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Development of a Sustainable Abaca (*Musa textilis* Née) Production in a Diversified Multi-strata Agroecosystems in Leyte, The Philippines

Master Thesis

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Project on the Utilization of Abaca Fibers in the Automotive Industry

Author's Declaration

To Whom It May Concern:

I, Mr. Marlito M. Bande (Matriculation Number 346861), hereby affirm that I have written this M.Sc. Thesis entitled: **Development of a Sustainable Abaca (*Musa textilis* Née) Production in a Diversified Multi-strata Agroecosystems in Leyte, The Philippines** independently and entirely from my own work.

All the authors in all the publications that are quoted or mentioned in this manuscript have been credited. No piece of work by any person has been included without citing the author.

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Abstract

In the Abaca – Coconut agroecosystem, results show that availability of macronutrients from different blocks demonstrates some degree of spatial variability. This variability can be attributed to the history of land uses and farmer's management practice. On the other hand, it is not enough and safe to conclude that the low nutrient concentration in abaca leaves is due to low nutrient stocks in the soil solution since the standard values for abaca is still unknown. Therefore, under such a system, it can be concluded that the morphological and physiological performance of abaca depends upon on the following factors: a) type of planting materials that exhibit fast recovery of its root system and increase in leaf emergence rate (e.g. tissue cultured seedlings), b) plant nutrition, c) climatic and environmental factors (i.e., strong winds and pests), d) water availability during planting, and e) farm management and practices.

On the other hand, it can be concluded that the trees planted under the Rainforestation concept plays a significant role in the nutrient fluxes and the improvement of soil acidity. This is due to the fact that trees function as "nutrient-pumps". Therefore, integrating abaca under the rainforestation concept is a best option. This may provide additional income to the farmer adopters while maintaining the trees for biological purposes by restoring the functions of an agroecosystem and improving soil quality. However, under such a system, topography is one of the major factors that affect nutrient availability in the soil and plant uptake leading to poor growth performance of abaca. Another factor is wind speed which has a direct impact on the physiological functioning and mechanical damage to the plant.

1. Introduction

Abaca (*Musa textilis* Née) is a plant related to banana, both belonging to the family *Musaceae*. The abaca plant was first described by DON LUIS NÉE (1801) who gave the earliest confirmation that abaca is indigenous to the Philippines. According to TABORA, JR. (1978), the earliest account on the use of abaca was written by PIGAFETTA the Spanish priest who chronicled the voyage of Magellan in 1521, where he observed that the natives were already wearing clothing of abaca material as early as the 16th century. ALZINA in 1668 on the other hand recorded one of the earliest descriptions of the abaca plant, its processing and utilization (TABORA, JR. 1978).

As early as 1825, abaca has been used locally in the Philippines to generate foreign exchange (SEIDENSCHWARZ 1994, ESCANDOR 2001). Lacuna-RICHMAN (2002) wrote that abaca has been a part of traditional agriculture in Southeast Asia, particularly in the Philippines. CAPISTRANO and MARTEN (1986) documented that the plant is grown as a third phase crop in the forest plots, after a slash-and-burn¹ area has become less fertile and unable to produce initial crops of rice (*Oryza sativa*) and maize (*Zea maize*), and after even less demanding second phase crop such as cassava (*Manihot esculenta*) and sweet potato (*Ipomea batatas*).

Abaca rope was one of the major exports of the Philippines since 1825 (TABORA, JR. 1978). This was after the American Navy discovered that abaca was an excellent material for marine cordage (CONSTANTINO 1980). The opening of two ports – one in Legazpi, Albay and another in Tacloban, Leyte – to international shipping in 1873 was another boost to the abaca industry in the Visayas: farmers in Cebu, Samar and Leyte started establishing their abaca farms (CONSTANTINO 1980). On the other hand, Ynchausti y Compañía, a Spanish firm, maintained a rope factory in Balut, Tondo, and got their raw materials from Sorsogon. This started the clearing of virgin forestlands in the province to give way to the abaca plantations (CONSTANTINO 1980). Since 1909,

¹ Also known as *kaingin* or shifting cultivation agriculture. This process is done by clearing a patch of forest of its trees and other vegetation, allowing them to dry before burning, then planting preferred annual crop(s) on the cleared areas (SAJISE 1980 cited by GROETSCHEL 2001)

Americans began to venture into abaca trading and established plantations in Davao. EDWARDS (1945) reported that the Japan also became interested in abaca for its navy, and chose Davao as their plantation site. However, the use of nylon for cordage had greatly reduced the market for this product, to the extent that it had placed the entire abaca industry in danger of collapsing during the 1960s and 1970s (PCARRD 1977). Despite this setback, abaca experienced a revival in the world market when RICHMOND (1907) discovered alternative uses of abaca wastes. These included the processing of abaca for specialty paper, such as those used for condensers, tea and coffee filters, cable insulation, currency, and weatherproof maps and charts (LACUNA-RICHMAN 2002). According to the Philippines' Department of Agriculture – Agribusiness and Marketing Assistance Service (DA-AMAS), abaca pulp was found to be a possible substitute for coniferous pulp paper production at a four to one ratio, making it a viable replacement option for pulp-importing countries such as the Philippines. Presently, the fibre can be used to replace artificial fibres with natural fibres in composite materials in the automobile industry (OLIVER 2004). Abaca handicrafts and textiles on the other hand are potential areas of expansion for the abaca production and processing industry.

DA-AMAS (2002) recorded that the production of the abaca fibre increased at the rate of 2.38% from 1990 to 1999. Eastern Visayas which includes the islands of Leyte, Biliran, Samar and Pana-on supplied the bulk of the product contributing an annual average of 25,239 metric tons or 39% of the total production. Likewise, the average annual growth rate of area devoted to abaca is 1.78%, wherein, Eastern Visayas shared 25% or 26,478 hectares of the total area devoted to abaca.

LACUNA-RICHMAN (2002) revealed that despite the importance of abaca to the national economy, its potential as a source of a higher income to growers while serving as a crop that may actually help in slowing down deforestation, is given little policy attention. As a common component in traditional agroforestry systems in central Philippines, abaca is overlooked, a situation that may be ascribed to what OLOFSON (1983) - as cited by LACUNA-RICHMAN (2002) - describes as the ideological emphasis on 'scientific' experimental agroforestry systems, over seemingly non-scientific forest farming practices.

1.1 Research Area

1.1.1 Geographical Location

Leyte or *Tandaya* in the pre-spanish period, is located in southeastern Visayas approximately between 124°17' and 125°18' east longitude and between 9°55' and 10°48' north latitude (ASIO 1996). It has a total of 799,500 hectares and is the eight biggest island of the Philippine archipelago. It is politically divided into Northern Leyte and Southern Leyte (Figure 1).

The island has a high rugged backbone of mountain, known as the Central cordillera, traversing its axis. Further to the north, the central cordillera is joined by another mountain range which dominates the peninsula of towns of Leyte and Capoocan. The section of the cordillera extending from Capoocan to Baybay is roughly broken by steep slopes which peaks attain heights of 700 to 1,100 m. Southward from Baybay, the central cordillera becomes less steep with lower elevations, and later divides into each of the peninsula of Macrohon and of Calubian at the Southern tip of the island. On the northeastern edge of the island, a range of hills extends from the town of Palo northward to Babatngon. At the northwestern side, another range of hills extends from Merida to San Isidro (BARRERA et al. 1954, YAMBOT 1975 cited by DARGANTES 1996).

The two study sites are located within the municipality of Baybay. The first site (Barangay² Caridad) is about 14 km northeast of Baybay town at an elevation of 122 above mean sea level (amsl) and the second site (Barangay Mailhi) about 23 km southwest of Baybay at 351 amsl elevation (Figure 2).

1.1.2 Geomorphology

According to ASIO (1996), the geomorphology of the island owes its present form to the combined effects of or interactions of endogenic processes such as plate tectonics (and the resulting uplift and faulting) and vulcanism, and exogenic

² Barangay was formerly officially called Barrio and derived from the Malay word Balangay, meaning a type of sailboat. Thus, the word historically refers to small, independent, and 'clannish' settlements established by the Malay ancestors of the Filipinos. Today, the barangay represents the smallest division of self-government. Several barangays make up a town or municipality. Thus they may appear as a town quarter or also as a village (GROETSCHTEL et al 2001)

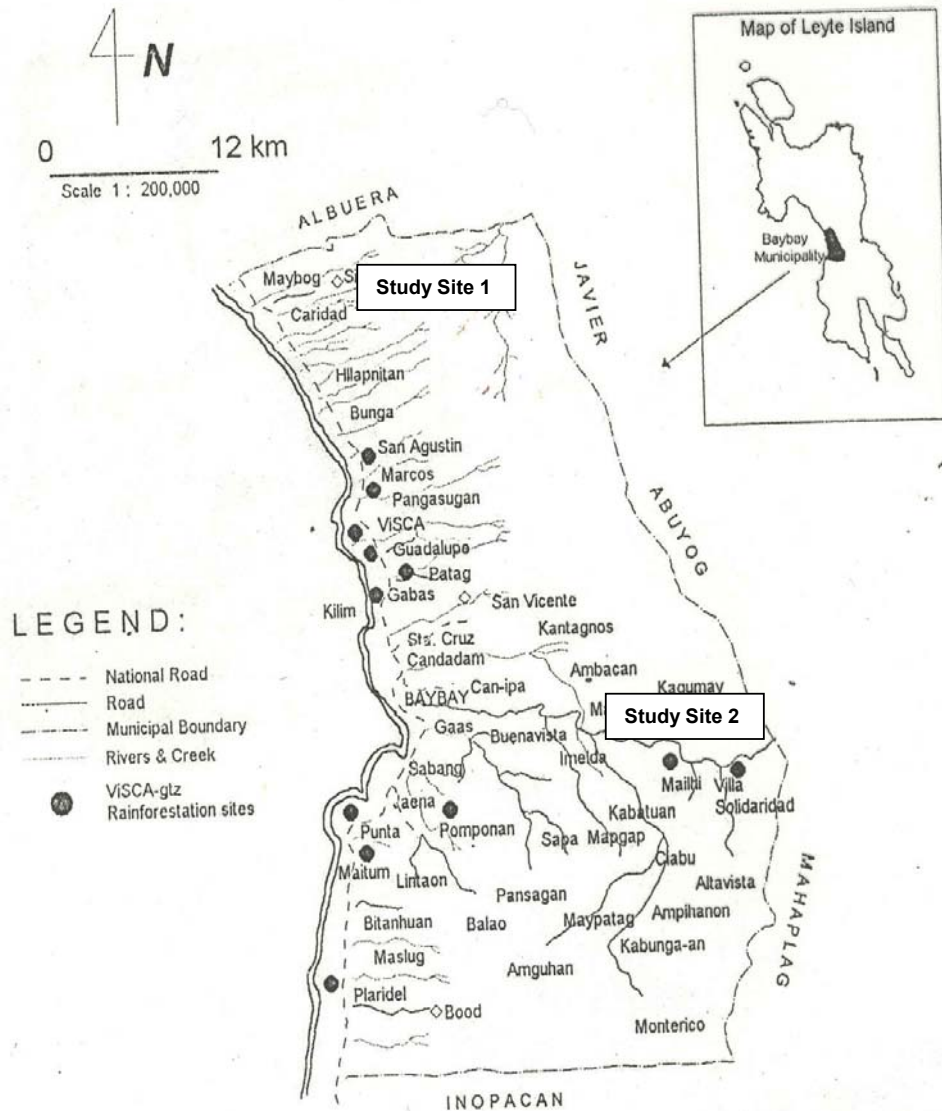


Figure 2. Map of Baybay showing the location of the study site

processes such as weathering, erosion, transport and deposition. Vulcanism, faulting and uplift were probably the major processes which created the mountain range. Vulcanism must have deposited the volcanic materials and the existence of the major fault and its accompanying secondary faults, must have produced the steep and rugged nature of the mountains. ASIO (1996) believes that weathering, erosion, transport and deposition could have played a major role in creating the rivers and streams as well as the alluvial plains.

