	62.35a
10-20 cm	62.37a	29.57b	31.69b	59.27a
0-20 cm	63.59a	32.09b	32.40b	62.36a
DTPA-extractable Fe (mg/kg)				
0-10 cm	59.49a	61.34a	56.33a	100.73a
10-20 cm	66.34a	56.24a	59.40a	116.36a
0-20 cm	62.91a	58.79a	57.86a	108.54a

[1]Within a row, means with a common letter are not significantly different at the 5% level by DMRT.

gen-based fertilizers which are commonly used by pineapple farmers. The survey indicated that 63 % of the farmers are applying fertilizers way beyond the recommended rate of 250 kg N/ha or 24 sacks/ha for ammonium sulfate or 10 sacks/ha for urea. Twenty-one percent of the farmers are under-fertilizing and only 16 % of them are fertilizing close to the recommended amount.

All soil samples are low in nitrogen so that fertiliser recommendations focused on this nutrient. The recommendation is based on the planting density of each farm. Ammonium sulfate application is recommended as g/plant (Table 6a).

The soils contain low levels of P but as stated earlier, pineapple requires little P. Nevertheless, some phosphate fertiliser (90 kg P_2O_5/ha) was recommended to avoid long-term P depletion. Since all soils have sufficient potassium, fertilisation with this nutrient was not recommended (Table 6b).

Comparison of soils grown to pineapple and soils in relatively undisturbed sites

Soil quality indicators are often better in undisturbed soils relative to cultivated soils, reflecting some decline in soil fertility due to long-term cropping (Table 7). Bulk densities of undisturbed soils are slightly higher than bulk density of cultivated soils reflecting the influence of cultivation in the latter. Total nitrogen content of undisturbed soils is significantly higher than in the cropped soils for the 0-10 cm and 0-20 cm depths. On the other hand, exchangeable K in the 10-20 cm layer is significantly higher in the cultivated soils. The pH of soils in the undisturbed sites is significantly higher than in the cultivated sites.

Exchangeable Ca in the 10-20 cm depth is significantly better in the undisturbed sites. Organic carbon and extractable P values are also higher for the undisturbed sites compared with the cultivated sites but the differences were not statistically significant.

Micronutrients Cu and Zn levels of the uncropped sites (0-10 cm and 10-20 cm depths) are significantly higher than those of the cropped sites. Manganese and Fe levels of the soils cropped to pineapple did not differ statistically to levels in the uncropped sites.

The amount of mineralizable N in uncropped soils is significantly higher than the mineralizable N of the cropped soils.

These results imply that if soils are allowed some rest or fallow period, some replenishment of nutrients lost through plant uptake may be expected.

Relationship between soil qualities and pineapple productivity

Average fruit yield based on interviews with the farmers was 21.1 t/ha with a minimum value of 7.5 t/ha and a maximum of 44 t/ha. This average value is very close to the 21 t/ha provincial average fruit yield reported by the Bureau of Agricultural Statistics (BAS, 2003). Table 8 shows the average fruit yield of the four towns. Tagaytay has the highest recorded average yield followed by Silang, then Indang and lastly Alfonso. Analysis of variance, however, revealed no significant yield differences between towns.

Table 9 shows the linear correlation coefficients between selected soil quality indicators and fruit yield reported by the farmers. Exchangeable Mg and organic C are closely positively related to yield. Magnesium is a component of chlorophyll, the green pigment in leaves that uses sunlight energy to convert carbon dioxide to carbohydrates. Decrease of this nutrient in soil below 10 mg/kg can affect plant metabolism (Kelly, 1993). Organic matter acts as a source and sink of nutrients in soils and it appears that it is also a sensitive indicator for crop yield. Thus, any changes in these variables are likely to be good predictors of pineapple productivity. Other soil quality indicators were not significantly correlated with fruit yield.

Decline of soil pH with time

Figure 1 shows that the longer the soils are cropped to pineapple, there is a trend towards declining topsoil (0-10 cm) pH. This is the soil layer where nitrogenous fertiliser application and incorporation occur. If a line is fitted through these points, the regression line is not statistically significant at the 5 % level but significant at the 7.5 % level [Fitted line: Soil pH=4.47 – 0.01 (Yrs Under Pineapple Cultivation), P=0.063]. This indicates that, with time, more significant decline in soil pH is inevitable if farmers continue applying ammonium-based fertilizers without employing any soil amelioration measures such as liming.

CONCLUSIONS AND RECOMMENDATIONS

Soil quality indicators are often better in non-cultivated sites compared to the sites cropped to pineapple. Thus, it is important to allow fallow period to rest the soil in order to replenish lost nutrients. More significant decline in soil pH is anticipated if farmers do not employ any soil amelioration measures such as liming. Farms with soils having low pH value should employ liming. A long-term research programme on monitoring of pineapple soil quality (e.g. every five years or so) should be initiated.

