

Integrated Soil Fertility Management (ISFM) on Coconut + Lanzones (*Lansium domesticum* Corr) Agro-ecosystem in Southern Mindanao, Philippines (1993 – 2007): with Emphasis on the Multi-nutrient Coconut-Specific Mineral Fertilizer*. Part I. Crop Productivity, Quality and Profitability

Severino S. Magat¹, Millicent I. Secretaria², Junaldo A. Mantiquilla³ and Rogaciano Z. Margate³

Abstract

A 15-year (1993-2007) integrated soil fertility management (ISFM) of coconut + lanzones fruit agro-ecosystem was conducted using five fertilizer combinations (FCs) in a dominantly tropical wet climate (Koppen-Geiger Climate Classification Kotték et al 2006) of Davao, Southern Mindanao (07°05'N 125°37'E). It aimed to determine the response of this agro-ecosystem to the combined multi-nutrient fertilizer N+P+K+Cl+S+B (14-5-20-0.02B-15.5Cl-4.5S) and organic fertilizer (OF) sources at different ratios (IF:OF at 1:0;1:2; 2:4 and 4:4) on coconut yield, lanzones growth, yield and fruit quality; soil properties; leaf nutrient levels; total farm productivity and profitability.

The application of even the lowest rate of the multi-nutrient mineral fertilizer (MNF) at 1 kg/tree/yr produced an appreciable improvement in annual nut and copra yields per ha, from benchmark 8,890 nuts or 1.6 t to levels 3 - 4 t copra after 1-2 years of MNF applications. The average sustained yields of 17,000 nuts or 4 t copra per ha/yr was achieved over the next 12 years at this low MNF input. Application of the combined MNF and OF enhanced lanzones fruiting. Except in 2004, fruit harvest increased from year 8 to year 14 with FC1 and FC2 producing higher yields, and quality of fruits (sweetness, brix reading) improved at lower rates of MNF (0.38kg/tree) and organic fertilizers. The ISFM of the agro-ecosystem is productive and sustainable even at low input of the MNF developed for coconut capable of generating large volume of biomass for a stable soil fertility.

Overall, the profitability indices as benefit-cost ratio (BCR) and internal rate of return (IRR) showed that the best fertilizer application for both crops was FC1-----the lowest annual rate of MNF (coconut@ 1kg/tree and lanzones @ 0.38/tree), without organic fertilizer application. At 18% interest, the FC1 has the highest BCR of 2.5, IRR of 328% and NPV of PhP115,645 per ha. A fertilization guide for the coconut + lanzones agro-ecosystem is presented based on this long-term research work. (1USD = 45PHP)

Keywords: Coconut, *Cocos nucifera*, lanzones, *Lansium domesticum*, coconut+ fruit tree ecosystem. inorganic multi-nutrient fertilizer, organic fertilizer, integrated soil fertility management coconut-specific fertilizer, site-specific nutrient management.

* A part of the paper presented to the 2008 National Research Symposium, Department of Agriculture, Government of the Philippines, under the Applied Research -Technology Information/Generation – Agriculture Category. Eventually won the 2008 Best Agriculture and Food Modernization Act R & D Paper.

¹ Scientist IV, Philippine Coconut Authority (PCA), Diliman, Quezon City

² Scientist I, PCA-Davao Research Center, Bago Oshiro, Davao City

³ Former Researcher, PCA-Davao Research Center, Davao City

Introduction

In 1991, the Philippine Coconut Authority (PCA) conceptualized the integrated soil fertility management (ISFM) and defined it as the combined use of organic/natural and inorganic fertilizers in coconut farming aimed at achieving maximum economic yields through a sustainable, economical, environment-friendly and socially-acceptable production system (Magat, 1997). In most cases, field studies involving ISFM are long-term as the agronomic, soils and mineral nutrition aspects of farming techniques are intensively tested before conclusions and final recommendations are formulated under the mono-cropping and inter-cropping conditions of coconut farming. Site-specific ISFM covers the integrated nutrient management (ICM) aspects and the complementary soil physical and biological conditions that influence the growth and productivity of crop (s) and its ecosystem. We may consider that ISFM is one of the major components of the effective and efficient integrated crop management (ICM) in agriculture and farming, to be locally and globally competitive.

Intercropping in coconut farms is widely practiced in the Philippines as well as in many coconut producing countries, but sadly, only few farmers yet have attained consistent success in increasing their farm productivity. Aguilar and co-workers (1991), documenting successful coconut-based farms, concluded that three factors strongly control the success of farmer-managed farms in the Philippines, namely: 1) right agro-environment; 2) positive attitude of the farmer; 3) availability of proper technologies (practical and affordable).

As intercropping aims for higher yields of coconut and intercrops to have maximum farm productivity and a profitable return to investment (labor, seeds, fertilizers and farm chemicals), proper cultural practices and fertilization or nutrient management of both coconut and intercrops should be necessary (Magat, 1990).

Fertilizer is considered worldwide as of the single, most important inputs that can immediately improve production of most agricultural crops as coconut and its suitable intercrops (i.e. corn, peanut, sweet potato, pineapple, banana, coffee, cacao and other fruit crops). At the same time, the sustainability of coconut farming system depends highly on technologies applied to conserve the soil resources or improve the soil productivity, and in this regard an integrated soil fertility management (ISFM), a balance of cultural, biological and chemical or inorganic methods should be the most positive and acceptable approach and/ or farming practice consistent with integrated crop management system (ICMS) aimed at the long-term sustainability and productivity in coconut farming for the benefit of small and medium-scale farms, and less privileged and resource-limited farmers.

Objectives

General Objective:

To develop a practical, affordable, viable and environmentally - safe integrated soil fertility management (ISFM) using a crop-specific multi-nutrient inorganic fertilizer and organic fertilizer sources for a productive and sustainable coconut + fruit intercropping agro-ecosystem, and at the same time conserving fragile soil environments in coconut lands.

Specific Objectives:

- 1) To determine the effects of the application of the crop-specific inorganic (IF) fertilizer and organic fertilizers (OF) at different ratios by weight (1 IF: 0 OF; 1 IF:2 OF; 2 IF:4 OF; 4 IF:2 OF and 4 IF:4 OF) as applied to nut-bearing coconuts and fruit intercrop (lanzones) on: 1) productivities of each component crop; and 2) total productivity of the coconut + lanzones agro-ecosystem;
- 2) To know the effectiveness and efficiency of the pre-formulated crop-specific multi-

nutrient fertilizer 14-5-20-0.02 (B) w/ 15.5% Cl and 4.5% S, supplying the generally-deficient soil/plant nutrient of coconut areas in the country;

- 3) To determine the production economics of the coconut + lanzones agro-ecosystem, and the most beneficial ISFM (fertilizer combination)
- 4) To generate an average fertilization guide with emphasis on ISFM of the agro-ecosystem based on the long-term study results.

Materials and methods

Experimental Area:

A research station area/block with bearing coconut palms (average age of 25 years) was used at the Philippine Coconut Authority-Davao Research Center (PCA-DRC) located 07°05'N 125°37'E under a tropical wet climate (Koppen-Geiger Climate Classification, Kottek et al 2006). It belongs to an intermediate to wet coconut growing zone with a type 1 rainfall type (rainfall almost uniformly distributed year-round) or type B-humid climate (utmost 3 dry months yearly) The PCA-DRC soil is extensively the Tugbok clay soil (classified as Typic Tropudalfs) with moderate structure, deep, well drained, slightly acidic, high base saturation, and generally deficient in nutrients N, Cl and S (Magat 1981).

Planting Materials:

Coconut - existing stands of 20 - 30 year old coconuts, Laguna tall variety 'LAGT' planted in 8m x 8m square system (156 trees/ha).

Lanzones fruit tree - recommended variety (e.g. 'Paete' grafted) intercropped under coconut (1 row of fruit tree between 2 rows of coconut trees; 4m spacing between fruit trees and 4m from coconut trees).

Experimental Treatments: (Coconut and Lanzones fruit intercrop)

Fertilizer Combinations (FC): Kind and level (IF - inorganic fert.: OF - organic fert);

- | | |
|----------------|----------------|
| 1) FC1 (1 : 0) | 4) FC4 (4 : 2) |
| 2) FC2 (1 : 2) | 5) FC5 (4 : 4) |
| 3) FC3 (2 : 4) | |

Experimental Design

Three (3) replications, nine (9) coconut palms/treatment-plot and with 15-20 lanzones trees/plot in a randomized complete block design (RCBD)

Rates of Fertilizers:

Relevant climate and soil data were gathered. Benchmark and periodic data on some important soil chemical, physical and biological properties were determined following the Research Guide on the conduct of Agronomic and Nutrition Studies in Coconut (Margate and Magat, 1991).