1.1.3 Climate

The present climate of Leyte is characterized as a humid tropical monsoon climate (tropical rainforest climate, monsoon type after Köppen 1935)(JAHN et al 1995 cited by ASIO 1996). Because of the presence of the high central mountain range, the climate in the eastern part of the island is a little bit different to that in the western part (ASIO 1996). The former has a pronounced maximum rain period with no dry season (Type II in the Corona system)(CORONA 1920 cited by ASIO 1996) while the latter has no pronounced maximum rain period with no dry season (Type IV).

1.1.3.1 Rainfall

According to ASIO (1996), the rainfall distribution generally shows a more pronounced maximum rain period of up to 500 mm per month in the eastern side of Leyte than in its western side with only 300 mm per month. The higher amount of rainfall on the eastern side is influenced by exposure to the trade winds while the western side receives less rainfall due to the deflection of the trade winds (DARGANTES 1996).

Interestingly, the area between Baybay and Ormoc where the research site is located has been reported to receive more rainfall during the months of July and August than the rest of the island (BARRERA et al 1954 AS cited by DARGANTES 1996). Despite annual precipitation totaling to 2620 mm, temporary droughts in Baybay have occurred (BALZER and MARGRAF 1994 cited by GROETSCHERL 2001). According to BALZER and MARGRAF (1994), the temporary drought is attributed to its maximum potential evaporation in May and its minimum in December which leads to a short dry period in May. The average total amount of annual potential evaporation is 1205 mm; thus, the net annual precipitation is only 1415 mm (BALZER and MARGRAF 1994).

1.1.3.2 Temperature

Average temperature in the eastern side of Leyte is a little bit higher than in the western side (ASIO 1996). For the research sites, temperature is rather constant through out the year with a maximum of 28.4 °C in June and its minimum of 26.3 °C in January. The main daily temperature differs only by 2.1 °C throughout the year while the average difference between the daily maximum and minimum temperature is 8.6 °C.

1.1.4 Natural Resources and Land Use on Leyte Island

1.1.4.1 Forest

In the past, forest was one of the most significant natural resources of Leyte Island. According to YAMBOT (1975), in 1972, forest covered 87% of the forestland area but this had decreased to 35% in 1987 with an estimated loss of 242,000 hectares. DARGANTES (1996) estimated that in 1990, forest cover was only 12.1% of the forestland based on the data collated by the Environmental Research Division of Manila Observatory (ERD-MO 1991). GROETSCHERL et al (2001) cited that the main cause of this decline can be attributed to large scale logging operations and the extensive conversion of forest land into agricultural areas, especially into coconut (*Cocos nucifera* L) and abaca plantations.

A national logging ban in 1987 led to gradual withdrawal of the big logging companies and its enforcement in the Leyte Island became more prevalent after the Ormoc disaster in 1991³ (GROETSCHER et al 2001). DARGANTES (1996) reported that today, the main causes for the ongoing forest conversion can basically be attributed to the rampant practice of slash-and-burn cultivation, extending settlement, and to some extent, illegal logging activities.

On the other hand, both research sites were under forest until 1954 as indicated in old land use maps and confirmed by interviews with landowners and farmers cultivating the adjacent land. In both sites, secondary forest still exists.

1.1.4.2 Land use and Land Holdings

The present land use of Leyte is predominantly grassland, scrubland, coconut and abaca in upland areas which were originally under dipterocarp forest and rice in lowland areas (ASIO 1996).

The major crops grown on the island are coconut, rice, abaca, sugarcane (*Saccharum officinale*), banana (*Musa acuminata* Roxb.), sweet potato and maize (BUREAU OF AGRICULTURAL STATISTICS 1998 cited by GROETSCHER et al 2001). In research site 1 (Barangay Caridad), major crops grown are coconut and banana. Research site 2 (Barangay Mailhi), on the other hand, is devoted to rainforestation farming⁴ with patches of coconut, banana and cassava.

According to GROETSCHER et al (2001), the majority of Leyte's farmers have land holdings of less than 1 to 5 ha tilled land. A census of the Bureau of Agricultural Statistics (BAS) from 1991 showed that 93% of the farms in Leyte Province belong to this cluster, covering 62% of the total farm area. In Southern Leyte, 92% of all farms range from less than 1 to 5 ha in size. This cover 71% of the total farmland.

1.1.5 Demographic and Economic Conditions

1.1.5.1 Population

The National Statistics Office (NSO) Census of 2000 indicated that the Leyte Province's population was registered at 1,572,472 while Southern Leyte has a population of 358,446. According to GROETSCHER et al (2001), population growth rates from 1995 to 2000 were about 0.8% in Leyte Province and 2.63% in Southern Leyte. Moreover, the number of households for Leyte Province and Southern Leyte, as of the 2000 census, were 318,303 and 72,625, respectively. This indicates an average household size of 5.01 persons in Leyte Province and 4.8 persons in Southern Leyte.

1.1.5.2 Economic Conditions

³ In November 5, 1991 heavy rainfalls caused the flooding of parts of Ormoc City and 8000 people lost their lives. This catastrophe turned official attention towards the tremendous problems caused by deforestation and necessity of watershed protection.

⁴ Rainforestation farming is a reforestation strategy using native or indigenous forest and fruit tree species developed under the Applied Tropical Ecology Program. The program was a cooperation between the German Agency for Technical Cooperation (GTZ) and the Visayas State College of Agriculture (ViSCA) (which is now Leyte State University).

Leyte's economy basically revolves around agriculture. GROETSCHER et al (2001) reported that the main source of income for the majority of population comes from the production of crops, livestock and marine products. Data from the NSO and National Statistic Coordination Board (NSCB) (1997) showed that the average annual family income has been P67,291⁵ in Leyte Province and P65,369 in Southern Leyte while annual family expenditures averaged P54,501 and P50,691, respectively. The 1997 annual per capita poverty threshold for Region 8 was P8,728 for all areas (both urban and rural) as reported by NSO.

1.2 Literature Review

1.2.1 Identification of the Research Problem

1.2.1.1 Soil Degradation in the Philippine Uplands

Soil erosion is defined as the physical removal of topsoil by various agents, including raindrops, water flow, wind velocity and gravitational pull (STARK 2000). It involves the removal of soluble and insoluble material (LAL 1990). NELSON et al (1998a) pointed out that erosion differentially moves the finer, most fertile fractions of the topsoil. STARK (2000) believes that once the naturally occurring erosion process is accelerated by human activity, agricultural productivity can be greatly reduced. Soil erosion is the most important factor causing soil degradation, a process which leads to the decline in soil fertility through deterioration of the physical, chemical and biological properties of the soil. According to LAL (1990) soil degradation might be caused by any or a combination of the following factors: accelerated erosion, depletion through intensive land use, deterioration in soil structure, changes in soil pH, leaching, salt accumulation, build-up of toxic elements, or excessive inundation leading to poor aeration and soil-reducing condition.

Of the 13 million ha of the Philippine cropland, about 9 million ha, mostly upland areas, were subjected to erosion in the early 1980s (CABRIDO 1985). LEONES (1987) reported extensive erosion which occurred over 75% of all the non-public land areas in the Philippines. SAJISE and BRIONES (1996) stressed that soil degradation is the most prevailing environmental issue associated with current agricultural development in the Philippines. THENG (1991) believed that the extent and severity of soil degradation upon clearing of tropical forests for

⁵ Approximate exchange rate: 65 P = 1C

agriculture would depend on the cultivation system being imposed and how the soil is being managed.

1.2.1.2 Agricultural Development in Leyte Island

Coconut, abaca and root crops planted in *kaingin* had been significant components of cultivated forestlands in the island (ACOSTA 1991; DARGANTES and KOCH 1995b cited by DARGANTES 1996). Generally, the amount of remaining forest cover can be used as an indicator of the critical situation regarding land access for the increasing number of people dependent on agriculture (GROETSCHHEL et al 2001). The decreasing productivity and increasing instability of the island's upland resource base is reflected in the increasing poor economic status of the upland population (STARK 2000). The adjacent lowland communities are likewise negatively affected by floods, drought and siltation (SAJISE 1986). One concrete example was the catastrophic flash flood in Ormoc City on November 5, 1991 which turned national and international official attention towards the tremendous problems caused by deforestation and the necessity of watershed protection (BALOLOY and ATIENZA 1992).

1.2.1.2.1 Coconut Production

The coconut production in Leyte plays a significant role in terms of land use and land cover domination 21.4% of the island's area, as well as in terms of cash income (GROETSCHHEL et al 2001). Copra and other coconut products are the major agricultural export products of the island. However, the effect of unstable and overall declining prices of copra in recent years is a considerable economic problem at least for the large number of small-scale producers (GROETSCHHEL et al 2001). This situation eventually leads to the cutting down of coconut trees on a large scale as building construction material that creating vast open lands which are either left idle for a long period of time or planted with cash crops such as cassava, sweet potato, maize or upland rice (GONZAL et al 2003). GÖLTENBOTH et al (2003) stressed that this type of farming system causes soil erosion especially on the hillsides, which does not only reduce soil fertility and water holding capacity, but also causes sedimentation problems in the coastal areas. PANINGBATAN (1993) and SAJISE (1983) estimated that the rate of soil erosion on slope lands can be high, with annual soil losses ranging from 23-

218 mt ha⁻¹ from bare plots with gradients of 27-29% to 36-200 mt ha⁻¹ on plots cultivated up and down the slope. Furthermore, CALIENTE (1993) reported that siltation ranges from 0.06 to 44.54 g m⁻² per day with an average of 0.04 g m⁻² per day in coastal waters near Baybay.

1.2.1.2.2 Abaca Production

DA-AMAS (2002) reported that the production of abaca fiber increased at a rate of 2.38% from 1990 to 1999. Eastern Visayas supplied the bulk of the product contributing an annual average of 25,239 metric tons or 39% of the total production. Leyte Province produces 6,000 metric tons or 10% of the total production while Southern Leyte contributes 11,000 metric tons or 17% of the total abaca production.