Analysis of nutrient elements in pineapple tissues should be done to get an

Table 6a. Fertilizer recommendations for nitrogen for each pineapple farm.

	Farm of:	Total N in 0-20 cm depth (%)	Rating	Number of plants/ha	Ammonium sulfate (g/plant)
1.	David Cabral	0.079	Low	10000	114.4
2.	Angeles Vicedo	0.138	Low	20000	57.1
3.	Leonardo Matel	0.079	Low	20000	57.1
4.	Nicolas Silan	0.079	Low	20000	57.1
5.	Simon Avilla	0.08	Low	20000	57.1
6.	Aniceto Pejana	0.075	Low	12000	95.2
7.	Cenon Rodil	0.084	Low	30000	38.1
8.	Carding Herrera	0.081	Low	20000	57.1
9.	Domingo Ruiz	0.079	Low	45000	25.4
10.	Eusebio Mojica	0.091	Low	25000	45.7
11.	Cerio Cumprada	0.102	Low	20000	57.1
12.	Narciso Resurrecion	0.076	Low	10000	114.4
13.	Elpidio del Mundo	0.097	Low	10000	114.4
14.	Marciano Vislenio	0.102	Low	30000	38.1
15.	Catalino Vislenio	0.1	Low	20000	57.1
16.	Nestor Morales	0.091	Low	25000	45.7
17.	Eufronio Mendoza	0.102	Low	20000	57.1
18.	Rizal Alano	0.088	Low	25000	45.7
19.	Rizal Ortega	0.102	Low	20000	57.1
20.	Cesar Degrano	0.097	Low	25000	45.7
21.	Antonio Umali	0.80	Low	30000	38.1
22.	Roberto Ferma	0.091	Low	20000	57.1
23.	Fermin Joya	0.092	Low	12000	95.2
24.	Mario Humarang	0.086	Low	20000	57.1
25.	Carmen Dimapilis	0.093	Low	20000	57.1
26.	Vivencio Daño	0.085	Low	30000	38.1
27.	Raymundo de Guzman	0.098	Low	20000	57.1
28.	Elejio Pia	0.085	Low	30000	38.1
29.	Benedicto Rodriguez	0.087	Low	30000	38.1
30.	Pedring de Leon	0.087	Low	25000	45.7
31.	Lisa Layaban	0.093	Low	10000	114.2
32.	Leonardo Mendoza	0.1	Low	20000	57.1
33.	Willy Cortez	0.113	Low	20000	57.1
34.	Nicanor Miranda	0.094	Low	25000	45.7
35.	Florante Belen	0.107	Low	30000	38.1
36.	Librado Toledo	0.094	Low	22000	51.9
37.	Daniel Tumbo	0.102	Low	28000	40.7
38.	Lito Mendoza	0.091	Low	25000	45.7
39.	Savino Baysa	0.085	Low	25000	45.7
40.	Irenea Zacharias	0.091	Low	25000	45.7

Critical Value = 0.10%

estimate of nutrient balance and nutrient depletion in soils. Further studies should be done to measure nitrate pollution via leaching in soil and sediment runoff in adjacent rivers and creeks of pineapple farms receiving heavy inputs of nitrogen fertilizers.

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Table 6b. Fertilizer recommendation for phosphorus for each pineapple farm.

	Farm of:	Phosphorus in 0-20 cm depth (mg/kg)	Rating	Number of plants/ha	Solophos P_2O_5 [0-18-0] (g/plant)
1.	David Cabral	6.7	Low	10000	50
2.	Angeles Vicedo	3.35	Low	20000	25
3.	Leonardo Matel	4.8	Low	20000	25
4.	Nicolas Silan	9.45	Low	20000	25
5.	Simon Avilla	4.4	Low	20000	25
6.	Aniceto Pejana	2.2	Low	12000	42.7
7.	Cenon Rodil	8.3	Low	30000	16.7
8.	Carding Herrera	2.55	Low	20000	25
9.	Domingo Ruiz	6.35	Low	45000	11.11
10.	Eusebio Mojica	5.7	Low	25000	20
11.	Cerio Cumprada	4.4	Low	20000	25
12.	Narciso Resurrecion	15.4	Low	10000	50
13.	Elpidio del Mundo	1.9	Low	10000	50
14.	Marciano Vislenio	3.9	Low	30000	16.7
15.	Catalino Vislenio	2.2	Low	20000	25
16.	Nestor Morales	3.6	Low	25000	20
17.	Eufronio Mendoza	2.75	Low	20000	25
18.	Rizal Alano	4.65	Low	25000	20
19.	Rizal Ortega	9.6	Low	20000	25
20.	Cesar Degrano	3.05	Low	25000	20
21.	Antonio Umali	4	Low	30000	16.7
22.	Roberto Ferma	4.9	Low	20000	25
23.	Fermin Joya	6.35	Low	12000	42.7
24.	Mario Humarang	5.75	Low	20000	25
25.	Carmen Dimapilis	3.2	Low	20000	25
26.	Vivencio Daño	5.95	Low	30000	16.7
27.	Raymundo de Guzman	7.7	Low	20000	25
28.	Elejio Pia	4.95	Low	30000	16.7
29.	Benedicto Rodriguez	1.9	Low	30000	16.7
30.	Pedring de Leon	3.35	Low	25000	20
31.	Lisa Layaban	4.5	Low	10000	50
32.	Leonardo Mendoza	2.2	Low	20000	25
33.	Willy Cortez	10.05	Low	20000	25
34.	Nicanor Miranda	6.4	Low	25000	20
35.	Florante Belen	2.75	Low	30000	16.7
36.	Librado Toledo	6.55	Low	22000	22.7
37.	Daniel Tumbo	9.45	Low	28000	17.8
38.	Lito Mendoza	1.35	Low	25000	20
39.	Savino Baysa	2.75	Low	25000	20
40.	Irenea Zacharias	10.45	Low	25000	20

