EFFECT OF SOME LAND QUALITIES AND SOIL PROPERTIES ON PRODUCTIVITY OF COCONUT IN THE PHILIPPINES[1]

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ABSTRACT

Data on land qualitites (climate, external drainage, slope) and soil properties (texture, solum, depth, bulk density, internal drainage, chemical properties) were subjected to analysis of variance and simple and multiple correlation and regression to determine the relative influence of these parameters on coconut yields. Results showed very pronounced effect of drainage, solum depth and soil series on nut yield. Yield was highest in soil that is well-drained, with at least 80 cm thick of solum, and whose texture is coarse to medium. Similarly, yield was highest also in relatively flat areas and where the climate has only a short dry period. Compaction of the subsoil rather than the topsoil adversely affected yields. Responses of coconut to different levels of nutrients in different sites were variable and appeared to be modified by climate, landform and soil texture. High magnesium-potassium ratio consistently reduced yield regardless of other soil conditions.

INTRODUCTION

The coconut palm (*Cocos nucifera* L.) is found growing in widely diverse soils. In the Philippines, coconut grows in flatlands as well as steep uplands, in coastal areas and far inland, in well-drained and poorly drained soils, in sandy as well as clayey soils, in highly fertile as well as marginal soils and in acidic as well as alkaline soils.

Although coconut survives apparently adverse conditions, productivity is greatly affected. For instance, it is generally observed that the palm grows poorly in poorly drained and in compacted soils. On the other hand, it thrives along sea coasts, in alluvial plains and in coarse to medium-textured soils. The degree by which the different land and soil qualities affect productivity has been the subject of numerous studies but it is likely that a combination of these properties determines the performance of the coconut.

MATERIALS AND METHODS

Land qualities and soil properties of coconut areas including yield data in 58 provinces and cities all over the Philippines were gathered and subjected to analysis of variance and simple and multiple correlation and regression (SAS, General Linear Model).

Most of the raw data were taken from results of the survey in 1974-1980 by the Philippine Coconut Authority (PCA) of 1,131 sites in the country. These were supplemented with data from the data bank of the Department of Soil Science at UPLB, the Bureau of Soils and PAG-ASA. Yields were estimated by PCA from Laguna tall (Typica) variety of about the same age.

Statistical analysis were done on whole data sets of 1,131 sites and on data grouped according to climate type, landform and soil texture. Regression curves were tested for best fit for linear, quadratic and log-normal models.

RESULTS AND DISCUSSION

Effects of Land Qualities.

Climate. The results of correlation studies between rainfall and nut yields were not conclusive but nut yields tended to be higher in areas under climate type 3. This climate is an intermediate type with no pronounced maximum rain period and with a short dry season of one to three months only. In upland areas, the yields were positively correlated with the amount of rainfall during the first six months of the previous year. Yields also increased significantly with increasing number of rainy days during the preceeding year.

According to the report of the United Coconut Association of the Philippines (UCAP, 1979) the ideal rainfall level for coconut growing is 125 mm to 192 mm per month. The country's rainfall level does not depart very much from the ideal range, having a normal level of 218 mm. During the period of 1968-78 the Philippines' rainfall level exceeded the upper limit of 192 mm only 10% of the time. Distribution of rainfall matters more than the total amount that falls during the year. The UCAP report (1979) indicates that coconut will not suffer from drought with a rainfall of 1500 mm per year (125 mm/month) more or less evenly distributed. Palms will tolerate only three conservative months of this level of rainfall. In his study of crop occurrence according to coronas climatic types, Philipson et al., (1972) found that

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[1]Portion of the senior author's Ph.D. dissertation, University of the Philippines at Los Baños, College, Laguna. This article is reprinted with permission from the Philippine Journal of Crop Science, 1983, 8(3): 153-158.

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coconut in the different regions of the Philippines predominates as a primary crop wherever the area has no dry season or where only short dry periods occur. One of the early studies to relate coconut yields with rainfall was done by Balasubramanian (1956) in Madras State. Correlations were made between yields and rainfall for 29-year records. His study showed that rainfall affects coconut yields in particular months of the year and there is also an interaction with the type of soil.