Moreover, the average annual growth rate of area devoted to abaca is 1.8% wherein eastern Visayas shared 25% or 26,000 ha of total area planted to abaca. This states that an actual area of abaca production of 20,330 ha in Leyte Province and 8,560 ha in Southern Leyte (DA-AMAS 2002).

Promoting the benefits of abaca as an intermediate crop from slash-and-burn farmland to generate income should be considered in balance with the possible increase in number of households who have no livelihood option other than abaca production (LACUNA-RICHMAN 2002). NISHIMURA (1996) described local responses to limits to expansion imposed on lowland farming by population increase and fragmentation of landholdings in the western Visayas, which occurred as early as 1970s. One of the common local responses was to clear land in upland forest areas for increased crop production. Leyte island is not exempted from this phenomenon, except that at present the same natural limitations to agricultural expansion occurs even for the uplands, and there is at the same time some pressure from the government to conserve upland forest (LACUNA-RICHMAN 2002).

1.2.1.3 Soil Conservation Technologies

Indigenous soil conservation technologies used by traditional farmers in the Philippine uplands have been well documented. STARK (2000) cited Banaue

rice terraces system in northern Luzon Island as the best-known example of structural technologies. Terraces have been established to produce rice on steep lands for hundreds of years (PURC 1980; CELESTINO and ELLIOT 1986). Contour rock walls are another soil and water conservation method which has been used traditionally in several regions of the Philippines (PURC 1980). Soil conservation measures employed by farmers in the Cordillera Mountains (northern Luzon) involves spreading of grass and plant debris to contour water flows (IIRR et al 1992).

However, STARK (2000) pointed out that indigenous or in-place technologies well adapted to local conditions often become inadequate in the face of new challenges and pressures resulting mainly from population increase, technological progress and rise of expectations. As a result, research stations and universities started focusing on designing, screening, testing and evaluating improved technologies in on-station and on-farm research and development programs. Farmers' local knowledge often built the base for the development of such improved technologies. In fact, many practices which appeared as 'new technologies' on the development scene e.g. agroforestry practices have most often been used by traditional farmers for centuries (STARK 2000). SAJISE (1996) reported that experimentation and innovation by pioneer migrant settlers in adapting to new agro-ecosystems and evolving social system provided starting points in the development of improved technologies.

1.2.1.3.1 Rainforestation Farming: An Innovative Approach

In 1990, a collaborative research between the Republic of the Philippines and the Federal Republic of Germany was implemented at the Visayas State College of Agriculture which is now Leyte State University, Baybay, Leyte through the Philippine-German Tropical Ecology Program. The program focused on the understanding of natural and agro-ecosystems in order to discover elements of sustainability in traditional and conventional farming systems and to eventually find innovative approaches to farming in the Visayas (MARGRAF and MILAN 1996). One of the major findings was that many farmers on the island of Leyte are practicing forms of shifting cultivation during the day and are fishermen at night which allows a separation of protein from carbohydrate production (MILAN

AND MARGRAF 1990 cited by SCHULTE 2002). MILAN and MARGRAF (1990) believed that this reduces the cultivation pressure on both sub-ecosystems but calls for a holistic approach in research and development. However, SCHULTE (2002) at the same time emphasized that it cannot be overlooked that the forest resources continue to disappear at an alarming rate. Hence, in an attempt to combine the essential elements of forest and food production systems, the following working hypothesis has guided the research: *A farming system in the humid tropics is increasingly more sustainable the closer it is in its species' composition to the original local rainforest* (MILAN and MARGRAF 1994b).

In 1992, the Tropical Ecology Program started a demonstration farm and nursery to establish the "Closed Canopy and High Diversity Forest Farming System" in short "Rainforestation Farming" in a cooperative undertaking with the Department of Environment and Natural Resources (DENR) and several departments at ViSCA to develop a farming system that mostly resembles the structure of a natural Philippine rainforest ecosystem. A research and model farm on 2.8 hectares within ViSCA boundaries was gradually being developed. Within the Baybay municipality area, research fields on volcanic as well as limestone soils (a total of 38 ha) are provided for long trails by cooperating farmers and landowners. The *kaingin* farmers of the pilot areas are organized, receive informal education and trainings.

MARGRAF and MILAN (1996) believed that if protection of the forests' biodiversity and management for income generation have to go hand in hand, flanking environmental education is obligatory. However, experience shows that farmers recognize easily the economic potential of the rainforestation farming system; it is more often that conventional thinking of administrators and old-school-foresters as well as economist that pose a serious set back (SCHULTE 2002). Secondly, the emphasis of the government is still laid on exotic 'miracle trees' (i.e. *Gmelina arborea*, *Acacia mangium*, *Acacia auriculiformis*, and *Eucalyptus spp.*) even for large-scale reforestation. It is not yet sufficiently recognized that, although intentions are good, this practice is indirectly contributing to deforestation and the drastic reduction of biodiversity. Some of the reasons cited by MARGRAF and MILAN (1996) are:

- a. the fast growing exotic have low wood quality; hence, high quality rainforest trees still need to be harvested in their natural environment;
- b. the monoculture of exotic trees does not support the survival of wildlife species of our local rainforest some of which are important pollinators and distributor of seeds;
- c. the fast growing exotics are all pioneer species with a short life span which support a management of repeated clear cutting;
- d. local lumber species, even their quality is much higher, are regarded low and are consequently only cut but not propagated; and
- e. using exotic trees as reforestation species does not support the protection and preservation of the remaining natural forest.

On the other hand, the study of ASIO and MILAN (2002) revealed that Rainforestation farming as an innovative approach for the rehabilitation of degraded lands clearly appeared to be effective not only in restoring the forest vegetation but also in improving soil quality. This was observed in two different rainforestation farms in acidic volcanic soil at Mt. Pangasugan and in calcareous limestone soil at Punta, Baybay, Leyte. Results of the study revealed that for acidic soil, there was a darkening of soil colour and a thickening of the humus-rich surface horizon. In addition, there was an improvement of soil structure and moisture holding capacity, an increase in soil pH of the surface layer from 4.2 to 4.8 as well as an increase in available phosphorus and exchangeable potassium contents of the surface soil. For the calcareous soil, there was also a considerable improvement in soil physical properties like darkening of the surface layer due to humus accumulation, and an increase in surface layer thickness and moisture holding capacity of the soil. The improvement of soil quality was dramatic in the calcareous soil than in the acidic soil since the former was much more degraded, i.e. more compact, lower humus and nutrient content than the latter. Results also showed a decrease in soil pH from 8.2 to 7.4 as well as a slight increase in available phosphorus in the surface layer. The decrease in soil pH of the calcareous soil is a positive effect since it minimizes the occurrence of nutritional problems which are prevalent under highly calcareous conditions.

Moreover, KOLB (2002) was able to prove recently that the growth development of the research and demonstration plots near the ViSCA is

promising a few years after establishment. However, SCHULTE (2002) believes that this scheme will have to be attuned to the capacity of the local communities who are involved as 'farmer-researchers' to adjust the technology to practicability and ensure mutual learning. It will be the farmers' choice to either select elements of a forest structure and eventually combine it with compartmentalization into agricultural systems familiar to them, or direct their efforts towards creating a true copy of the original rainforest and become 'rainforest-farmers' (SCHULTE 2002).

Nevertheless, it is still too early to answer the question if rainforestation farming will be an economically more appropriate alternative under the actual circumstances on the Visayas (SCHULTE 2002). Thus, further investigation is needed and will serve as a guide for transforming the actual subsistence-level single-species systems into community-based rainforestation farming helping to rehabilitate the degraded land as well as to overcome the distinct economic inequalities on the Visayas in general and Leyte in particular.

1.2.2 Statement of the Problem

The establishment of an agroecosystem, as exemplified by clearing and cultivation, is primarily intended to serve human needs for agricultural products (KOCH et al 1990 cited by DARGANTES 1996). Once established, the agroecosystem is then geared towards the attainment of high crop yields. According to DARGANTES (1996), stability, which may only be maintained in special and exceptional cases and only within short periods, usually assumes a subordinate role to the objective of producing outputs with immediate economic value. As RUTHENBERG (1980) cited by DARGANTES (1996) pointed out:

“Outputs (of most ecological systems untouched by humans) are to a minor degree economic (e.g. game) but most non-economic (e.g. water joining groundwater). Natural systems, however, are unproductive in terms of human objectives. The basic principle of farming is to change the natural system into one which produces more goods desired by humans. The man-made system is an artificial construction which requires economic inputs obtained from the environment to maintain its output level. Farming thus implies the abolition of an unproductive ‘steady state’ in favour of a man-created more productive but unstable ‘state’ ...”

Conceptually, therefore, the natural ecosystem and the socio-economic system could be seen to compromise two poles of a charged environment wherein the manifested utilization pattern represents the resultant influence of one pole over the other (KOCH et al 1990 cited by DARGANTES 1996). Under these conditions, the interactive influences of the ecosystem and the socio-economic system exert undue influence over the ecosystem and subdue the elements and processes which maintain this equilibrium. And in Leyte, this is manifested by the loss of 163,000 hectares of the islands' forestlands to agriculture (ACOSTA 1991 cited by DARGANTES 1996).

GROETSCHHEL et al (2001) stressed that the amount of remaining forest cover can be used as an indicator of the critical situation regarding land access for the increasing number of people dependent on agriculture. The decreasing productivity and increasing instability of the island upland resource base is reflected in the increasing poor economic status of the upland population (STARK 2000). Therefore, a combined effort (i.e., government, research institutions and forest occupants) is required to propagate ecological technologies to stop environmental degradation (PASCUAL 1998) since the extent and severity of soil degradation upon clearing tropical forest for agriculture would depend on the cultivation system being imposed and how the soil is being managed (THENG 1991). Thus, a development of a sustainable environmentally sound agroecosystem must be in place within the framework of a holistic community-based reforestation farming in order to rehabilitate the degraded lands as well as to overcome the distinct economic inequalities of the upland population in Leyte.

1.2.2.1 Development of a Sustainable Abaca Production

Despite the importance of abaca to the national economy in general and to Leyte's economy in particular, its potential as a source of greater income to upland farmers while serving as a crop that may actually help in slowing down deforestation, is given little research and policy attention (LACUNA-RICHMAN 2002). Planting abaca give *de facto* rights to the land it is planted on, and reforestation efforts should take this into account as more families are forced by circumstances to settle on areas designated as forest land. LACUNA-RICHMAN

(2002) reported that abaca is frequently the only source of cash income of poorer households in Leyte, who have only abaca as a single cash crop, and various subsistence crops as supplement of their household.