Leaf sampling of bearing coconut trees were done prior to application of treatments and ensuing years, following standard procedures (Magat 1976 and Magat 2007). Also, the leaf sampling of lanzones intercrop at different development stages and final cropping year were done, following the methods presented by Magat (2005). The benchmark and succeeding periodic (annual) soil and leaf samples properly dried and identified before these were submitted to the Plant Tissue Analysis Laboratory, Plant and Soil Analysis Division, Philippine Coconut Authority, Central Office, Diliman, Quezon City. Soil samples were analyzed for selected soil properties, and both coconut and lanzones fruit tree samples were analyzed for macronutrients (N, P, K, Ca, Mg, Na, Cl and S) and micronutrients (B, Zn, Fe Mn and Cu), following standard procedures and methods (Raquipo and Pabustan, 2003).

Agronomic (growth and yield) data of coconut and intercrops were gathered following acceptable sampling techniques and yield estimations. The total crop productivity and net income (per unit area over time, i.e. per tree,

Table 1. Actual fertilizers applied (per tree/year) under the five fertilizer combinations (FCs), on ISFM coconut + lanzones agro-ecosystem (PCA-DRC, 1993-2007)

L A N Z O N E S CROP Component												
	FIELD		SIX		Yr 1		Yr 2		Yr 3 ^a		Yr 4 ^b	
TRMNT (IF : OF)	PLANTING		MONTHS		(1994)		(1995)		(1996)		(1997)	
	g IF	g OF	g IF	g OF	kg IF	kg OF	kg IF	kg OF	kg IF	kg OF	kg IF	kg OF
FC-1 (1 : 0)	63	0	125	0	0.25	0	0.38	0	0.38	0	0.32	0
FC-2 (1 : 2)	63	125	125	250	0.25	0.50	0.38	0.75	0.38	1.0	0.32	1.26
FC-3 (2 : 4)	125	250	250	500	0.50	1.00	0.75	1.50	0.75	2.0	0.64	2.50
FC-4 (4 : 2)	250	125	500	250	1.00	0.50	1.50	0.75	1.50	1.0	1.26	1.26
FC-5 (4 : 1)	250	250	500	500	1.00	1.00	1.50	1.50	1.50	2.0	1.26	2.50
L A N Z O N E S CROP Component											COCONUT	
TRMNT (IF : OF)	Yr 5 ^c		Yr 6 ^d		Yr 7 ^d		Yr 8-9		Yr 10-15 ^e		Yr 10-15 ^e	
	(1998)		(1999)		(2000)		(2001-2002)		(2003-2007)		(1993-2007)	
	kg IF	kg OF	kg IF	kg OF	kg IF	kg OF	kg IF	kg OF	kg IF	kg OF	kg IF	kg OF
FC-1 (1 : 0)	0.43	0	(80 g KCl+	0 (25	(80 g KCl+	0	0.38	0 (25 pc	0.38	0	1	0
FC-2 (1 : 2)	0.43	0.75	400g	pcs	400 g	0	0.38	coco	0.38	0	1	2
FC-3 (2 : 4)	0.62	1.50	RP)	coco husk/	RP	0	0.75	husk	0.75	0	2	4
FC-4 (4 : 2)	0.99	0.75	ditto	tree)	Ditto	0	1.50	ditto	1.50	0	4	2
FC-5 (4 : 4)	0.99	1.50	ditto	ditto	Ditto	0	1.50	ditto	1.50	0	4	4

^aAdditional treatment in October 1996: applying 50 g of zinc sulfate per tree on one sub-plot with split-plot design

^bInorganic fertilizer application reduced per latest nutritional diagnosis

^cHalf of rate for the year was applied, and subsequently with 40 g KCl + 200 g rock phosphate (RP) per tree in blanket application

^dBlanket application of 80 g KCl + 400 g RP, split in two application: Jun & Oct, while the commercial organic fertilizer (*Biogro*) was replaced by 25 coconut husk(full) divided to 4-6 into pieces before topsoil placement, per lanzones tree. *Biogro* commercial organic fertilizer has the NPK fertilizer grade of (1.2.5 - 4.5 - 1.75) with 5 - 25% CaO and 1-5% MgO and some micronutrients (produced by *BIOrganix* Technology, Inc)

^eFrom 2004, the physical blended 14-5-20 (with 0.02% B, 15% Cl and 4.5% S) inorganic fertilizer (IF) was replaced with the commercial granulated 14-5-20 (commercial ATLAS brand *CocoGro*)

per hectare) was based on the combined yield and calculated income of the coconut and the intercrop.

Data were evaluated using statistical analyses, aided by available computer software MS-EXCEL. Net income, benefit cost ratio (BCR) analysis, and other economic indices were computed to provide an understanding of economic options under the different fertilizer combinations of inorganic and organic fertilizer sources in ISFM of the coconut + lanzones fruit tree ecosystem.

Results and discussion

A. Effects of ISFM: inorganic and organic fertilizer combinations (FC) on coconut

A.1 Coconut Yield

In 1993, at the start of the study, the mature nut-bearing stands of the Laguna Tall variety 'LAGT' palms had a benchmark annual average yield of 57 nuts/tree (range: 49-66 nuts/tree) and 1.6 t copra (1.4-1.8 ton copra/ha), the average productivity of coconut commonly observed in highly suitable wet growing zones of the country. The initial data revealed that the trees were largely homogeneous in terms of productivity before treatment application.

One year after the first fertilizer application, clearly a significant increase in yield in nut and copra per hectare was already noted (Figures 1 and 2), almost doubled the initial yield in all fertilized palms with different fertilizer combinations (FCs). This yield further increased in the succeeding years. However, there was a drop in the yield in 1998-99 due to the long dry spell or El Nino occurrence from 1997-1998 as observed from the annual rainfall data at PCA-DRC.

In years 2000 and 2001, average yield of five tons copra per ha had been achieved at the Davao Research Center, particularly in this study (Figure 2). This was highly attributed to highly ideal growing conditions during those periods due to the improvement of climatic

condition of the experimental location after a long dry spell.

Consistent with the early years of coconut production, differences in nut and copra yields of fertilizer treatment combinations did not reach statistical significance (at 5% level). Clearly, this means that even with the application of FC-1 (1 kg/tree/yr of inorganic fertilizer, with no organic fertilizer), the lowest rate of the multi-nutrient fertilizer, without organic fertilizer, annual yield over 3 tons copra per ha (or over 100 nuts per tree) was produced in most of years of cropping.

Nevertheless, Figure 2 shows that with the application of FC-4 (4 kg inorganic fertilizer plus 2 kg organic fertilizer), the highest annual yield of 4-5 tons/ha (about 146.5 nuts/tree and 34 kg copra/tree or 5.0 tons copra per ha were achieved but not in fertilizer combinations with higher rates of organic fertilizers (4 kg/tree/yr) as FC-3 and FC-4 treatments. The addition of at least two kg of organic fertilizers as in FC2 (one kg inorganic + two kg organic fertilizer) appears enough and beneficial in improving further the productivity of palms, mainly attributed to increase in nut yield but not in copra weight (per nut). Copra is the dried coconut meat or kernel at 12% or lower moisture, normally, a required condition in selling the primary-processed coconut meat.

Results of this study firmly and consistently showed that the multi-nutrient coconut - specific fertilizer 14-5-20-0.02 (B), with adequate content of nutrients Cl (15.5%) and S (4.5%) is highly suitable, nutritionally-balanced, and practical for long-term productive coconut farming. In this study, it was applied either in the form of physically-blended single fertilizer materials using different inorganic fertilizer sources (used in early years of the study, 1993 - 2003) or the chemically processed granulated commercial multi-nutrient formula pre-formulated by the PCA for coconut-specific fertilizer. The latter

Figure 1. Nut yield (per ha, 156 trees) of 'LAGT' palms as affected by different fertilizer combinations (FC), PCA-DRC, 1993-2007