The average nut yield in coastal flatlands were significantly higher (40.2 nuts/tree/year) than those in other land forms (Table 1) This supports the worldwide observation of better performance of coconuts in coastal areas. The lowest mean yield of 33.9 nuts/tree/year was obtained in inland upland areas. However, the average nut yields between inland flat and coastal upland were not significantly different. In other words, the coastal areas are better than those inland (beyond two km of the seashore) only where the coast is flat.

Table 1. Influence of land form on copra and nut yields.

Physiographic Position	N	Mean Yield[1] nuts/tree/year	kg copra/ha/year
Coastal flat	317	40.2a	1,384a
Inland flat	315	37.0b	1,291ab
Coastal upland	236	34.9bc	1,226b
Inland upland	300	33.9c	1,109c

[1]Mean yields followed by the same letter are not significantly different at 5% level.

N = number of observations

Menon and Pandalai (1958) stated that the advantage of coastal areas stems from the more humid and stable temperature in the seacoast. Furthermore, the seacoast is likely more fertile due to the flow of nutrients from the uplands. This partly explains also why the coastal flat rather than coastal upland has the greatest edge over other areas in terms of nut productivity. However, it must be noted that the difference in nut yield between coastal flat and inland flat was only 3 nuts/tree/year. This implies that nearness to shore is not a decided advantage and that inland flat areas are also suitable for the palms.

Copra yields followed the same trend, except that there was no significant difference between coastal flat and inland upland.

Drainage. Significantly higher mean yields were obtained in areas with good external and internal drainage than those which are poorly drained (Tables 2 and 3). The difference between areas with good internal drainage and those which are poorly drained was 6.7 nuts/tree/year or an equivalent of 223 kg copra/ha/year, while that between good external drainage and poor external drainage was 300 kg copra/ha/year. This suggests that both external and internal drainage are nearly equally important to coconut palms.

Table 2. Influence of external drainage on nut and copra yield.

External Drainage	N	Mean Yield[1] nuts/tree/year	kg copra/ha/year
Well-drained	975	46.0a	1,278a
Fairly drained	153	42.7ab	1,187ab
Poorly drained	41	35.2b	978b

[1]Mean yields followed by the same letter are not significantly different at 5% level.

N = number of observations

Table 3. Influence of internal drainage[1] on nut yields.

Internal Drainage	N	Mean yield[2] (nuts/tree/year)	Equivalent nuts/ha/year[3]
Well drained	233	40.8a	6,365
Fairly drained	163	37.1b	5,788
Poorly drained	102	34.1b	5,320

[1]Internal drainage is based on characteristics for the soil series under which the site was classified in the reconnaissance soil survey maps of the Bureau of Soils.

[2]Mean yields followed by the same letter are not significantly different at 5% level.

[3]Based on a population of 156 trees/ha.

The coconut palm is adversely affected by prolonged waterlogging. In Laguna, Celino (1947) observed that coconut leaves were yellowish in waterlogged areas. The soil was shallow and very slowly impermeable to water. Fajardo (1953) noted that the healthy palms in Laguna were those growing in well drained and sandy loam or clay loam soils. Persistent waterlogging usually occurs in bottom lands. Here, the palm is harmed when the water table does not sink at least a foot below the surface within about three weeks of flooding. In other words, temporary stagnation does not harm the roots, but continuous submergence causes them to decay. In a comprehensive study of coconut growing in several countries, Teiwes (1962) concluded that the best soils were light, deep, permeable and well aerated.

Slope. Many coconut plantations in the Philippines are in uplands with slopes ranging from moderate to very steep. However, better yields are generally observed in flat alluvial pans which are well drained. The study showed that higher yields were produced in more level areas than those in steep slopes (Table 4). Plantations with slopes of 0-8% and 8-18% gave mean yields of 46.2 and 41.5 nuts/tree/year, respectively. The difference between the 0-8% and 18-30% slopes was 14.2 nuts/tree/year which is equivalent to 2,130 nuts/ha/

year. The higher yield of relatively flat areas may be attributed to their higher soil fertility and water storage as compared to the uplands.