Presently, in Leyte, abaca is grown in a monoculture plantation in secondary forest patches. In the traditional practice, the establishment of an abaca crop is usually the last stage before forest encroaches on agriculture. However, abaca plants are long-lived perennials, and in Leyte the same families have maintained the plots planted with abaca for many years. According to the study conducted by LACUNA-RICHMAN (2002) at Cienda, Gabas, Baybay, Leyte revealed that the most common intercrops with abaca are takudo (*Xanthosoma sagittifolium* L) and cassava. Likewise, one of the major findings was abaca is grown within the forest area rather than on the lowlands around the community. This is due to the fact that abaca requires some protection from typhoons which can be provided by the surrounding forest. In this sense, abaca can be considered an ideal crop for the forest-edge households in Leyte. After the first two to three years from planting, it is possible to harvest at least twice a year with little input in terms of fertilizer, pesticides or irrigation, and with minimal expense for initial processing.

Hence, abaca is a very suitable crop for integration in both rainforestation farming system and monoculture coconut plantations, by creating a diversified multi-strata agroecosystem. The integration of abaca in the rainforestation farming concept will serve as a guide for transforming the actual subsistence-level single-species systems into a holistic community-based rainforestation farming. The produce from fruit and forest trees could allow abaca-producing households to earn an income when their abaca crops become less productive, or when harvesting the fibre become close to impossible for particular households, for example, due to the lack of able-bodied family members to maintain the plot and harvest the crop. Thus, helping to rehabilitate the degraded land as well as to overcome the distinct economic inequalities of the upland population in Leyte. On the other hand, utilizing the open space between monoculture coconuts (which is about 21.4% of the island's area) will minimize further forest encroachment and clearing of tropical forest for agriculture.

However, additional investigations on the production of abaca fibre is necessary in particular regarding the selection of suitable varieties which include disease resistance, stable yield, vegetation period, high quality and farmers preference. Secondly, further studies on the improvement on biological productivity and site adaptability considering canopy structure and light interception, soil nutrient pool and plant nutrient uptake in relation to plant microclimate between the two different multi-strata production systems (i.e., rainforestation farming and coconut monoculture) need to be conducted.

The objectives of this study are: a) to evaluate two multi-strata abaca production systems based on site and plant nutrient status, site adaptability and biological productivity and b) to identify possible pathways for a sustainable abaca production scheme in the Philippines. In addition, these objectives may point to possible areas of concern in promoting the use of abaca as an agroforestry crop for reforestation purposes.

2. Materials and Methods

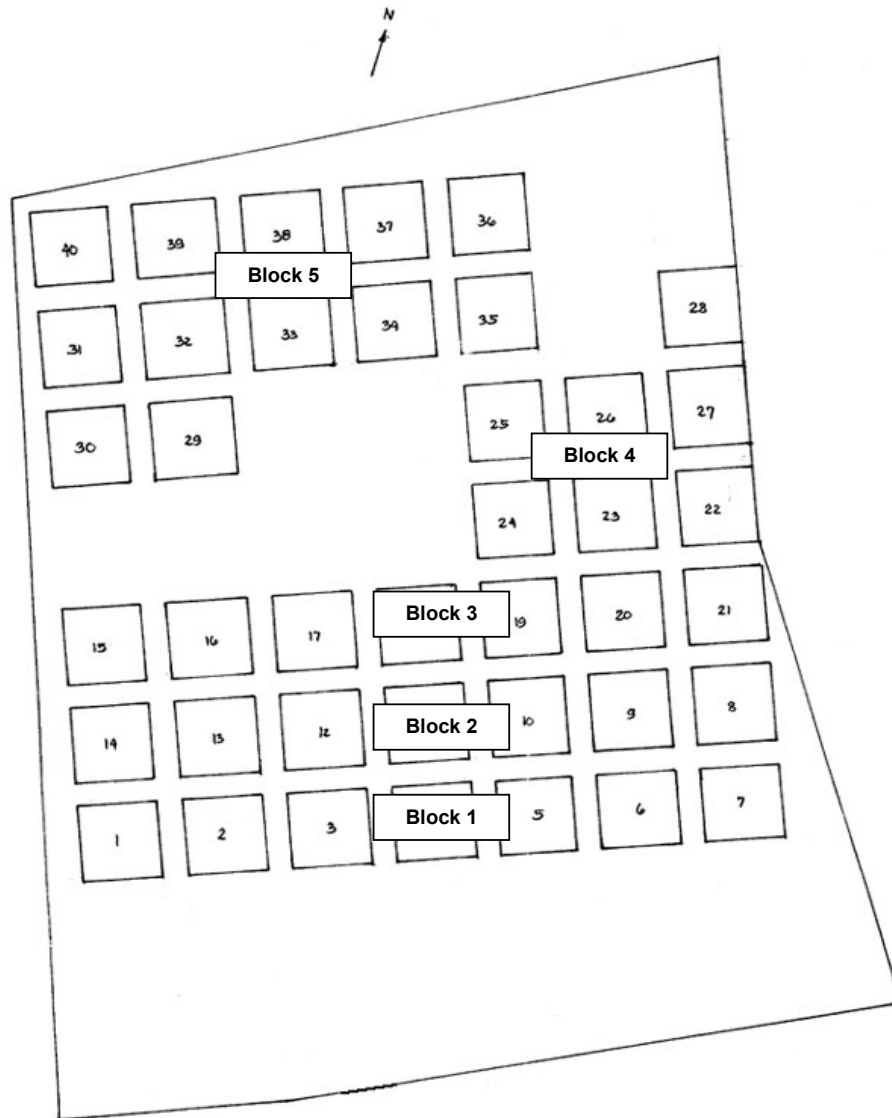
2.1 Establishment of the Study Sites

In September 2003, two study sites were established at two different areas near Baybay, Leyte, Philippines. The first site (Barangay Caridad) is located about 14 km northeast of Baybay town at an elevation of 122 amsl. The second site (Barangay Mailhi) is about 23 km southwest of Baybay at 351 amsl elevation. The two research sites are comparable in terms of soil physiography and geology. This was accomplished by a very detailed survey using auger to make sure that the soils were comparably similar as indicated for example, by morphological features such as colour, texture and horizonation. Furthermore, both research sites were under forest until 1954 as indicated in old land use maps and confirmed by interviews with landowners and farmers cultivating the adjacent land. In both sites, secondary forest still exists.

The first site is presently a 40-year old monoculture coconut plantation and with a declining productivity which is one of the major considerations for the site selection. During the establishment, two abaca varieties (*laylay* and *inusa*) were used based on site suitability, disease resistance, yield, vegetation period,

tensile strength (fibre) and farmer's preference. Likewise, a total of 40 quadrant plots were established with each plot of an area of 100 m² and planted to 25 abaca suckers (Figure 3). Quadrant design was used since slope exposition is more or less homogenous and there is a wide planting distance between coconut trees. Moreover, the site was divided into different blocks based on topography, vegetation cover and species composition. The intention was to consider each block as one treatment and the plots that belong to a particular block correspond as repetitions to the treatment. Thus, this particular site was divided into 5 blocks with 7 plots each block, except block 5 which has 12 plots

The second site is originally a 10-year old rainforestation farm. The site was selected since harvesting of pioneer tree species is already possible, and harvesting will improve the light illumination for the understory dipterocarp and fruit



Caridad Coconut-Abaca Demonstration Farm

Area : 11,076.5 m²
 Average Slope : 13°
 Exposition : North-East
 Walking Distance : 30 min
 Location : Upland

Main Crops : Abaca, coconut

Date of Survey : January 8, 2004
 Surveyed by : Jimmy O. Pogosa
 Darwin B. Posas
 Map Prepared by : JO Pogosa & DB Posas

- Subplots :
1. Abaca, coconut, bamboo, pioneer trees, banana (7,832 m²)
 2. Coconut, pioneer trees, banana (11,976.5 m²)

Figure 3. Planting design of Caridad site

tree species and site suitability for abaca. Prior to farm establishment, the area was divided into four different blocks mainly because of heterogeneity of the slope and undefined planting distance between trees. Thus, a circular design was used. A total of 5 circular plots were established per block (Figure 4). Each plot had an area of 180 m² and planted with 50 abaca suckers. Like the Caridad site, each block will be considered as one treatment and each plot that belongs to a particular block will be treated as repetition to the treatment.. A total of 750 *laylay* and 250 *inusa* abaca variety suckers were planted. To reduce variability for result comparisons between the sites, each site had an area of 1 hectare under the same soil parent material and climatic conditions.

On the other hand, the two-abaca varieties were evenly distributed in both study sites. This means that one plot was planted to one abaca variety (either *laylay* or *inusa*) under the same slope inclination and exposition in each study area. Since *inusa* variety suckers (planting materials) were smaller number than the *laylay* variety suckers, only one plot was planted to *inusa* in each block per study site. This decision was reached in order to evenly distribute the planting materials within the whole farm.

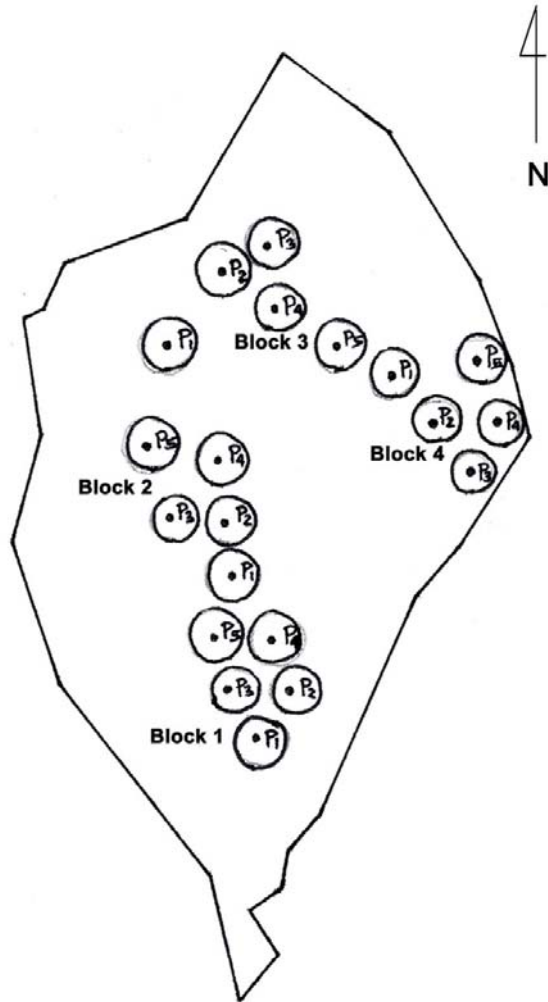
2.2 Data Collection

The data collection was carried out from September 2003 to June 2004 with the cooperation of the Institute of Tropical Ecology of the Leyte State University, Baybay, Leyte, Philippines. The study involved data collection on the following aspects: site nutrient status, plant nutrient uptake, and morphological and physiological performance of abaca plants.