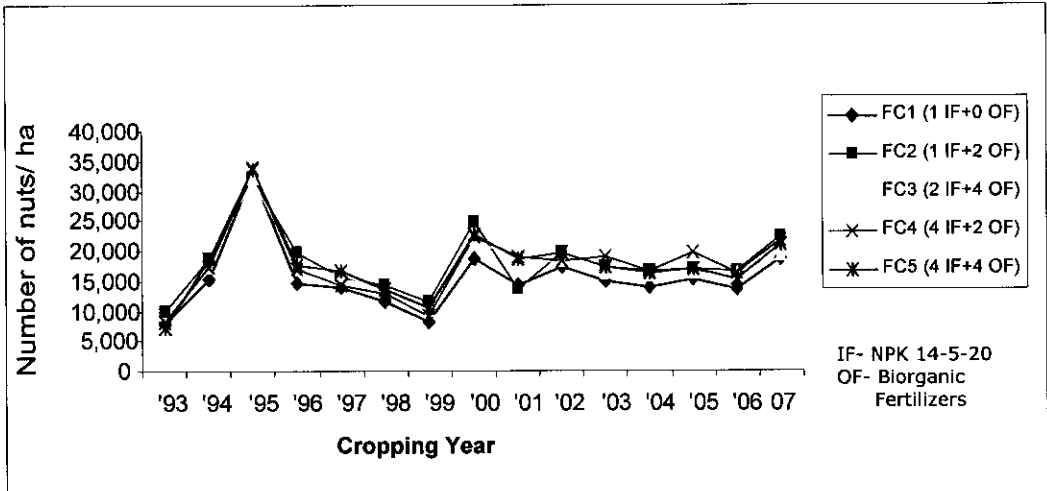
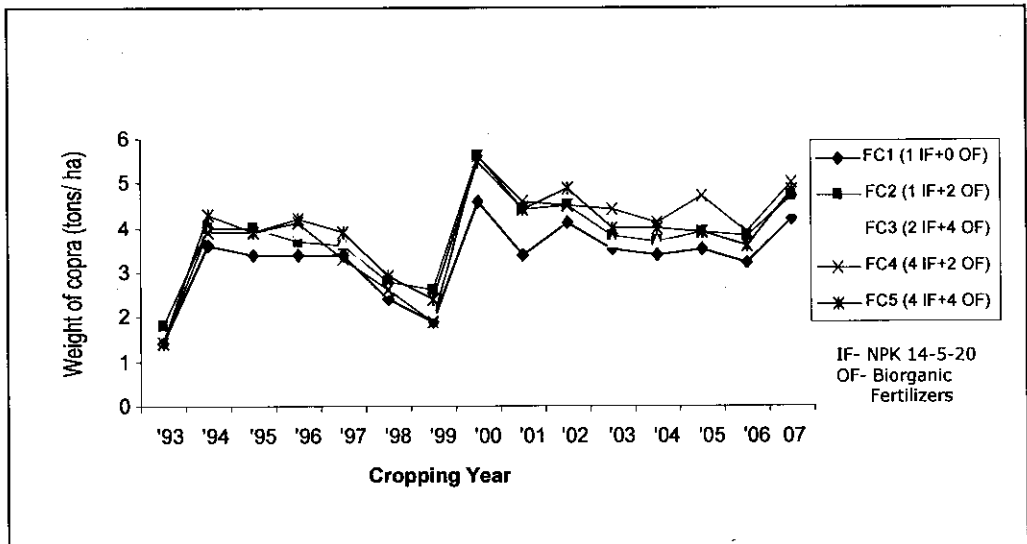


Figure 2. Copra yield (per ha, 156 trees) of 'LAGT' palms as affected by different fertilizer combinations (FC), PCA-DRC, 1993-2007



is now commercially available in the market under the trade name *CocoGro*. Aside from the macronutrients such as N, P, K needed by coconut, this kind of fertilizer also supplies to crops 0.02% B, 15.5% Cl and 4.5% S which are considered beneficial to the long-term productive and economically sustainable yields of coconut. The same inorganic fertilizer (IF) was used as the IF for the intercrop lanzones fruit tree in this ISFM study on coconut + fruit tree agro-ecosystem.

Moreover, results of this work strongly indicated that a very active nutrient recycling is likely contributing to the total soil fertility of the cropping system, hence the rate of application of low to moderate levels of the multi-nutrient inorganic and organic fertilizers are just adequate needed for the ISFM of the coconut-lanzones agro-ecosystem for its sustained productivity. As the application of external sources of organic fertilizers (OF) failed to influenced significantly the yields of coconut and lanzones (in ensuing sections), apparently, the biomass (dry matter) produced by the intercrop had likely provided or generated plant-based organic materials and its subsequent recyclable nutrients for the coconut + lanzones agro-ecosystem. As such, the intercropping of fruit trees as lanzones strongly appears a significant component of a practical and sustainable IFSM.

B. Effects of ISFM: fertilizer combinations (FC) on lanzones intercrop

B.1 Vegetative growth stage (field establishment to pre-bearing)

At three years and four from field planting (FP), the trees with FC-1 appeared to improved the growth. And with the addition of organic fertilizer (FC-2), this tended to have further improvement most of the on vegetative growth indices of the growing fruit crop (Table 3). However, among the fertilizer combinations differences noted were not yet significant.

At five years and 2 months from FP, the fertilizer factor highly significantly affected the total leaf area (sampled leaves from tertiary

branch)) of lanzones trees (Table 4). The fertilizer combinations with lower IF and OF (FC-1 and FC-2) had significantly bigger leaf area (77 m²) as compared to the higher rate of fertilizer applications (FC-3, FC4 and FC-5) with only 60 - 68 m². Higher fertilizer rates did not show proportional growth improvement in lanzones. This suggests that the low fertilization rate of 0.43 kg multinutrient IF (containing N, P, K, Cl, S and B) was rationally adequate for normal pre-bearing stage vegetative growth (pre-bearing stage) of lanzones trees.

Three years after field planting (1996), additional fertilizer treatment (Zinc) was established in lanzones intercrop by applying 50 g zinc sulfate per tree, on one sub-plot (w/ Zn) and other (w/o Zn) following a split-plot design. In the country, many perennial crops like banana, mango and cacao usually require Zn fertilization. Zn fertilization was done to understand the need and response of lanzones fruit under a coconut-based ecosystem.

Zinc, a micronutrient, being needed in very small amounts is an important component of various enzymes that are responsible for driving many metabolic reactions in all crops (<http://www.extension.umm.edu/distribution/cropsrosystems>), it ensures normal morphological development; activates enzyme carbonic anhydrase which promotes hydrolysis and hydration in the plant (Magat 1996).

On the nutritional status of lanzones, except for leaf B (at higher OF fertilizer rates), the fertilizer combinations (FCs) did not affect the vegetative growth of lanzones on its early stage-1996. However, in the succeeding year, the fertilizer combinations (FCs) tended to increase the leaf N, Cl and Mn with increasing rates of IF and OF, but inversely on leaf P and K. Only leaf Ca was significantly increased with Zn application (50 g/tree) but leaf P and K significantly decreased and did influence the leaf contents of micronutrients B, Zn and Mn. The leaf nutrient levels in FC-5 was significantly higher over FC-1 in terms of leaf

N, Cl and Mn; while that of leaf K content was significantly higher in FC-1 over FC-5 application.

B.2. Yield of lanzones intercrop

On its first year of fruiting, 2001, i.e. eight (8) years after field planting, the lanzones trees receiving FC-2 (1+2) had the most number of bunches and fruits per tree (Table 5). It produced 48% more bunches and 46% more fruits compared to the FC-1 trees (lowest IF application only), but only 39% more in terms of fruit weight. It appears to be an organic fertilizer (OF) effect after more than seven years of fertilizer application. However, the trend did not follow for higher rates (FC-3, FC-4 and FC-5) as fruiting was highly variable, i.e. some trees did not bear fruits yet, hence higher coefficient of variation (C.V.) generally were found on the selected yield indices of lanzones. It appeared that the lower dosage, FC-2 (1 F + 2 OF) was already enough for the growth and yield of lanzones.

On the ninth year from planting (2002) with all of the trees already bearing, the number of bunches and yield did not show any difference among treatments (Table 6). However, the higher treatment levels (FC-3, FC-4 and FC-5) had higher yield attributes compared to FC-1 or FC-2. The FC-4 application (4 IF + 2 OF) produced the highest yield of 2.8 ton fruit/ha the achievable yield potential as FC-5 (4 IF: 4 OF) gave only 2.4 t fruit/ha. This strongly indicates that fertilizing the lanzones intercrop more than the levels of FC-4 has no practical and economic benefits.

On the tenth year (2003), the yield indices (average weight of individual fruit, length of peduncle and number of fruits per bunch) did not significantly vary among the different fertilizer combinations (Table 7). The fruit yield was highly variable on the third year of bearing. The very high coefficient of variation obtained for number of bunches/tree and weight of fruits/tree was due to the high yield from treatment FC-1 (about 8.1 kg/tree) compared with the rest of the treatments (4.1-5.7 kg/tree),

which was in turn due to the high number of bunches obtained at 63 bunches/tree/year (Figures 3 and 4).

In the ensuing years, remarkable and highly productive yields of lanzones fruits were observed, particularly on the 12th year /2005 (Figure 5a) and 14th year/2007 (Figure 5b). The lanzones yield on the 13th year was considerably lower than those in the 12th and 14th years (Table 8). During these two very productive years of 2005 and 2007, lanzones trees with the lowest rate of multi-nutrient 14-5-20-0.02(B) inorganic fertilizer (0.38 kg/tree/yr) with no organic fertilizer (FC-1) produced the highest fruit yield per ha (ranging from 10-15 ton/ha). Likewise, other yield attributes of lanzones trees were clearly higher in FC-1 application over the other FCs (Table 9).