Critical Value = 10 ppm

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Table 7. Comparison of soil quality indicators in cropped and undisturbed soils.

Soil quality indicator	Cropped	Undisturbed
Bulk density (g/cm^3)		
0-10 cm	1.16	1.17
10-20 cm	1.14	1.16
0-20 cm	1.15	1.17
pH		
0-10 cm	4.31	4.63**
10-20 cm	4.41	4.69**
0-20 cm	4.37	4.66**
Exchangeable K (cmol+/kg)		
0-10 cm	0.54	0.58
10-20 cm	0.58	0.51*
0-20 cm	0.57	0.55
Exchangeable Ca (cmol+/kg)		
0-10 cm	15.03	16.21
10-20 cm	14.25	14.87*
0-20 cm	14.66	15.70*
Magnesium (cmol+/kg)		
0-10 cm	3.55	3.54
10-20 cm	3.64	3.52
0-20 cm	3.59	3.53
Extractable P (mg/kg)		
0-10 cm	6.1	8.5
10-20 cm	4.4	5.8
0-20 cm	5.2	7.2
Organic Carbon (%)		
0-10 cm	0.74	0.81
10-20 cm	0.82	0.74
0-20 cm	0.79	0.78

*Statistically significant at the 5% level of significance by a paired t-test.
** Statistically significant at the 1% level of significance by a paired t-test.

Table 8. Average fruit yields in the four pineapple growing municipalities of Cavite.

Reported fruit yield (t/ha)			
Indang	Alfonso	Tagaytay	Silang
21.0	18.2	22.8	22.0

Table 9. Soil quality indicators significantly correlated with yield.

Soil quality indicator	Correlation coefficient
Exchangeable Mg (cmol+/kg)	
0-10 cm	0.461**
10-20 cm	0.333*
Organic carbon (%)	
10-20 cm	0.602**
0-20 cm	0.557**

*Significant at the 5% level
** Significant at the 1% level

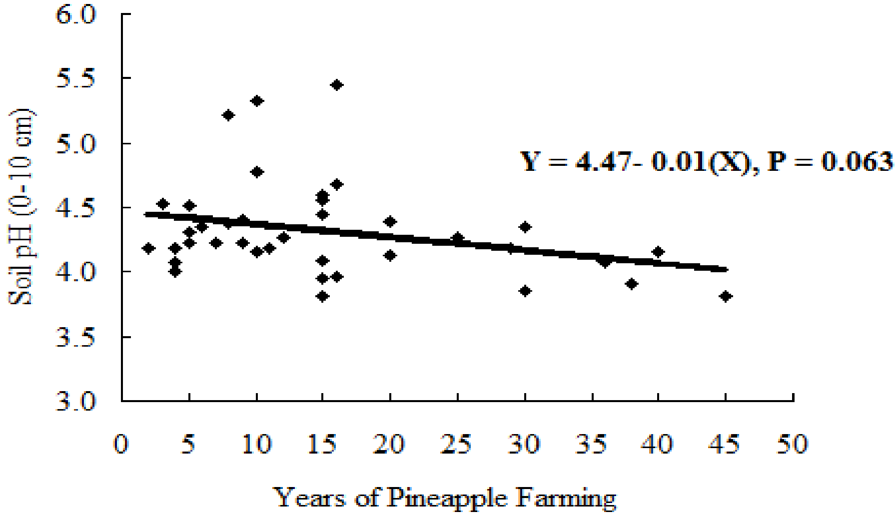

Figure 1. Declining trend of soil pH (0-10 cm) with time.

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