2.2.1 Site Nutrient Status

2.2.1.1 Field Examination and Sampling

Field examination was carried out on pits measuring 1x1 m to a depth of 1 m. Three soil profiles were conducted in each study site and were characterized using the standard procedures according to FAO-World Reference Base (FAO 1990). Site characteristics from each profile such as soil depth (horizon), colour (munsell), structure, structural stability, texture, percent skeleton, percent roots



Mr. Macario Romano's RF-Abaca Cooperator's Farm

Area : 1.63 ha.
 Slope : 17 - > 120%
 Exposition : South-West
 Altitude : 340 m asl
 Walking Distance : 10 min.
 Location : Upland

Date of Survey : 23rd of July 1996
 Surveyed by : W. Dirksmeyer
 M. Laran
 Map Prepared by : W. Dirksmeyer &
 A. Modina

Main Crops : RF-trees, coconut, banana,
 abaca

- Subplots:
1. RF-trees, coconut, pineapple, banana, casava, bamboo, abaca (1.63 ha.)
 2. Coconut, fruit trees, banana (1.59 ha.)

Figure 4. Planting design of Mailhi site

and layer boundaries were collected and evaluated using the methods described by JAHN et al (2002). Profile samples were collected from each horizon (per pit per study site) quantitatively by taking a continuous and uniform slice from the uppermost horizon down to the lowest.

For nutrient analysis, auger samples from three different soil depths; 0 to 30 cm, 30 to 60 cm, and 60 to 90 cm, were randomly collected in six different locations in each plot. All six samples from each different depth represent a mixture or composite of three sub-samples per plot. Hence, a total of 120 and 60 composite soil samples were collected from the coconut-abaca and rainforestation-abaca farms, respectively. However, due to the voluminous number of soil samples to be analysed and the amount of financial and time resources needed for such analysis, the results on 0 to 30 cm depths is only presented on this report.

2.2.1.2 Preparation of Soil Samples and Laboratory Analyses

The soil samples (both profile and composite samples) were air-dried, pulverized and sieved to pass 2 mm and 0.0428 mm and stored in glass bottles ready for the analysis. For the profile samples, simple routine analyses were conducted to determine percent organic carbon, base saturation, bulk density, and CEC (Ca^{2+} , Mg^{2+} , K^+ , Na^+ , Al^{3+} and H^+) using the methods described by SCHLICHTING et al 1995 (Appendix A).

On the other hand, the composite soil samples, analysis on the macronutrient content (i.e., N, P, K, Ca and Mg) and availability of various components between the two systems were determined. Available N, P, cation exchange capacity (CEC) potential as described by SCHACHTSCHABEL 1992 (exchangeable cations at pH7-7.5) and organic carbon were measured using the methods described by SCHLICHTING et al 1995 (APPENDIX A). Soil pH was determined in 10g air dried sieved (<2mm) soil dissolved in 25ml $\text{H}_2\text{O}_{\text{dest}}$, and 1M KCl using a ratio of 1:2.5 according to JACKSON (1958) and SCHLICHTING et al. (1995). The measurement was done by a pH electrode. The preparation of samples was carried out at the National Abaca Research Center (NARC) while the reading of the elements was carried out at the Philippine Rootcrops Research and Training Center (PRCRTC), Leyte State University, Visca, Baybay, Leyte.

2.2.2 Plant Nutrient Status

2.2.2.1 Collection of Leaf Samples

Abaca leaf analyses were conducted in order to determine plant nutrient uptake in relation to nutrient availability in the soil. Since the critical nutrient concentrations of abaca are still unknown, leaf samples were collected from both young (newly expanded leaf) and old (before the occurrence of flag leaf) leaves of abaca plants in each plot. For statistical reasons, leaf samples were collected from the 30% of the total number of plants per plot in each study site. This means that 7 (30% of 25 plants) and 15 (30% of 50 plants) plant-leaf samples per plot were collected in Barangay Caridad and Mailhi, respectively. Each of these 7 (in Barangay Caridad) and 15 (in Barangay Mailhi) plant-leaf samples represent a composite leaf sample for one plot per study site. Thus, a total of 40 composite leaf samples in Barangay Caridad and 20 composite leaf samples in Barangay Mailhi were collected.

2.2.2.2 Preparation of Leaf Samples and Laboratory Analyses

The composite leaf samples were washed and rinsed with tap and distilled water to remove dirt and other soluble materials. The harvested biomass was then sealed into labelled plastic bags along with a small quantity of distilled water to prevent desiccation damage. Prior to oven drying, the samples were air-dried and cut into small pieces. These were dried in the oven at 70 °C temperature for 27 hours. The dried samples were ground and sieved to pass 0.428 mm and sealed into labelled plastic bags ready for the analysis. Analyses were carried out at the Institute of Plant Nutrition of the University of Hohenheim.

Prior to preparation of ash solution, 500 grams of dried organic biomass samples (each composite sample) were weighed in a sensitive digital balance and placed in a porcelain crucible. These were burned in a muffle furnace at 500 °C temperature for at least 4 hours until a light coloured ash was obtained in each of the porcelain crucible. Then, ash solutions were prepared for P, K, Ca, Mg, B and Zn analyses while the N analysis was done by digesting the organic biomass in sulfuric acid. Details of all laboratory methods are given in Appendix B.

2.2.3 Morphological and Physiological Performance

Monthly growth performance was monitored in the two study sites for the period September 2003 until June 2004. The following were measured: (1) site specific climate that included measurements on radiation, temperature, humidity and wind (all these information were obtained at the LSU Agromet weather station). (2) canopy structure and light interception that included measurements of light in canopies of individual plant in each plot by using a light sensor, leaf area index by using the area-length regressions (KVET and MARSHALL, 1971 and adopted by COOMBS, 1985), leaf inclination by directly holding a protractor with a levelling device against the leaf, leaf orientation by using a compass, number and life-span of the leaves from the date of appearance to date of senescence; and (3) plant growth performance by measuring the total plant height and base diameter using a meter stick and tree diameter, respectively.

2.2.4 Comparison and Evaluation of the two Agroecosystems

Finally, the results of each parameter that is site and plant nutrient status and growth performance, were used in comparing the two production schemes. However due to time constraints, data for economic profitability was neither collected nor included as an additional criterion for the evaluation because the abaca plants were still on their vegetative stage during the conduct of the study. Thus, the economic benefits in adopting such a system cannot be quantified or measured (through the gross margin analysis) particularly on the effect on the farmer's income. Such data, however, should be considered in future studies.

2.2.5 Statistical Analyses

From individual plant measurements, averages were determined for analysis of variance calculation. Then, the correlation coefficient was calculated to determine the relationships between individual parameters.

3. Results

3.1 Soil Characteristics

This section deals mainly on the morphological and chemical characteristics of Caridad and Mailhi soils based on the results of field and laboratory investigations.

For this purpose, six profiles (three for each site) were selected and examined. The selection was mainly based on the gradient (upper, middle and lower slope) and elevation of each study site. This decision was reached upon considering the fact that differences in slope and elevation offer better opportunities for soil characteristics and site quality evaluation, comparison and interpretation within and between the two different agroecosystems.

3.1.1 Soil Morphological Characteristics

According to BUOL et al (1982) – as cited by ASIO (1996) – soil morphology is best evaluated from *in situ* examination of the soil profile. Thus, the presentation of this section focuses on the results of field soil examinations. The detailed description of the six profiles is given in Appendix C.

3.1.1.1 Horizonation

Horizonation is the development of horizons in soil as a result of a soil forming process or a combination of soil forming processes. Caridad soil is characterized by Ah-Bw-Bt₁-Bt₂-Bt₃ horizon sequence (Appendix C) to a depth of 1 meter. This indicates an accumulation of silicate clay that has formed in the horizon or has moved into it by illuviation or either both. The subsurface horizon is identified as argic (FAO 1988). Mailhi soil, on the other hand, is characterized by an Ah-Bw₁-Bw₂-Bw₃ horizon sequence with the solum reaching a depth of 1 meter.

3.1.1.2 Texture

Soil texture affects soil temperature, soil hydrology, soil air and nutrient supply and is therefore an important parameter to describe the ecological properties of soil. Field soil textures of Mailhi soils ranged from sandy clay to clay loam on the surface to silty clay in the subsoil. Likewise, the surface horizons of Caridad soil had clay loam textures.

3.1.1.3 Structure

Soil structure describes the way in which sand, silt and clay particles are bonded together in larger units called aggregates (ASHMAN and PURI 2002). According to ASIO (1996), this property is related to the genetic origin of the soil and greatly affects its physical characteristics.

Caridad soil is characterized by a strong to moderate coarse granular structure in the A horizon and a strong to moderate sub-angular blocky structure in the lower horizon. Such structure is common in tropical soils which are well developed and which have high clay content (ASIO 1996). Mailhi soil, on the other hand, shows a moderate medium to coarse granular structure in the A horizon as well as a moderate medium to very coarse granular structure in the lower horizon

3.1.1.4 Other Morphologic Features

Earthworms, ants and centipedes were observed in the surface horizon of both soils during the fieldwork. Adult termites and larvae were observed in the subsurface horizon in Caridad site. Additionally, roots could be observed even at the bottom (100 cm depth) in the profile of both soils although high intensity rooting development occurred only in the upper 40-50 cm.

3.1.2 Soil Chemical Properties

3.1.2.1 Organic Carbon

Organic carbon in agricultural soils contributes positively to soil fertility, soil tilt, crop production and over-all soil sustainability (BAUER and BLACK 1994; LAL et al 1997; REAVES 1997). WEST and POST (2002) stressed that changes in agricultural management can increase or decrease soil organic carbon (SOC).

Results showed that at the time of the study, Caridad soil had lower org C (average: 3.3%) in the A horizon compared to Mailhi soil. In all profiles examined, org C content decreased with depth to an average of 0.87%. OTSUKA et al (1988) and ASIO (1996) reported org C content of the A horizons of some volcanic soils in the Philippines ranging from 0.79 to 11.1%. Both authors

attributed the wide variation to the complicated accumulation of organic matter (OM) which depends on texture, composition of organic materials and age of soil layers, climate and topography at the site.

Meanwhile, Mailhi soil showed a much higher org C with an average of 4.0% compared to Caridad soil. Like the Caridad soil, org C content decreased with depth to an average of 1.3%. Results are presented in Table 1.