Furthermore, on the 100-fruit weight and quality of lanzones, the FC-1 consistently produced highest weight of lanzones fruits per tree and best quality of fruits in terms of its sweetness during the 2007 harvest (Table 10 and Figure 7). The insignificant difference of the fertilizer treatments on the fruit attributes (including length of peduncle) consistently indicates the effectiveness of the multinutrient inorganic fertilizer (FC-1) even at the lowest rate (0.38 kg IF/tree/yr) for lanzones. Likewise, likely, is the enhancement of soil fertility levels via the biomass production and subsequent generation of nutrients from the lanzones crop itself for the coconut-lanzones agro-ecosystem.

These results clearly indicate that at even at the lowest rate (FC1) of the multi-nutrient [14-5-20-15.5(Cl)-4.5(S)-0.02(B)] fertilizer for lanzones (0.38 kg/tree/yr) even without organic fertilizer is already adequate for optimum yield of this intercrop. Furthermore, this result may imply that the massive quantities of organic materials (litters from lanzones and coconut waste/residues) found on the soil under coconut+lanzones cropping system could be adequate in

Table 3. Mean Growth of young lanzones crop under coconut at different fertilizer combinations (FC) at 3.25 years after field planting, PCA-DRC

Fert. Treatment	Height	Leaf Area (sq. m.) ¹	Distance of Fruiting Panel ²	Girth (cm) ³	Number of Branches		Total Leaf Count ⁴	Leaves Branch ¹
					Primary	Secondary		
FC-1 (1+0)	280.74	76.61	241.25	13.36	1.22	13.08	819.81	7.75
FC-2 (1+2)	286.04	72.64	249.76	13.45	1.19	14.95	1,188.11	7.78
FC-3 (2+4)	264.6	58.31	221.74	11.95	1.25	13.36	907.42	7.14
FC-4 (4+2)	275.35	70.12	226.71	12.31	1.17	13.25	1,109.89	7.28
FC-5 (4+4)	262.25	64.34	221.61	12.11	1.19	13.56	805.78	7.25
Stat. sign.	ns	ns	ns	ns	ns	ns	ns	ns
C.V. (%)	5.1	15.1	4.9	6.6	9.0	9.1	22.8	5.1

¹ Mature sample leaves taken from 3rd tertiary branch from top

³ Taken one inch below graft union

² Taken from the point of union to the point of branching

⁴ Taken from two middle secondary branches

Table 4. Growth of lanzones at different fertilizer combinations at 5.2 years after field planting, PCA-DRC, 1998

Fert. Treatment	Height	Leaf Area (sq. m.) ¹	Distance of Fruiting Panel ²	Girth (cm) ³	Number of Branches		Total Leaf Count ⁴	Leaves Branch ¹
					Primary	Secondary		
Fertilizer Factor (FF)								
FC-1 (1+0)	382	77 a	333.2	18.7	1.3	19.2	279.5	7.4
FC-2 (1+2)	398	77 a	351.3	19.3	1.2	21.4	352.3	7.5
FC-3 (2+4)	365	68 b	316.4	17.6	1.2	19.6	351.2	7.4
FC-4 (4+2)	376	64 b	327.9	18.0	1.3	20.8	286.2	7.2
FC-5 (4+4)	353	60 b	303.5	17.0	1.2	18.9	269.5	7.1
Zinc Factor								
+Zn	372	71	325.1	18.1	1.2	19.5	312.2	7.3
-Zn	378	67	327.9	18.2	1.2	20.5	303.2	7.4
Stat. sign.	ns	**	ns	ns	ns	ns	ns	ns
FF	ns	ns	ns	ns	ns	ns	ns	ns
ZF	ns	ns	ns	ns	ns	ns	ns	ns
FF x ZF	ns	ns	ns	ns	ns	ns	ns	ns
C.V.-FF (%)	6.3	9.4	8.0	8.5	18.3	13.5	33.5	7.1
C.V.-ZF (%)	7.7	9.3	8.8	5.6	11.8	13.0	17.0	4.1

Figure 3. A representative lanzones tree with productive bunches, applied with only inorganic premix multi-nutrient fertilizer 14-5-20-0.02 (B) (FC1 – 1 part inorganic, without organic fertilizer), ISFM on Coconut-Lanzones agro-ecosystem, June 2003

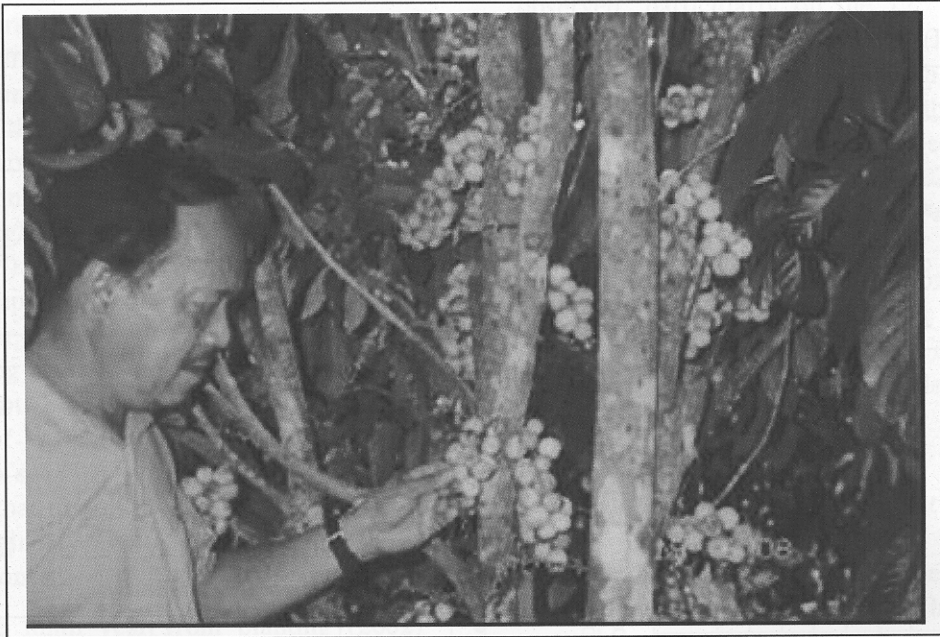


Figure 4. One of the best/highest yielding lanzones tree applied with FC1 (1 part inorganic fertilizer without organic fertilizer), ISFM on Coconut + Lanzones agro-ecosystem cropping, PCA-DRC, June 2003

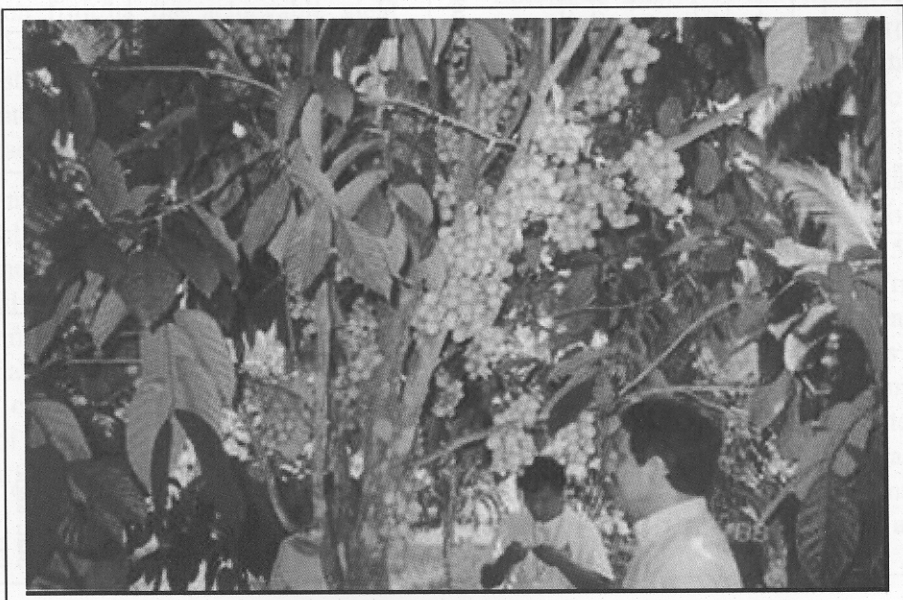


Table 5. Yield indices of lanzones fruit tree intercrop as influenced by fertilizer treatments at eight years from field-planting, PCA-DRC, 2001

TREATMENT	Bunches/tree (no.)	Fruits/tree (no.)	Wt. of lanzones Per tree (kg)
FC-1 (1+0)	8.25	125.02	0.9
FC-2 (1+2)	12.23	182.66	1.4
FC-3 (2+4)	6.28	90.44	0.6
FC-4 (4+2)	7.16	120.64	0.9
FC-5 (4+4)	2.17	29.39	0.2
Stat. sign.	ns	ns	ns
C.V. (%)	52.7	47.3	55.3

Table 6. Yield indices of lanzones fruit tree intercrop as affected by fertilizer treatments at nine years from field-planting, PCA-DRC, 2002