Table 4. **Influence of land slope on nut yield.**

Slope (%)	Mean yield[1] (nuts/tree/year)
0-8, level to undulating	46.2a
8-18, undulating to rolling	41.5ab
18-30, rolling to hilly	32.0b

[1] Means followed by same letter are not significantly different at 5% level.

Table 5. **Influence of surface soil texture on nut yield.**

Texture Group[1]	Mean yield[2] nuts/tree/year
Coarse	39.1a
Medium	39.9a
Fine	35.9b

[1] Coarse texture: sand, loamy sand, sandy loam;
Medium texture: silt loam, loam
Fine texture: sandy clay loam, clay loam, silty clay loam, sandy clay loam, sandy clay, silty clay, clay.

[2] Mean yields followed by the same letter are not significantly different at 5% level.

Effect of Soil Properties.

Texture. Since coconut grows best in well drained and aerated soils, it follows that relatively coarse and loose soils are best for the palm. In the present study it was found that on the average, higher nut yields are produced in coarse to medium-textured soils than in fine textured soils (Table 5). The difference between coarse and fine-textured soil was four nuts/tree/year. This is equivalent to about 600 nuts/ha/year.

In his study of plantations in Alaminos, Laguna, Carandang (1956) observed that soils in relatively poor yielding areas (50-60 nuts/tree/year) were clayey and that soils in the good area (60-75 nuts/tree/year) were deep, silty clay to silty clay loam and with strongly developed fine sub-angular blocky structure. Cordova (1965) reported that the high yielding areas in Tiaong, Quezon have silt loam soils. In Gumaca, Quezon. Escritor (1954) reported that the good yielding soils were sandy clay loam with clay loam subsoil. In many countries, coconut palms are observed to do best in alluvial soils from river or estuarine deposits high in sand and silt contents.

Soil depth. Regardless of landform (flatland or upland), the lowest yields are produced in areas with only 50 cm thick of topsoil (Table 6). For better yields, the depth of soil solum should be at least 80 cm. A deep soil provides the palm roots more volume for nutrient and water storage and for stronger anchorage of the coconut. Cordova (1965) observed that poor yielding areas of Quezon have less than one meter of top soil whereas the high yielding areas have more than 1.5 meters thick of topsoil.

Table 6. Effect of solum depth on nut yield in flat and upland areas.

Landform/depth (cm)		Mean yield[1] nut/tree/year
Flatland	120	42.2a
	80	50.9a
	50	23.6b
Upland	120	40.8a
	80	42.7a
	50	23.2b

[1] Mean yields followed by the same letter are not significantly different at 5% level.

Bulky density, porosity, field capacity and available moisture. Correlation studies revealed that bulk density of the subsoil was negatively correlated with nut yield (Table 7). There was no correlation between bulk density of topsoil (first foot) and nut-yield. The nut yields increased with increasing porosity of soil. The lower values indicate that other factors exert more dominant effect on yield. Felizardo (1972) observed that mere plowing of the soil produces an increase in nut yields.

Early works do not place much importance on bulk density as a factor affecting growth of coconut palms. The studies of Penaflor (1956) and Carandang (1956) indicated that there is no difference in profile characteristics, moisture equivalent and bulk density of soils between poor and high yielding coconut areas. They noted that root distribution was not affected significantly. On the other hand, Bruce (1956) in his study of coconut areas in Magdalena, Laguna reported that bulk density of poor yielding soils (30-50 nuts/tree/year) was significantly higher than good yielding soils (60-80 nuts/tree/year).

Chemical properties of soil. (a) Soil pH. Coconut grows under a wide range of soil pH. The PCA survey from 1974-80 of more than 1,000 farms nationwide revealed extreme values of soil pH of coconut farms of pH 3.6 to pH 8.7. Coconuts are generally very tolerant of both strongly acid and strongly alkaline soils. Many plantations in tropical Asia are derived from coralline limestone. In Sri-Lanka, most of the coconut soils are acidic but the palms are growing well.