Table 1: Organic carbon (org C) and total nitrogen (Nt) with depth in Caridad and Mailhi soil

Caridad Soil							Mailhi Soil						
Hor.	Profile 1		Profile 2		Profile 3		Hor.	Profile 1		Profile 2		Profile 3	
	OrgC (%)	Nt (%)	orgC (%)	Nt (%)	orgC (%)	Nt (%)		orgC (%)	Nt (%)	orgC (%)	Nt (%)	orgC (%)	Nt (%)
Ah	3.30	0.08	3.80	0.19	2.79	0.13	Ah	6.53	0.25	3.30	0.10	2.28	0.17
Bw	1.69	0.14	1.42	0.15	1.42	0.07	Bw ₁	2.45	0.13	1.45	0.02	1.19	0.09
Bt ₁	0.96	trace	0.74	0.03	1.12	0.07	Bw ₂	0.94	trace	0.43	0.04	1.01	0.05
Bt ₂	0.55	trace	0.62	0.03	0.51	0.04	Bw ₃	0.72	0.02	-	-	-	-
Bt ₃	0.51	trace	-	-	-	-							

3.1.2.2 Total N and C:N Ratio

Nitrogen is a macronutrient that is essential to the growth of plants. However, it is one of the most deficient nutrients in most soils since this is frequently transformed in the soil and mostly (95%) bound in organic matter (SCHEFFER and SCHACHTISCHABEL 1992). The term total nitrogen in this section includes organic-N, nitrate, exchangeable and minerally fixed NH_4^+ . According to BREMNER (1996) as cited by ZIKELI (1998), total nitrogen contents in soils ranges between <0.02% and >2.5%.

Results showed that Nt decreased with depth in both soils (Table 1). The same manner can also be seen with org C. This implies a close relationship between org C and Nt content of soils (PAGEL 1982 cited by ASIO 1996).

On the other hand, C:N ratios are indication of the type of OM present in the soil and in particular, the degree of humification (ASIO 1996). SCHEFFER and SCHACHTSCHABEL (1992) reported that a narrow C:N ratio (<10) indicates the presence of N-rich organic material and usually a rapid decomposition. On the other hand, if the C:N ratio is higher decomposition activity decreases.

Caridad soil showed a C:N ratio ranging from 9 to 39 and an average of 20 while the Mailhi soil had C:N ratio ranging from 10 to 66 and an average of 26.4 (Table 2). This higher C:N values is probably attributed to the frequent burning of coconut husk in Caridad site and the history of slash and burn cultivation in Mailhi site which led to the accumulation of black carbon in the surface horizon. Black carbon is rich in organic carbon but low in nitrogen and is a very stable element, which is not accessible to mineralization by microorganisms.

Table 2. C:N ratios of Caridad and Mailhi soils

Caridad Soil				Mailhi Soil			
<i>Horizon</i>	Profile 1	Profile 2	Profile 3	<i>Horizon</i>	Profile 1	Profile 2	Profile 3
Ah	39	20	22	Ah	26	32	19
Bw	13	9	22	Bw ₁	18	66	14
Bt ₁	-	27	15	Bw ₂	-	10	20
Bt ₂	-	23	12	Bw ₃	33		
Bt ₃	-						

3.1.2.3 Soil pH

Soil reaction measured in terms of pH influences other soil properties, i.e., cation exchange capacity, mobility of nutrients (e.g. phosphorus), aggregation of soil particles and aluminium toxicity (especially in tropical soils). Likewise, the exchange systems in soils are also influenced by pH.

For this purpose, the pH of the two soils was characterized using 10g air-dried <2mm samples with water (H₂O) and 1M KCl using a ratio of 1:2.5 according to JACKSON (1958) and SCHLICHTING et al. (1995). The reason behind the use of KCl is to minimize the commonly observed salt effect (SCHLICHTING et al 1995) wherein the K- and Ca-ions replaced the weakly adsorbed H- and Al-ions which is not possible in H₂O method.

Results showed that Caridad soil is slightly less acidic than Mailhi soil. However, there is a slight tendency for pH to increase with depth in both methods used particularly in profile 1. For Mailhi soil, its pH values indicate a more acidic condition than Caridad soil. But, Mailhi soil has an opposite quality than Caridad soil, where pH decreases with depth. This observation is typical in all of the three profiles examined using KCl. The detailed results are shown below (Table 3).

Table 3. Soil pH of Caridad and Mailhi soils

Caridad Soil							Mailhi Soil						
Hor.	Profile 1		Profile 2		Profile 3		Hor.	Profile 1		Profile 2		Profile 3	
	H ₂ O	KCl	H ₂ O	KCl	H ₂ O	KCl		H ₂ O	KCl	H ₂ O	KCl	H ₂ O	KCl
Ah	5.5	3.6	5.2	3.3	5.3	3.6	Ah	4.6	3.0	4.9	3.0	5.3	3.3
Bw	5.5	3.2	5.1	3.2	5.1	3.1	Bw ₁	4.8	3.3	4.7	3.0	5.2	3.0
Bt ₁	5.6	4.4	5.3	3.3	5.1	3.1	Bw ₂	4.8	3.0	4.7	2.9	4.8	2.9
Bt ₂	5.6	4.5	5.5	3.0	5.1	3.2	Bw ₃	4.8	2.9	-	-	-	-
Bt ₃	5.9	4.4	-	-	-	-							

3.1.2.4 Delta pH

According to SANCHEZ (1976), ΔpH is an indicator of charge systems within the soils. MEKARU and UEHARA (1972) – as cited by ASIO (1996) - defined it as the difference between pH in KCl and pH in H₂O as shown by the equation:

$$\Delta\text{pH} = \text{pH}_{\text{KCl}} - \text{pH}_{\text{H}_2\text{O}}$$

If the ΔpH is negative, the soil colloids are dominated by net negative charge (cation exchange capacity). This implies that the soil has the capacity to hold positively charged nutrients like NH_4^+ , Ca^{++} , Mg^{++} , K^+ and others. On the other hand, if the ΔpH is positive, the soil colloids possess positive charge which is dependent on soil pH and thus, is not permanent.

Table 4. Delta pH (ΔpH) of Caridad and Mailhi soils

Caridad Soil				Mailhi Soil			
Horizon	Profile 1	Profile 2	Profile 3	Horizon	Profile 1	Profile 2	Profile 3
Ah	-1.8	-1.8	-1.8	Ah	-1.6	-1.9	-2.0
Bw	-2.2	-1.9	-2.0	Bw ₁	-1.5	-1.8	-2.2
Bt ₁	-1.2	-2.0	-1.9	Bw ₂	-1.8	-1.8	-2.0
Bt ₂	-1.2	-2.5	-1.9	Bw ₃	-1.8	-	-
Bt ₃	-1.5	-	-				

3.1.2.5 Cation Exchange Capacity (CEC)

Soil components have the ability to adsorb uncharged molecules as well as cations and anions. According to SCHEFFER and SCHACHTSCHABEL (1992); cation adsorption plays an important role in the material cycle of ecosystems and in plant-soil relationships. This exchange process in the soils can be described by cation exchange capacity (CEC) which is defined as the total charge excess of cations over anions in the system (SUMNER and MILLER 1996).

In this investigation, potential CEC (CEC_p) and effective CEC (CEC_e) were determined. CEC_p is determined by NH_4OAc at pH 7.0 (BLACK 1965) Details of the method is discussed in Appendix A. CEC_e, on the other hand, is calculated according to FAO-UNESCO SOIL MAP OF THE WORLD (1998) by adding exchangeable bases (K^+ , Mg^{2+} , Ca^{2+} and Na^+) and soil acidity (H^+ and Al^{3+}).

Results are presented in Table 5. As can be seen, both CECp and CECe of Caridad soil in profile 1 decrease with depth. Profiles 2 and 3 show a different trend wherein there is a slight increase in Bw horizon in CECe. The higher values of CECp and CECe in the surface horizon (in profiles 1, 2 and 3) can be attributed to the higher percentage of organic matter which is according to SCHEFFER and SCHACHTSCHABEL (1992), organic matter contributes to CEC with its high amount of variable charge sites. The potential CEC values of both soils are high indications that these soils have high potential capacity to hold nutrients. The low effective CEC values however suggest that the actual amount of nutrients in the soil is much lower than its capacity to retain nutrients.

Table 5. Potential cation exchange capacity (CECp) and effective cation exchange capacity (CECe) in $\text{cmol}_c \text{kg}^{-1}$ of Caridad and Mailhi soils

Caridad Soil							Mailhi Soil						
Hor.	Profile 1		Profile 2		Profile 3		Hor.	Profile 1		Profile 2		Profile 3	
	CECp	CECe	CECp	CECe	CECp	CECe		CECp	CECe	CECp	CECe	CECp	CECe
Ah	36.01	9.45	35.19	8.30	28.34	8.35	Ah	32.45	13.28	29.44	12.72	30.81	9.30
Bw	32.17	5.88	34.09	9.26	28.00	10.60	Bw ₁	27.25	10.88	31.35	12.65	30.53	12.74
Bt ₁	26.70	4.72	37.10	7.95	27.79	9.01	Bw ₂	29.44	9.40	38.47	14.93	30.12	13.84
Bt ₂	21.22	3.03	27.79	11.06	32.72	8.81	Bw ₃	45.59	11.83	-	-	-	-
Bt ₃	21.86	2.71	-	-	-	-							

3.1.2.6 Exchangeable Bases and Base Saturation

THOMAS (1992) cited that the term exchangeable bases refers to cations K^+ , Mg^{2+} , Ca^{2+} and Na^+ . The amount of exchangeable bases in soils is an indicator of nutrient supply that is available for plants.

Results are given in Table 6. As can be seen, the amounts in Caridad soil are higher compared to Mailhi soil. However, both soils follow the order $\text{Ca} > \text{Mg} > \text{K} > \text{Na}$. According to ASIO (1996), the dominance of Ca relative to the other bases is attributed partly to volcanic parent material. In addition, he

pointed out that with the decrease in OM content and CEC, there is also a decrease in exchangeable cations with depth. With regard to percent base saturation, Caridad soil has relatively high value (both BSpot and BSeff) compared to Mailhi soil suggesting high nutrient status of the former than the latter.

Table 6. Exchangeable bases ($\text{cmol}_c \text{ kg}^{-1}$) and base saturations (%) of Caridad and Mailhi soils

Caridad Soil							Mailhi Soil						
Hor.	Ca	Mg	K	Na	BSpot	BSeff	Hor.	Ca	Mg	K	Na	BSpot	BSeff
Ah	3.13	2.00	1.89	0.21	22.1	83.2	Ah	1.52	0.86	0.79	0.29	11.2	33.7
Bw	2.19	0.93	1.17	0.32	14.8	58.4	Bw ₁	1.08	0.52	0.38	0.30	7.6	18.5
Bt ₁	2.47	0.82	0.85	0.47	15.5	68.2	Bw ₂	0.45	0.24	0.25	0.28	3.8	9.3
Bt ₂	3.10	0.98	0.57	0.41	18.3	73.0	Bw ₃	0.37	0.31	0.19	0.28	2.1	8.1
Bt ₃	1.38	0.29	0.61	0.26	11.1	93.7							

3.1.2.7 Exchangeable Acidity and Aluminium Saturation

Soil acidity influences nutrient availability and the physical properties of the soil. Likewise, it describes the amount of exchangeable aluminium ions that causes aluminium toxicity in soils which is a common problem under tropical conditions. According to SCHEFFER and SCHACHTSCHABEL (1992), soil acidity is based on the amount of dissociable H^+ and exchangeable Al^{3+} present in soils.