TREATMENT	Bunches/tree (no.)	Accum. Yield (kg/tree)	Accum. Yield (kg/ha) ^b
FC-1 (1+0)	53.0	4.13	1,938.50
FC-2 (1+2)	41.26	4.14	1,940.60
FC-3 (2+4)	53.87	5.02	2,352.70
FC-4 (4+2)	69.94	5.93	2,779.60
FC-5 (4+4)	56.95	5.08	2,382.50
Stat. sign.			
1) Fert. Factor	ns	ns	ns
2) Zinc Factor	ns	ns	ns
FF x ZF	ns	ns	ns
% C.V. (1)	17.6	9.3	
% C.v. (2)	14.1	6.7	

Figure 5. Highly productive intercrop lanzones trees applied with only inorganic multi-nutrient fertilizer 14-5-20-0.02 (B), the FC1 (1 IF: OF) without organic fertilizer application), ISFM on Coconut + Lanzones agro-ecosystem, (a) Aug. 2005, (b) Aug. 2007, left and right photos, respectively, PCA-DRC, Bago Oshiro, Davao City



Figure 6. Photos of 100-fruit lanzones as influenced by fertilizer treatment combinations (FCs) under the ISFM on coconut+lanzones fruit tree agro-ecosystem, Davao City (Southern Mindanao, Philippines. (Note: T1, T2, T3, T4, T5 refer to FC-1, FC-2, FC-3, FC-4, FC-5), respectively, PCA-DRC, Sept. 2007

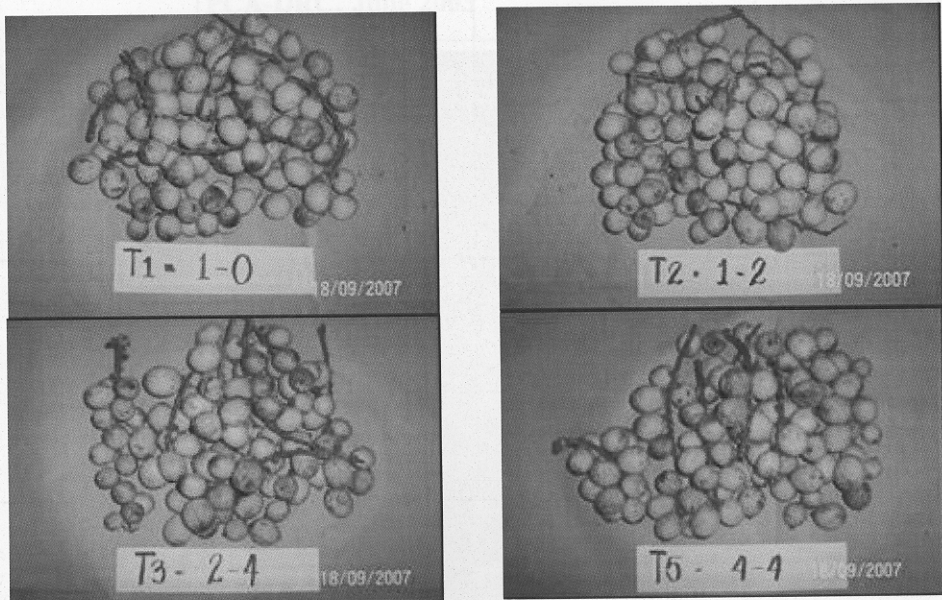


Figure 7. Massive natural accumulation of litters on the ground (shed leaves of lanzones and coconut crops, the biomass residues (farm wastes), under the IFSM on coconut+ lanzones agro-ecosystem, PCA-DRC, 2007



supplying the needed nutrients from an organic source of fertilizer (Figure 7).

A guide for normal and adequate leaf nutrient levels for bearing lanzones fruit crop was earlier presented by Magat (2005) for macronutrients (%): N, 2.72; P, 0.20; K, 2.03; Ca, 1.37; Mg, 0.38; Na, 0.03; Cl, 0.25; S, 0.19; and for the micronutrients (ppm): B, 54; Zn, 32; Mn, 68; Fe, 162; Cu, 21. In final cropping year of 2007, leaf sampled after the final harvest, except for leaf P, K Mg, Cl, S and Na, the other leaf nutrients (N, Ca, B, Zn, Mn, Fe and Cu) were apparently lower than normal. This decrease in the leaf nutrient levels indicates that the heavy fruiting during the year had required higher quantities of nutrients by the agroecosystem. Thus, requiring fertilizers to enhance vegetative growth for the next cropping year.

D. Effect of fertilizer treatments on the quality (sweetness) of 'Paete' lanzones fruits

The effect of fertilizer treatments on the sweetness of lanzones fruits was evaluated

during the 2005 and 2007 crop harvests (Table 11). In 2005, there was no significant difference on the sweetness of lanzones fruits as affected by the fertilizer combinations (FCs) and Zn application. However, it is interesting to note that the FC-1 treatment (lower rate) of inorganic fertilizer (0.38 kg 14-5-20-0.02B/ lanzones tree/year) produced sweeter lanzones fruits over the higher rates of inorganic fertilizer rate (0.75 and 1.5 kg/tree). There is a direct, linear relationship between the brix value and degree of fruit sweetness (i.e., the higher the value of °brix reading, the sweeter the fruit). Remarkably, the °brix reading of the lanzones fruit (based from its sap) in 2007 were appreciably higher over the 2005 fruit harvest.

The brix reading, measured by a refractometer primarily is a measure of the carbohydrate level in plant juices (<http://www.highbrixgardens.com/highbrix/highbrix.html>). Based on the refractive index of crop juices (RICJ), the brix reading of 'Paete' lanzones ranging from 17-25 is

considered excellent. This indicates that the crop with the higher RICJ normally has a higher sugar content, higher mineral/nutrient content, among others (<http://www.highbrixgardens.com/highbrix/highbrix.html>). This adds up to a sweeter tasting, more mineral-rich nutritious fruit with lower nitrate and water content, lower freezing point and better storage attributes. Hence, results of the brix reading of lanzones fruits from five fertilizer treatments revealed that among these treatments, the FC-1 applied lanzones fruits had the highest fruit quality (in terms of fruit sweetness), albeit its low annual rate of inorganic fertilizer application (and without organic fertilizer application). Higher rates of inorganic fertilizer tended to reduce the sugar content in lanzones fruits. These results clearly indicate that the multi-nutrient fertilizer applied: 14-5-20- 0.02 (B) with 15.5% Cl and 4.5% S enhanced the fruit quality (in terms of sweetness level), favorable in increasing the marketability, price and farmer's net benefit.

E. Effects of ISFM: fertilizer combinations on the profitability indices of the total productivity of coconut + lanzones agro-ecosystem

To determine the overall effect of fertilizer applications (5 FCs) on the productivity and profitability coconut + lanzones cropping system, an economic analysis of this cropping system was done for the whole duration of the study (15 years, 1993-2007).

Based on the assumptions of inputs and prices indicated in Annex Table 1, the productivity indices such as gross returns, production costs, net returns, net present return value (NPV), benefit-cost ratio (BCR) and internal rate of return (IRR) were computed for the five ISFM fertilizer treatments (FCs). For this presentation the calculations was limited the lowest prices and at 18% interest to capital are showed (Annex Table 2).

The profitability indices as the benefit cost ratio (BCR) and the internal rate of return (IRR) showed that: the lower the rate of fertilizer combinations like FC-1 and FC-2 applications,

the higher is the BCR and IRR indices obtained (Annex Table 3). Moreover, it indicated that the most profitable fertilizer treatments for both crops for the duration of 15 years was that of the fertilizer combination (FC-1), the lowest application rate (per tree) of 1.0 kg 14-5-20-0.02(B) for coconut and 0.38 kg/tree for lanzones at zero organic fertilizer (OF) applications (both coconut and lanzones crops), generated the highest BCR of 2.5 and IRR of 328% as compared to BCRs 2.2 - 1.41 and IRRs of 238% - 53% under the FC-2 to FC-5 applications, with moderate and high rates of IFs with OFs, respectively (Annex Table 3). In simple terms, this means that for every PhP1.00 investment, the farmer in return gets PhP2.50 by using only the lowest rate of inorganic fertilizer (14-5-20, w/ 0.02% B, 15.5% Cl and 4.5% S) w/o organic fertilizer application. This FC-1 is the most profitable compared fertilizer combinations with both IF and OF as the FC-2 to FC-5 and other FCs, supplying increasing rates of IFs and Of.