On the other hand, neutral to alkaline pH may be more favorable for coconuts in some cases. These authors observed that nut yield increased substantially as pH increased from less than 5.0 to nearly 8.0 in coastal flatlands where the top-

Table 7. Matrix of correlation (r) among coconut yields and some physical properties of soil (ungrouped data, N = 45-60)[1]

	BD_1	BD_2	PS_1	PS_2	FC_1	FC_2	AM_1	AM_2	Nuts	Copra
BD_1		0.491***	-0.986***	-0.501***	0.443***	0.475***	0.161	0.438***	-0.182	-0.186
BD_2			-0.466***	-0.997***	-0.016	-0.092	0.111	-0.015	-0.314**	-0.238*
PS_1				0.475**	0.475***	-0.434***	-0.130	-0.407***	0.179	0.177
PS_2					0.021	0.091	-0.101	0.009	0.308**	0.237*
FC_1						0.457***	0.847***	0.661***	-0.141	-0.215*
FC_2							0.457***	0.779***	-0.119	-0.158
AM_1								0.625***	0.048	0.014
AM_2									-0.122	-0.122

*** significant at 1% level; ** significant at 5% level; * significant at 1% level.

[1]BD – bulk density; PS – pore space; FC – field capacity; AM – available moisture; 1 – topsoil; 2 – subsoil.

Table 8. Matrix of correlation (r) among coconut yields and nutrient content of coconut leaves (ungrouped data, N = 209).

	N	P	K	Ca	Mg	Na	Cl	S	Nuts	Copra
N		-0.110**	-0.084	0.326***	-0.290***	0.095	0.410***	0.498***	0.240***	0.149**
P			0.359***	0.090	-0.135**	-0.409***	-0.312***	0.167***	0.181***	0.056
K				-0.150**	-0.652***	-0.644***	-0.275***	0.153***	0.153**	0.048
Ca					-0.085	-0.026	-0.236***	0.190***	0.076	0.068
Mg						0.357***	0.122*	-0.348***	-0.189***	-0.130**
Na							0.365***	-0.131**	-0.079	-0.039
Cl								0.049	-0.033	0.166***
S									0.287***	0.220***

* Significant at 10% level; ** Significant at 5% level; *** Significant at 1% level.

soil was coarse-textured and belonged to climate Type 2 (Figure 1).

(b) Nutrient requirements. Correlation between nut yields and leaf composition reveals some interesting aspects of coconut nutrition (Table 8). The data show that N, P, K and S are positively correlated with nut yields while N, Cl and S are positively correlated with copra yields. It appears that Mg is somehow involved in an antagonistic or unbalanced relationship with an important cation namely, K(r = 0.652). Thus, in the study of coconut nutrition, close attention must be given to Mg/K ratio. Figures 2a and 2b show that as Mg/K ratio of subsoil increased, nut yields in coastal and inland flat lands decreased.

Antagonisms and synergisms also exist among nutrients that are essential to coconut. Salgado (1948) pointed out that heavy application of phosphate appears to impair absorption of potash. Experiments in Ceylon indicated that application of Ca as lime induces increased absorption but eventual depletion of K. Experiments in the Ivory Coast showed a strong antagonism that exists between Mg and K which means that a high level of one depresses uptake of the other. From researches in India, it has been suggested that Mg deficiency can occur under continued application of highly refined potash fertilized along with ammonium and Ca salts.

Comparison of yields of palms growing in different soil series showed that the higher yields are produced from San Manuel (Table 9). This soil is a fertile alluvium and one of the most extensive soils in flatlands. The red soils are of low fertility and are strongly acidic. The hydrosols are poorly drained soils.

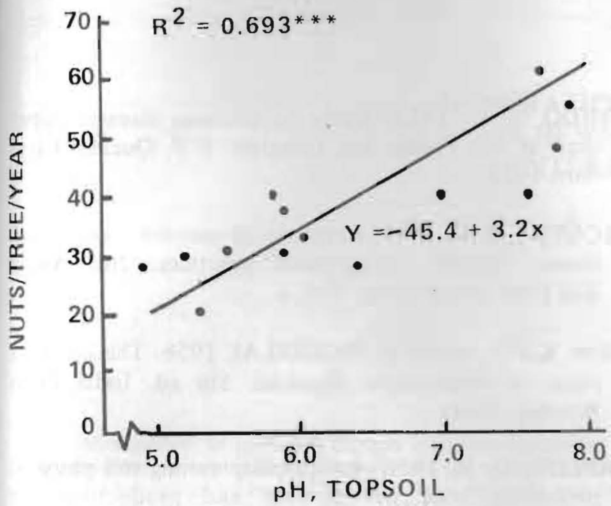

Figure 1. Effect of increasing pH of top soil on nut yield in coastal flatland under climate 2 with coarse-textured topsoil.