Results revealed that the amounts of H^+ and Al^{3+} in Caridad soil are comparable in the surface to the subsurface horizons while aluminium saturation ranges from 0.9 to 15.9%. With regard to Mailhi soil, much amount of H^+ and Al^{3+} and these tend to increase with depth (Table 7). Aluminium saturation ranges from 27.7 to 41.9%. This indicates that aluminium toxicity is a constraint to crop production in Mailhi.

Table 7: Exchangeable acidity (EC) and aluminium saturation of Caridad and Mailhi soil

Caridad Soil					Mailhi Soil				
Horizon	Al ³⁺ cmol _c kg ⁻¹	H ⁺ cmol _c kg ⁻¹	Total EC cmol _c kg ⁻¹	Alsat %	Horizon	Al ³⁺ cmol _c kg ⁻¹	H ⁺ cmol _c kg ⁻¹	Total EC cmol _c kg ⁻¹	Alsat %
Ah	0.8	0.7	1.5	0.9	Ah	3.5	4.8	8.3	27.7
Bw	1.5	2.4	3.9	15.9	Bw ₁	4.1	5.7	9.8	34.3
Bt ₁	1.2	1.5	2.7	14.1	Bw ₂	4.8	6.7	11.5	37.9
Bt ₂	1.2	1.4	2.6	12.3	Bw ₃	5.0	5.9	10.9	41.9
Bt ₃	0.1	0.1	0.2	3.8					

3.2 Site Nutrient Status

This section deals mainly on the specific site nutrient status of Caridad and Mailhi soils. According to SCHLICHTING et al (1995), vegetation growth depends on both physical soil properties (i.e., rooting depth and soil resistance to root growth, soil hydrology, soil air and erodability) and chemical properties (i.e., nutrient budget or growth inhibiting factors like aluminium or boron toxicity or nutrient deficiency).

In this particular investigation, auger samples from three different soil depths - 0 to 30 cm, 30 to 60 cm, and 60 to 90 cm - were randomly collected in six different locations in each plot. All six samples from each different depth represent a mixture or composite of three sub-samples per plot. Hence, a total of 120 and 60 composite soil samples were collected from the coconut-abaca and Rainforestation-abaca farms, respectively. However, due to voluminous number of soil samples to be analysed and the amount of financial and time resources needed for such analysis, only the results on 0 to 30 cm depths is presented on this report.

During the farm establishment, the two study sites were divided into different blocks based on topography, vegetation cover and species composition (Figure 3). The intention was to consider each block as one treatment and the

plots that belong to a particular block correspond as repetitions to the treatment. Caridad site was divided into 5 blocks with 7 plots each block, except block 5 which has 12 plots. Mailhi site, on the other hand, was divided into 4 blocks with 5 plots per block (Figure 4).

Results are presented in Table 8 in Caridad sites. To summarize, results reveal that Caridad soil has an average total and available nitrogen (Nt) of 1.9 g kg^{-1} . While the available phosphorus, and the exchangeable potassium, calcium and magnesium has an average value of 4.1 mg kg^{-1} , 251.4 mg kg^{-1} , 495.7 mg kg^{-1} and 192.6 mg kg^{-1} , respectively. Furthermore, it has an average pH value of 5.4, acidity of $1.4 \text{ cmol}_c \text{ kg}^{-1}$ and aluminium of $\text{cmol}_c \text{ kg}^{-1}$

Table 8. Site specific soil nutrients stocks, pH and soil acidity (H^+ and Al^{3+}) in different blocks of Caridad site within 0-30 cm soil depth

Block Number	Nt g kg^{-1}	P mg kg^{-1}	K mg kg^{-1}	Ca mg kg^{-1}	Mg mg kg^{-1}	pH (in H_2O)	H^+ $\text{cmol}_c \text{ kg}^{-1}$	Al^{3+} $\text{cmol}_c \text{ kg}^{-1}$
Block 1	2.5	3.9	285.1	524.5	241.8	5.2	1.8	1.4
Block 2	2.2	4.4	307.1	421.1	214.2	5.6	1.3	1.4
Block 3	1.6	4.6	251.0	375.1	187.6	5.4	1.7	1.9
Block 4	1.1	4.6	193.4	445.8	170.9	5.3	2.0	1.0
Block 5	1.9	3.6	233.2	622.0	166.9	5.6	0.8	1.2

Mailhi soil, on the other hand, has an average total and available nitrogen of 1.7 g kg^{-1} , available phosphorus of 3.4 mg kg^{-1} , exchangeable potassium of 130.5 mg kg^{-1} , exchangeable calcium of 140.3 mg kg^{-1} , and exchangeable magnesium of 85.3 mg kg^{-1} . Likewise, the soil has an average pH, acidity and aluminium value of 4.9, 6.5 mg kg^{-1} and 4.7 mg kg^{-1} , respectively. Table 9 shows the site specific soil nutrient stocks, pH and soil acidity (H^+ and Al^{3+}) in different blocks of Mailhi site within 0-30 cm soil depth.

According to the study of JAHN and ASIO (1998) in both Alisol and Adosol, they concluded that both soils have excellent physical qualities regarding rootability

and air and water supply to plants. Likewise, both soils show a reasonable amount of nutrient reserves but with a very low amount of phosphorus for plant nutrition.

Table 9. Site specific soil nutrient stocks, pH and soil acidity (H^+ and Al^{3+}) in different blocks of Mailhi site within 0-30 cm soil depth

Block Number	Nt g kg ⁻¹	P mg kg ⁻¹	K mg kg ⁻¹	Ca mg kg ⁻¹	Mg mg kg ⁻¹	pH (in H ₂ O)	H ⁺ cmol _c kg ⁻¹	Al ³⁺ cmol _c kg ⁻¹
Block 1	1.1	1.8	231.6	276.3	163.1	5.1	7.0	5.2
Block 2	1.4	3.0	85.4	111.1	79.2	4.9	5.1	4.4
Block 3	1.6	4.0	142.8	112.3	60.0	4.9	5.9	3.7
Block 4	2.6	4.8	62.4	60.3	39.0	4.7	7.9	5.3

3.2.1 Total and Available Nitrogen

Tables 8 and 9 show that values from different blocks shows some degree of spatial variability. This variability in both soils (Caridad and Mailhi) in total nitrogen can be credited to the history of land uses of both sites. A study of ASIO et al (1998) on Alisol and Andosol soils show similar results particularly in Alisol. They cited that the less defined differences in the total N (among secondary land uses in the Alisol) could be attributed to the complex history of most of the land uses.

In Caridad site, the variability of total nitrogen values in the different blocks is probably due to the burning of coconut husk during copra harvesting and the presence of kudzu (*Pueraria phaseoloides*) as cover crop which could have an effect on the amount of total nitrogen in the soil profile. For Mailhi site, it is probably due to the contribution of leguminous trees planted within the blocks under the Rainforestation concept. According to JENNY (1950) – as cited by ASIO et al (1998) - the high N content of Colombian forest soils is due to the contribution of leguminous tree species. Furthermore, the amount of easily decomposable material coming from the tree biomass may have enhanced N mineralization in the soil profile.

3.2.2 Available Phosphorus

Phosphorus is often the most limiting nutrient in ecosystems on weathered tropical soils (TIESSEN 1998). PAGEL (1982) explained that phosphorus strongly influence vegetational growth since it is an important constituent in most of the metabolic process of plants.

As can be seen in Table 8, available phosphorus in different blocks of Caridad soil ranges between 3.6 to 4.6 mg kg⁻¹ while, in Mailhi soil, the values range from 1.8 to 4.8 mg kg⁻¹ between blocks. However, both values are very low. According to HOFFMANN'S (1991) nutritional standard for phosphorus on agronomic crops, soils with values within the range between 0-22 mg kg⁻¹ is classified as low (category A) for plant nutrition. Similar findings were reported by ASIO et al (1998) in Andosol (2-4 mg kg⁻¹) and Alisol (1 mg kg⁻¹) in the surface horizon. They explained that this is due to the mineralogical characteristics of both soils.

3.2.3 Exchangeable Potassium

According to PAGEL (1982), potassium is frequently deficient in humid tropical soils due to high degree of weathering and its high mobility. Depending on the parent material, clay mineral composition and degree of weathering total potassium contents in the soils vary from 0.01 to 2.73% (PAGEL 1982).

Average values of exchangeable potassium in the different blocks of Caridad and Mailhi soils show high variability. The same findings were observed by ZIKELI (1998) in Mt. Pangasugan soil (Andosol) and ASIO et al (1998) in Ormoc soil (Andosol) and Baybay soil (Alisol). In the case of this study, the variability of exchangeable K on the surface soil of the different blocks in Caridad soil could have been caused by land uses and periodic burning and decomposition of coconut husk.

Meanwhile, for Mailhi soil, variability of average values might be due to the tree species composition within blocks as trees frequently function as “potassium-pumps” withdrawing potassium from deeper to the surface horizons where this accumulates with organic material. A study of ZIKELI (1998) on the

nutrient content of litters in Mt. Pangasugan (which has similar elevation with the study site and about 20 kilometers away from Mailhi) recorded an average value of 1969 mg kg⁻¹ DM of potassium of the three sites examined. In addition, the inputs via rainfall or stemflow and through fall may play a significant role in differences of values between plots. Again, the study of ZIKELI (1998) in Mt. Pangasugan on nutrient contents of rainwater revealed a range between 0.92 to 1.52 mg l⁻¹ of potassium.

Finally, the average value of available potassium in Caridad soil which is 251.4 mg kg⁻¹ qualifies under category D (very high) based HOFFMANN'S (1991) nutritional standard for potassium on agronomic crops which explains that soils having available potassium values within the range between 233-332 mg kg⁻¹ are classified as very high in K for plant nutrition. On the other hand, the average value of Maihi soil which is 130.5 mg kg⁻¹ qualifies under category B. This means that soils having available potassium values of 67-141 mg kg⁻¹ are moderate for plant nutrition.

3.2.4 Exchangeable Calcium and Magnesium

Results revealed that Caridad soil has a high available calcium and magnesium compared to Mailhi soil in the surface horizon. The high availability of Ca and Mg in Caridad soil could be attributed to the ash produced during the burning of coconut husk. According to SANCHEZ (1976) – cited by ASIO et al (1998) – in an Alfisol in Ghana, ash contained 1.5 to 3 tons Ca ha⁻¹ and 180 kg Mg ha⁻¹. It can be due also to the contribution of work weathering. In Mailhi soil, this may be due to soil erosion. As can be seen in Table 9, Ca and Mg decreased from blocks 1 to block 4. Based on the site topography, block 4 has a gradient of 67% and an elevation of 380 amsl while block 1 has 7% and 326 amsl gradient and elevation, respectively.

The variation on the average values of Ca and Mg between different blocks in both sites on the surface horizon is attributed to human disturbance.