The NPV is a way of comparing the value of money now with the value of money in the future taking inflation and returns into account. It is the difference between the present value of cash inflows and present value of cash outflows (<http://www.investopedia.com/terms/n/npv.asp>). It is used in capital budgeting to analyze the profitability of an investment or project. Thus, if NPV is negative, the project should be rejected because cash flows will also be negative. If NPV is positive and high, the project is highly profitable as in the case of coconut + lanzones agro-ecosystem with FC 1 treatment. On the other hand, the benefit cost ratio is the ratio of the benefits of a project, expressed in monetary terms, relative to its costs, also express in monetary terms. (http://en.wikipedia.org/wiki/Benefit-cost_ratio). ABCR value of 1.0 means that for every peso invested, there is one peso profit, hence the higher the value of BCR (> 1) the more profitable is the project, as in this CBFS project. Another economic index, the internal rate of return is the discount rate and),

Table 7. Yield and growth indices of lanzones fruit tree intercrop, PCA-DRC, 2003

TREATMENT	Ave. Weight of one fruit (g)	Length of Peduncle (cm)	No. of fruits Per Bunch	No. of Bunches/tree	Yield of fruits per tree (kg)	Yield of fruits per ha (kg)
FC-1 (1+0)	8.9	11.8	14.6	63.1	8.1	1,642
FC-2 (1+2)	8.6	11.5	14.5	32.8	4.1	1,454
FC-3 (2+4)	9.5	11.9	14.6	40.6	5.7	2,580
FC-4 (4+2)	9.0	13.2	14.3	41.8	5.4	1759.0
FC-5 (4+4)	9.8	11.7	15.1	30.4	4.6	1407.0
Stat. sign.	ns	ns	ns	ns	ns	
C.V. (%)	12.8	8.4	7.2	72.0	66.8	

Table 8. Yearly lanzone yield data (kg/ha¹) under 'LAGT' coconut palms as affected by fertilizer combinations, PCA-DRC, 2001-2007. (Note: almost nil yield in 2004)

	2001	2002	2003	2005	2006	2007
FC 1 (1+0)	422	1,939	1,642	10,037	755	15,008
FC 2 (1+2)	657	1,941	1,454	8,723	610	9,990
FC 3 (2+4)	281	2,353	2,580	9,474	844	11,448
FC 4 (4+2)	422	2,780	1,759	8,114	1,051	11,589
FC 5 (4+4)	94	2,383	1,407	6,612	352	9,896

¹ at 469 lanzones trees per ha

Table 9. Yield character of lanzones fruits as affected by different fertilizer combinations, PCA-DRC, 2005

Factor (A) (B)	Peduncle Length (cm)	Fruits/Bunch (no.)	Bunch/Tree (no.)	Lanzones Wt Per tree (kg)
FC1 + Zn	15.3	15.7	203.6	21.9
- Zn	15.5	16.8	216.9	20.8
FC2 + Zn	13.8	14.8	228.3	19.5
- Zn	14.1	14.5	206.1	17.7
FC3 + Zn	14.8	16.3	211.9	19.4
- Zn	14.8	14.8	220.9	21.0
FC4 + Zn	14.7	14.4	178.7	18.0
- Zn	14.8	14.9	193.6	16.6
FC5 + Zn	14.3	14.9	151.7	13.5
- Zn	14.6	16.3	144.9	14.6
Stat. sign. (A)	ns	ns	ns	ns
(B)	ns	ns	ns	ns
C.V. (%) (A)	5.3	8.0	53.2	59.1
(B)	4.5	9.4	13.0	18.1
Trmt. Means				
FC1	15.4	16.2	210.3	21.4
FC2	13.9	14.7	217.2	18.6
FC3	14.8	15.6	216.4	20.2
FC4	14.8	14.7	186.2	17.3
FC5	14.5	15.6	148.3	14.1
+ Zn	15.2	15.2	194.8	18.5
- Zn	14.5	15.5	196.5	18.1

Table 10. Fruit yield and quality attributes of 'Paete' lanzones intercrop as affected by fertilizer treatments at PCA-DRC, September, 2007

Fertilizer Comb. (FC)	Weight of lanzones fruit per tree (kg)	Weight of lanzones per fruit (g)	Length of Peduncle (cm)	Sweetness Index* (°Brix)
IF ^a OF ^b				
FC-1 1 0	32.0	11.8	15.7	25.7
FC-2 1 2	21.3	11.5	15.2	25.3
FC-3 2 4	24.4	11.8	15.3	25.3
FC-4 4 2	24.7	13.2	17.7	24.8
FC-5 4 4	21.1	12.1	16.0	25.2
Stat. sign.	ns	ns	ns	ns**
C.V. (%)	28.8	7.7	3.3	

a-First number refers to the level of inorganic fertilizer (NPK 14-5-20 (0.38-1.50 kg)

b-Second number refers to the level of organic fertilizer

* Taken from ten fruits sample/tree at 10 trees/fertilizer treatment using a refractometer

** Using t-test, no significant different between 2 treatments at a time was noted.

Table 11. Effect of fertilizer treatments on the sweetness of "Paete" lanzones fruits (in °brix reading), PCA-DRC

Factor		Sugar content (° brix)	
(A)	(B)	2005	2007
FC-1	+Zn	18.3	
	- Zn	17.8	
FC-2	+Zn	18.1	
	-Zn	17.6	
FC-3	+Zn	17.7	
	-Zn	17.0	
FC-4	+Zn	17.9	
	- Zn	17.8	
FC-5	+Zn	17.2	
	-Zn	18.1	
Stat. sign.	(A)	ns	
	(B)	ns	
C.V. %	(A)	4.2	
	(B)	5.7	
Trmt. Means			
FC-1		18.1	25.74*
FC-2		17.9	25.3
FC-3		17.4	25.3
FC-4		17.9	24.8
FC-5		17.7	25.2
	+Zn	17.8	
	- Zn	17.7	

*Using t-test, no significant difference between two treatments at a tie was observed.

results in a net present value of zero for a series of future cash flows (http://www.valuebasedmanagement.net/methods_irr.html)

Moreover, for the coconut + lanzones fruit tree agro-ecosystem, at 18% interest of capital and product farmgate prices of PhP 21/kg copra and PhP 10/kg lanzones fruit, the NPV for the FC-1 and FC-2 were PhP 115,645 and 115,947, respectively, and total net returns in 2007 of PhP 212,227 (highest) and 173,058, respectively. Obviously, if the lanzones fruit price is doubled (PhP 20/kg), assuming all other conditions remains the same, this agro-ecosystem NPV, BCR, IRR, Total Net Returns

(coconut + lanzones), and Net Returns from lanzones fruit tree should increase by at least 50% with the best ISFM option (FC-1).

In this long-term ISFM study under the coconut + lanzones fruit tree agro-ecosystem, the lack of a clear direct positive response to application of organic fertilizer sources does not mean that there was no addition of plant-based organic materials/fertilizers as the organic matter and nutrient supply generated by the biomass from the coconut and lanzones agro-ecosystem had been likely substantial. Hence, under an ISFM of coconut-based farming system, the capability of the component intercrop (s) as the lanzones fruit tree in this long-term cropping should not be ignored, rather considered a significant source of valuable organic fertilizer inputs from the decomposition of litters and other crop residues inherent in the coconut + lanzones fruit tree agro-ecosystem for a profitable and sustainable farming.

Conclusion and recommendation

1. Results of this long-term integrated soil fertility management (ISFM) efforts involving the application of different combinations (FCs) of inorganic (IF) and organic (OF) fertilizers, specifically, respectively as the blended and/or commercial multi-nutrient fertilizer (MNF): N-P-K-Cl-S-B inorganic/mineral fertilizer grade 14-5-20-0.02(B) with 15.5% Cl and 4.5% S and the organic fertilizers (commercial and/or coconut husks) at different proportions on a coconut + lanzones cropping system revealed an appreciable early and long-term effects of fertilizer treatments on coconut yield, vegetative growth and fruit yield of lanzones intercrop, and soil fertility levels.
2. From the benchmark annual yield (pre-fertilizer application) of bearig stands of the Laguna Tall variety of 1.4 - 1.8 t copra / ha it increased to 3 - 4 tons after

E. A recommended guide on the ISFM: average fertilization of coconut + lanzones agro-ecosystem (based on findings of this 15 years work at PCA-DRC)

Component Crop/Stage	Inorganic Fertilizer (IF) ¹		Organic Fertilizer (OF)		Timing of application
	Grade/Kind	Rate/tree	Kind	Rate/tree	
Nut-bearing Coconut:					
Year 1	NPK 14-5-20 (w/ Cl, S, B)	2-3 kg	(DCM/BOF) ³	5 -7 kg	Start of rains
Year 2	NPK 14-5-20	2 kg	-ditto-	-ditto-	-ditto-
Year 3 and onwards	NPK 14-5-20	1 kg	Optional	Optional	Optional
Lanzones Crop:					
Establishment time (field-planting or FP)	NPK 16-20-0	50 g	DCM/BOF	250 g	Start of rains
6 months	NPK 16-20-0	75 g	-ditto-	400 g	Moist soil
Vegetative to pre-flowering¹:					
1 yr	NPK 14-14-14	400 g	-ditto-	500 g	Split
2 yrs	-ditto-	500 g	-ditto-	700 g	Split
3 yrs	-ditto-	500 g	-ditto-	700 g	Split
4 yrs	NPK 14-5-20	500 g	-ditto-	700 g	Split
5 yrs	-ditto-	500 g	-ditto-	1000 g	Split
6 yrs	-ditto-	500 g	-ditto-	1000 g	Split
Fruiting²:					
7 yrs	NPK 14-5-20	600 g	-ditto-	0	Split
8 - 10 yrs and onwards	NPK 14-5-20	750 g	-ditto-	0	Split

¹ first ½ of fertilizer rate at onset of rainy season and remaining half at 1 -1.5 months before start of dry season; for areas with good distribution or spread of rainfall and no distinct dry season (short dry season), apply anytime during the year (avoid applying during strong rains).