Table 9. Differences in average nut yield among some of the most extensive soil series in the Philippines.

Soil series	Total area[1] (ha)	N	Mean yield[2] (Nuts/tree/year)
San Manuel	1,080,726	20	49.2a
Faraon	1,012,836	20	45.5ab
Umingan	207,161	20	41.0abc
Bolinao	843,352	20	39.7abc
Red soils[3]	1,593,057	20	31.8cd
Hydrosols	502,332	20	29.3cd

[1]Total extent of soil nationwide.

[2]Means followed by the same lettar are not significantly different at 5% level.

[3]Luisiana, Antipolo and Adtuyon series (other red soils were not included in analysis).

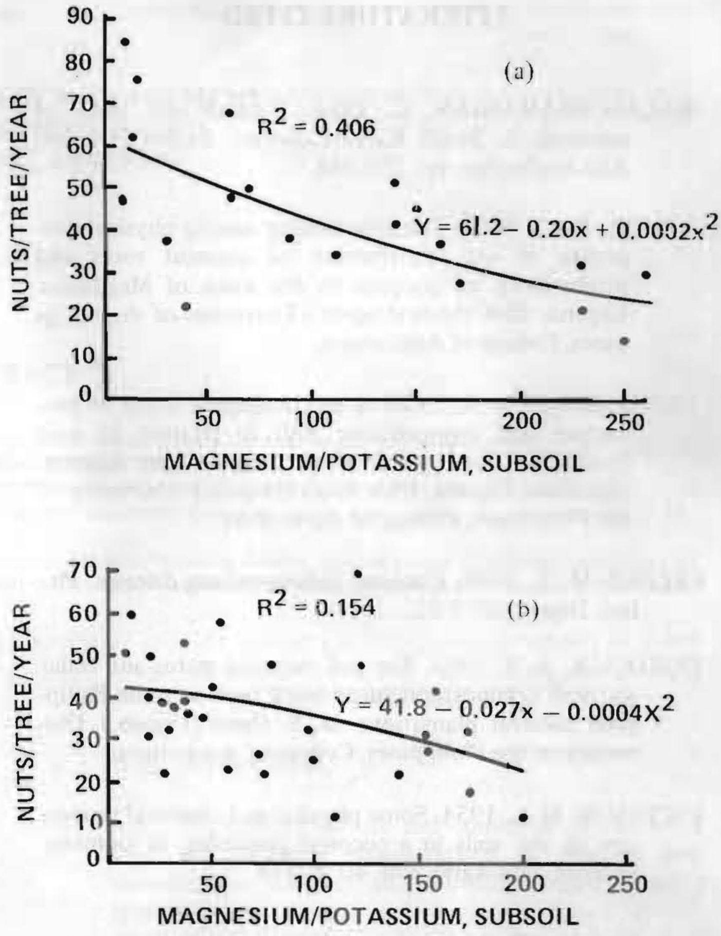

Figure 2. Effect of increasing Mg/K ratio of subsoil on nut yield in (a) coastal flatland (b) inland flatland, under climate 2, with fine-textured topsoil.

CONCLUSIONS

Landform, drainage, depth of soil, slope, bulk density and texture of topsoil were found to exert a significant effect on nut yield. It appears that the best yields are produced in coastal flat areas with coarse textured topsoil under climate 3. The lowest yield were obtained from the uplands with fine textured topsoil under climate 1 (distinct wet and dry season) or climate 2 (no dry season with pronounced three-month rain period).

Based on this study and those done elsewhere the following general conditions may be considered ideal for coconut growing:

1. Climate with more or less uniformly distributed rainfall or short dry season.
2. Landform is coastal flat, or of inland is also relatively flat but well drained.
3. Soil pH is near neutral.
4. Depth of soil solum is at least 80 cm.
5. Soil texture is coarse to medium.
6. There is optimum balance of cations, particularly Mg and K.
7. The soil is sufficiently fertile.

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