² first ½ of fertilizer rate 2-3 weeks after the annual final harvest, then, remaining ½ few weeks after fruit-set or mid period between fruit-set and fruit maturity (about 2-5 months before harvest, depending on the soil fertility level, meaning if general stand of fruiting trees is good (or above average performance), the last ½ of fertilizer rate better applied at mid-maturity (half-way) of fruits.

³ DCM – dried chicken manure; BOF – commercial or farm-based composted bioorganic fertilizers.

- 1-2 years from initial fertilizer application and remained at this level in the next 13 years at stable yields of 4 t /ha. The non-significant difference in nut and copra yields of fertilizer combinations (FC's) in almost all years indicates that even with the application of FC-1 (one kg of inorganic fertilizer (MNF), with no organic fertilizer) or the lowest rate of the MNF without organic fertilizer, annual yield over 3.5 tons copra per ha (or over 125 nuts per tree) was produced in most of cropping years.
3. Under the subject agro-ecosystem, the application of some fertilizer combinations enhanced the fruiting of lanzones on the 8th year (2001) from field-planting. Except in 2004 where there was no economic yield, fruit harvest of lanzones increased from the 8th year to the 15th year with FC -1 and FC-2 producing the higher yields than FC-3, FC-4 and FC-5 fertilization. Furthermore, the quality of lanzones fruits in terms of its sweetness (in brix reading or sweetness level) was enhanced with lower rates of inorganic and organic fertilizers. This clearly indicates that the lower rates of inorganic fertilizer and organic fertilizers were already adequate to provide a sustainable coconut + lanzones farming system possibly due to the massive crop-based organic materials (litters from lanzones and coconut farm waste materials) and the very active nutrient recycling of the agro-ecosystem.
 4. The improvement of coconut yield and highly productive lanzones fruiting stage in this cropping system could be due to the significant effect of fertilizer combinations on some important leaf nutrients such as N, P, K, Ca, Cl and B. On the other hand, the non-significant effect of zinc (Zn) application on the vegetative growth and yield of lanzones suggests that the soil of the study area had adequate or sufficient supply of micronutrient Zn during the cropping years.
 5. The fertilizer treatments did not produce significant effect on the chemical soil properties near coconut rhizosphere but affected significantly top- and sub-soils near lanzones rhizosphere. Fertilizer treatments with organic fertilizer appeared to increase level of soil organic matter, % base saturation and exchangeable bases e.g. Ca, Mg. The long term effect of organic fertilization have contributed to the better physical (bulk density) and better soil properties of lanzones soil environment.
 6. Considering the over-all years of the agro-ecosystem of coconut + lanzones cropping, the profitability indices such as benefit cost ratio (BCR) and internal rate of return (IRR) showed that the best profitable fertilizer treatment for both crops was the fertilizer combination (FC-1) at lowest annual rate of 1.0 kg/tree for coconut and 0.38 kg/tree for lanzones (at zero organic fertilizer application) as it produced the highest BCR (2.5) and IRR (328%) -Annex Table 3 as compared to 2.2 - 1.42 BCR and 238 - 53% IRR for fertilizer combinations FC-2 to FC-5, respectively (Annex Table 3)..
 7. In the final cropping year of 2007 of this 15-year long-term cropping with the use of the pre-formulated 14-5-20-0.02 (B) inorganic fertilizer alone as the fertilizer FC-1 (1 kg IF w/o OF) achieved an impressive economic benefit---net returns (NR): on coconut - PhP 67,000 + lanzones fruits - PhP145, 000 or a total NR of PhP 212, 200 per ha at a total cost of only PhP 26,010 per ha. At 18% interest and farm gate prices of PhP 5-21/kg copra (coconut) and PhP 10/kg lanzones fruit, an NPV of PhP115,645 per ha for the long-term cropping period (lanzones started from field-planting under bearing stands of coconut). If farmgate price of the lanzones fruits is doubled, assuming all other conditions same, all

profitability indices are expected to at least increase by 50%.

8. Hence, this long-term coconut + lanzones cropping agro-ecosystem proved to be a sustainable farming system. With proper integrated soil fertility management (ISFM) as a major component of the integrated crop management (ICM) using crop specific fertilizer as the PCA formulated multi-nutrient 14-5-20-0.02B even at the lowest rate of fertilization which contributed to stable soils contributing to the high total productivity levels of coconut lands.
9. It may be noted that for the first time, the ecological and economic contributions of a fruit tree represented by the lanzones intercrop serves as an indirect source of organic fertilizers thru the agro-ecosystem had been shown in this long-term study. Moreover, findings of this long-term study opened the need to conduct further studies in understanding the quality and quantity of the recyclable biomass and available recyclable macro- and micro-nutrients generated in the widely practiced coconut + lanzones agro-ecosystem as an important aspects of ISFM (or integrated nutrient management) of integrated crop management (ICM) to optimize productivity and conserve our farmlands.

Acknowledgement

The researchers and authors of this completed R &D wish to express their profound gratitude to the following:

- 1) The PCA Management, particularly the Office of Deputy Administrator, Research, Development and Extension Branch (RDEB) Carlos B. Carpio for the logistical and moral support to this long term project;
- 2) The ATLAS Fertilizer and Chemicals, Inc. (AFCI) Management for the commercial production of the PCA pre-formulated crop-specific multi-nutrient

fertilizer grade 14-5-20 (w/ 0.02% B, 15.5% Cl, 4.5% S) under the brand *CocoGro*, and providing this fertilizer grade starting 2004 for project use and substantial financial support for leaf and soil analyses;

- 3) The FERCHEMEX Company for providing the required early years commercial organic fertilizer (1993-1998) and the inorganic/mineral fertilizer materials (NH₄Cl, KCl, Rock Phosphate, Gypsum, ZnSO₄ and borax) for the physically-blended 14-5-20-15.5 (Cl) - 4.5 (S)-0.02 (B) inorganic fertilizer (IF) used for the different FCs;
- 4) The PCA-Davao Research Center (DRC) Management for their consistent support, most especially to: (1) Ms. Marianita N. Eroy, Science Research Specialist II and Officer-in-Charge, Agronomy & Soils Division (ASD) for her valuable support and guidance; and (2) Dr. Liberty H. Canja, Sc. Research Specialist II, ASD for contributing her valuable expertise and assistance in the economic analysis of the coconut + lanzones fruit tree agro-ecosystem;
- 5) Ms. Carmelita D. Pabustan, Division Chief III, Plant and Soil Analysis Division-Plant Tissue Analysis Laboratory (PSAD-PTAL), PCA and her staff for the intensive and extensive leaf and soil analyses of submitted samples;
- 6) Mr. Edilberto G. Cuison, Utility Worker, and Mr. Salvador C. Abendan, Laboratory Aide, ASD and their support labor force for their extensive assistance covering all the vital experimental field and laboratory activities;
- 7) Ms. Maricel D.M. Francisco, Secretary, Office of the Manager, Agricultural Research Management Department, RDEB, for her dedicated assistance in the final computer lay-outing of this report presentation; and

8. Finally, to Dr. (Mrs) C. Jayasekera, Director, CRI-Sri Lanka, for sharing her valuable time and comments in the review to improve the technical and scientific contents of our paper which is hoped to reach as many people possible.
9. Above all, to our Almighty Father God for blessing this original work and giving us wisdom and strength to undertake this 15-year long-term study so that we may be able to generate meaningful research findings for the *social, ecological and economic benefits* of the coconut farmers in particular and other sectors of the local and global Coconut Industries.

References

- Magat, S.S. 1976. Soil and Leaf Analyses in relation to coconut yield. *Phil. J. Coconut Studies* 1(2): 1-12.
- Magat, S.S. 1990. Growing conditions and growth habits of coconut in relation to coconut-based farming systems. Pp.17-40. In: *Coconut Based Farming Systems*, S. de Silva (ed.). Jakarta, Indonesia: Asian and Pacific Coconut Community. 606 p.
- Magat, S.S. 2007. A field guide: estimating the yield of coconuts, soil sampling and leaf sampling. Diliman, Quezon City: Agricultural Research Management Department. RDEB, Philippine Coconut Authority. 12 p.
- Magat, S.S. 2005. Crop Nutrition and Fertilization Management of Selected Tropical Fruit Crops. Los Banos, Laguna. 228 p.
- Magat, S. S., J. Habana, A.G. Labarcon and L.B. Froilan. 1981. Mineral nutrition (leaf) survey of coconut in the Philippines. I. Nutritional deficiency and fertilization. PCA-ARB, Diliman, Quezon City.
- Magat, S.S. and K. M. Goh. 1988. Effects of chloride fertilizers on yield and uptake of chloride, potassium and sodium by fodder beet (*Beta vulgaris* L.) in two New Zealand soils. *Journal of Agriculture Science, Camb.* 111:207-216.
- Magat, S.S. 1996. Notes on Mineral Nutrition of Coconuts: role of Nutrients, Its Deficiency Symptoms and Nutrient Needs. Technology Notes produced by CANFARMS, Agric. R & D Branch. PCA-Diliman, Quezon City.
- Magat, S.S. 1997. Coconut yield improvement in farmers' fields through research-based fertilization management in the Philippines. *CORD J.* 8(2): 1-25.
- Margate, R. and S. S. Magat.1991. Research guide on the conduct of Agronomic and Nutrition Studies in Coconut. Book Series No. 119/1991. Published by PCARRD-DOST and Rainfed Resources Development Project. Govt. of Phil. & United States Agency for international Development.
- Raquepo, M.C.M. and Pabustan, C.D. 2003. A Summary of Analytical Methods for Plant, Soil, Fertilizer and Water: A Quick Reference. Diliman, Quezon City: Plant and Soils Analysis Division, Research, Development and Extension Branch, Philippine Coconut Authority. 18p.
- Secretaria, M.I. and J.N. Maravilla. 1997. Response of hybrid coconut palms to application of manures and fertilizers from field to full bearing stage. *Plantations, recherché, développement Journal.* 4 (2):126-135.

Annex Table 1. Assumption for cost and return analysis for coconut + lanzones cropping system, PCA-DRC, 1993 - 2007

YEAR	Lanzones price at 10% increase				Copra price at 10% increase				50 kg/ bag	50 kg/ bag	50 kg/ bag	50 kg/ bag	25 kg/ bag	25 kg/ bag	50 kg/ bag	25 kg/ bag	PER 1000 NUTS		
	P1	P2	P3	P4	P1	P2	P3	P4	AC	ROCK PO4	KCl	GYPSUM	BORAX	ZnSO4	BIOGRO	COCOGRO	Wage rate	Dehusking	Copra Making
1993	0.0	0.0	0.0	0.0	5.5	6.6	7.9	9.5	8.1	16.3	5.30	3.0	29.2	38.4	6.00		90	80	120
1994	0.0	0.0	0.0	0.0	7.5	9.0	10.8	13.0	8.2	16.3	5.04	3.0	29.5	38.8	6.30		90	80	120
1995	0.0	0.0	0.0	0.0	7.3	8.8	10.5	12.6	8.2	16.3	5.19	3.0	29.8	39.1	6.30		90	80	120
1996	0.0	0.0	0.0	0.0	9.3	11.2	13.4	16.1	8.3	17.1	5.60	3.2	30.1	39.5	6.62		90	80	120
1997	0.0	0.0	0.0	0.0	11.2	13.5	16.1	19.4	8.4	17.1	4.91	3.2	30.4	39.9	6.62		90	80	120
1998	0.0	0.0	0.0	0.0	15.7	18.9	22.6	27.1	8.5	17.1	6.81	3.2	30.7	40.3	6.62		90	90	132
1999	0.0	0.0	0.0	0.0	18.4	22.1	26.5	31.8	8.6	17.1	7.15	3.2	31.1	40.8	6.62		90	90	132
2000	0.0	0.0	0.0	0.0	10.4	12.5	15.0	18.0	8.7	17.1	7.58	3.2	31.4	41.2	6.62		150	90	132
2001	10.0	12.0	14.4	17.3	6.2	7.4	8.9	10.7	8.8	18.1	8.69	3.3	15.8	41.6	6.95		150	90	132
2002	10.0	12.0	14.4	17.3	11.6	13.9	16.7	20.1	8.8	18.1	9.21	3.3	32.0	42.0	6.95		150	90	132
2003	10.0	12.0	14.4	17.3	12.4	14.9	17.9	21.4	8.9	18.1	9.91	3.3	32.3	42.4	6.95		150	100	145
2004	10.0	12.0	14.4	17.3	19.3	23.2	27.8	33.4								24.89	185	100	145
2005	10.0	12.0	14.4	17.3	16.3	19.6	23.5	28.2								24.89	185	100	145
2006	10.0	12.0	14.4	17.3	15.0	18.0	21.7	26.0								24.89	185	100	145
2007	10.0	12.0	14.4	17.3	21.0	25.2	30.2	36.3								24.89	185	100	145

Assumptions: Coconut-based on "A Coconut Production Guide for use of different fertilizer combinations" by S.S. Magat, M.N. Eroy and M.I. Secretaria (2005) Lanzones-based on Davao National Crop Research & Development Center Information Service (DIS) Technoguide Series 2003 on Lanzones Production

Daily wage rate = Php 150.00
 Ringweeding (coconut)-man-days/yr = 27 md
 Fert. Application (coconut)-man-days/yr = 4 md
 Fert. Applications (lanzones)-man-days/yr = 2 md (based on actual practice at DRC)
 Harvesting = Php 3.30/tree, 6 x/yr
 Piling & hauling = 2 md, 6 x/yr
 Copra making (splitting, scooping, drying, sacking)
 Planting density: coconut = 156/ha, lanzones = 469/ha.

Annex Table 2. Cost and return analysis of coconut + lanzones cropping system, @ Price level 1^a, PCA-DRC, cropping 1993 - 2007

FC (t+0)	*	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Gross Returns																
	Coconut	7,700.00	27,000.00	24,820.00	91,620.00	36,116.62	97,705.85	95,005.91	47,896.62	21,012.00	47,601.00	49,400.00	65,756.00	57,155.00	48,128.00	88,158.00
	Lanzones	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4,220.00	19,385.00	16,420.00	0.00	100,370.00	7,550.00	150,080.00
	TOTAL	7,700.00	27,000.00	24,820.00	91,620.00	36,116.62	97,705.85	95,005.91	47,896.62	25,232.00	66,986.00	65,820.00	65,756.00	157,525.00	55,678.00	238,238.00
Production Cost																
	Coconut	10,864.66515	12,376.17408	15,881.76536	12,292.20719	12,157.65667	11,990.92333	11,224.83228	16,121.08189	15,232.70046	15,974.71825	15,777.64732	19,667.71400	19,946.91600	19,712.53000	20,970.75200
	Lanzones	769.500536	960.895793	1,378.192895	1,423.205956	1,209.218499	1,632.725782	532.9576679	670.481127	1,712.552134	1,741.977852	1,774.989286	4,805.8938	4,805.8938	5,039.364	5,039.364
	TOTAL	11,634.17	13,337.07	17,259.96	13,715.41	13,346.88	13,623.65	11,757.79	16,791.56	16,945.25	17,716.70	17,552.64	24,473.61	24,752.81	24,751.89	26,010.12
Net Returns																
	Coconut	-3,164.67	14,623.83	8,938.23	19,327.79	25,978.96	25,754.92	23,780.47	31,775.53	5,779.30	31,626.28	27,622.35	46,088.29	37,208.08	28,415.47	67,187.25
	Lanzones	-769.50	-960.90	-1,378.19	-1,423.21	-1,209.22	-1,632.72	-532.96	-670.48	2,507.45	17,648.02	14,645.01	-4,805.90	95,564.10	2,510.64	145,040.64
	TOTAL	-3,934.17	13,662.93	7,560.04	17,904.58	24,769.74	24,102.20	23,247.51	31,105.05	8,286.75	49,269.30	42,267.36	41,282.39	132,772.18	30,926.11	212,227.89

NPV @18 115,645.63

Sum of discounted gross benefit = 192,590.08
 Sum of discounted = 76,944.45
 BCR (18%) = 2.50
 IRR (18%) = 327.58%

^a copra price = Php 5.5/kg - Php 21 (farm gate)
 lanzones fruit price = Php10/kg (farm gate)

Annex Table 3. Economic indices of the production economics of coconut + lanzones agro-ecosystem as affected by different fertilizer treatment at PCA-DRC, 1993 - 2007

Fertilizer Treatment	Net Present Value @18% (Php)	Benefit Cost Ratio @ 18%	Internal Rate of Return @ 18% (%)
FC 1 (1+ 0)	115,645.63	2.50	327.58
FC 2 (1+ 2)	115,947.96	2.21	237.84
FC 3 (2+ 4)	82,822.49	1.67	71.35
FC 4 (4+ 2)	78,389.74	1.59	69.42
FC 5 (4+ 4)	62,522.21	1.42	53.42