3.3 Plant Nutrient Uptake

Information on the concentration of nutrients in plant tissues is useful in diagnosing nutrient deficiencies provided standard values are known (LAHAV 1996). TWYFORD (1967) added that such data could help to distinguish between nutrient deficiencies when symptoms are similar (e.g. nitrogen and copper in bananas), or when there are multiple deficiencies. Plant analysis can diagnose toxicity as well as deficiency (BERGMANN 1988). However, RÖMHELD (2003) pointed out that soil analysis can also be helpful since it provides a measure of the nutrient available in the soil, but this must be conducted together with plant analysis since the latter can tell us whether these nutrients are being absorbed.

Analysis of plant parts for mineral elements and the attempt to set standards for interpreting leaf analysis data came to the fore in the late 1960s (MARTIN-PRÉVEL and MONTAGUT 1966B; MONTAGUT and MARTIN-PRÉVEL 1965; GOWEN 1996). However, each researcher has approached the problem differently, probably reflecting a lack of unifying concepts in understanding the growth and nutrition of *Musa spp.* (LAHAV 1996).

According to LAHAV 1996, to diagnose nutrient deficiencies and excess using plant analysis is appealing, but it can be used only with reservation, because many factors affect the concentration of nutrients in an organ, apart from nutrient supply.

The primary basis for the representation of the results in this section is based from composite leaf analyses. The analysis was carried out in order to determine the level of abaca nutrition, although the critical nutrient concentrations are still unknown. The measurement of K and Ca was done with the flame-photometer, while Mg, P, and Zn was with the atomic-absorbance-spectrometer. The N was measured using the elemental analysis. Details of methods are given in Appendix B.

Similar to section 3.2 (site nutrient status), the results are presented in blocks per study site. This will simplify comparison of results within the system.

3.3.1 Critical Nutrient Concentrations in Banana and Plantain Leaves

Since there is no available data for critical nutrient concentration of abaca leaves research results on banana and plantain are taken into account to compare results and to understand the effect of nutrient deficiency on the morphological and physiological performance of *Musa textilis*. According to GARNICA (1997), critical nutrient concentration in banana and plantain leaves vary according to the method used.

MARTIN-PRÉVEL (1977) cited three different methods in obtaining banana samples for leaf analysis. The first method is the method developed by French researchers which recommends taking 10 cm leaf samples consisting of lamina and central rib from leaf number 3. Another approach is the method developed by Israeli researchers, more or less similar to the first method, but the sample should be taken during the adolescent stage of the plant. The last method is the one developed by Australian researchers which recommends taking the leaf sample from the third leaf during the adolescent stage of the plant and should not contain the central rib. Table 10 shows the critical nutrient concentrations according to the investigations of various authors.

In the case of this investigation, leaf samples were collected from both young (newly expanded leaf) and old (before the occurrence of flag leaf) leaves of abaca plants in each plot. For statistical reasons, leaf samples were collected from the 30% of the total number of plants per plot in each study site. This means that 7 (30% of 25 plants) and 15 (30% of 50 plants) plant-leaf samples per plot were collected in Barangays Caridad and Mailhi, respectively. Each of these 7 (in Barangay Caridad) and 15 (in Barangay Mailhi) plant-leaf samples represent a composite leaf sample for one plot per study site. Thus, a total of 40 composite leaf samples in Barangay Caridad and 20 composite leaf samples in Barangay Mailhi were collected.

Table 10. Critical nutrient concentrations in banana and plantain leaves or petioles

	N g kg ⁻¹ DM	P g kg ⁻¹ DM	K g kg ⁻¹ DM	Ca g kg ⁻¹ DM	Mg g kg ⁻¹ DM	Zn mg kg ⁻¹ DM	Authors
<i>Banana</i>	28.2	2.2	34.9	5.5	2.9	36	TURNER and BARHUS (1977)
	24.9	2.6	32.5	5.9	3.5	-	DUMAS (1960)
	29.0	1.7 ^a	17.9 ^a	23.5 ^a	6.8 ^a	18	LAHAV et al (1981)
<i>Plantains</i>	32.2	2.0	33.5	5.2	5.0	21	TURNER and BARKUS (1977)

Source: GARNICA (1997)

Note: ^a in the petiole

Compared to banana and plantain, results show that the nutrient concentrations in the abaca leaves of both sites are in critical conditions under the assumption that abaca has the same standard value to either banana or plantain. Details of the results are presented in Table 11. This confirms the results of the soil analyses in both sites which show that nutrient stock in the soils are very limited to support high planting density.

Table 11. Nutrient concentrations in abaca leaves of Caridad and Mailhi sites

Study Site	N g kg ⁻¹ DM	P g kg ⁻¹ DM	K g kg ⁻¹ DM	Ca g kg ⁻¹ DM	Mg g kg ⁻¹ DM	Zn mg kg ⁻¹ DM
Caridad site	21.2	1.5	36.1	4.0	3.1	18.9
Mailhi site	26.1	2.1	25.9	2.3	2.4	17.6

3.3.2 Nitrogen

Nitrogen is considered second only to potassium in terms of the amount needed for growth and production of abaca (TABORA, JR and SANTOS 1978). Results show that the Caridad site has slightly less nitrogen concentration in the leaves with an average of 21 g kg⁻¹ dry matter compared to Mailhi site. Interestingly, as can be seen in Figure 5, there is a variation of nitrogen concentration in abaca leaves within the different blocks which ranges between 18 to 24 g kg⁻¹ dry matter.

Compared to Caridad site, Mailhi site has a much higher nitrogen concentration in the leaves with an average of 26 g kg⁻¹ dry matter. Like Caridad site, its nitrogen concentration varies among different blocks (Figure 5) to an average range of 25 to 28 g kg⁻¹ dry matter. However, if one compares this concentration (in both sites) to the values of critical nitrogen concentration of banana and plantain leaves (Table 10) one can observe that this is below the critical concentration. Therefore, there is a nitrogen deficiency within both sites and this is supported by the results of the soil nutrient analysis (Table 8 and 9).

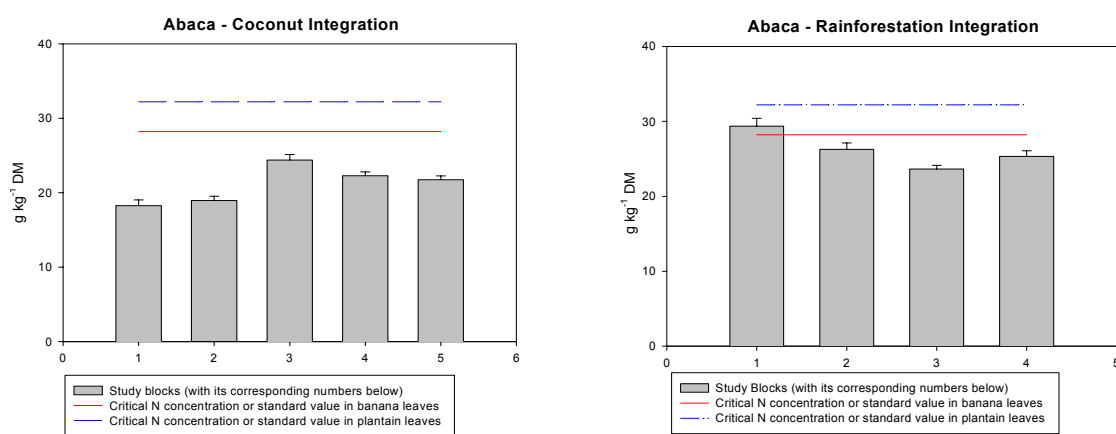


Figure 5: Nitrogen concentration in abaca leaves in different blocks of the two agroecosystems showing the critical N concentrations in banana and plantain leaves

VORM and DIEST (1992) reported that nitrogen is strongly redistributed from old *Musa* leaves to young ones. Hence, deficiency symptoms appear quickly and soon all leaves are affected. The leaves are pale green in colour with the midribs, petioles and leaf sheaths becoming reddish pink (MURRAY 1959). However, the study of GARNICA (1997) on plantains show that stunted growth was the first recognizable symptom of nitrogen deficiency after three months of planting. With increasing age, leaves changed colour from green to yellow then the edges of older leaves became necrotic towards the central rib.

In the case of this investigation, stunted growth and the leaves of the shoot showed a distinctive chlorosis and subsequently became necrotic (Plate 1). In addition, all the leaves of the plants demonstrated a light-yellow colouring particularly in Caridad site and in the upper elevation (block 4) of Mailhi site. According to GARNICA (1997), these symptoms occur when aged plants with

nitrogen deficiency cannot mobilize any further N compounds from older plant parts. Without nitrogen, proteins in chloroplast and cytoplasm are broken down which lead to a disruption or total arrest, of the chlorophyll biosynthesis (BERGMANN 1992).



Plate 1: Stunted growth, yellow-green colouring of leaves with compressed petioles (leaf photo) and edges of older leaves become necrotic towards the central rib (right photo).

3.3.1 Phosphorus

In Caridad site, the average phosphorus concentration in abaca leaves is $1.5 \text{ mg g}^{-1} \text{ DM}$, which is a little bit lower, compared to Mailhi site. In addition, as can be seen in Figure 6, there is no significant difference on the average concentration in each block. This observation was confirmed by the analysis of variance calculation. Meanwhile, Mailhi site has an average concentration of $2.1 \text{ mg g}^{-1} \text{ DM}$. However, analysis of variance shows that there is a significant difference between block 1 and block 4. Interestingly, results show that concentration decreases as elevation increases (Figure 6).

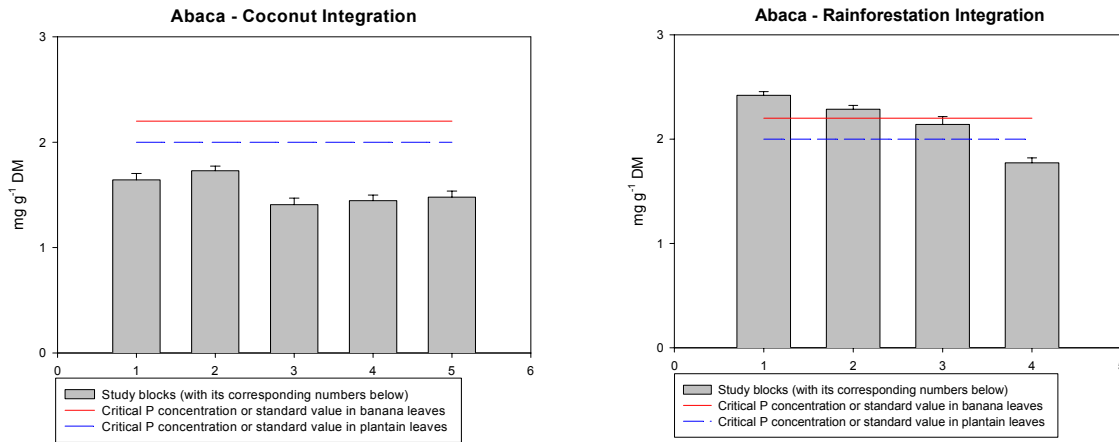


Figure 6: Phosphorus concentration in abaca leaves in the different blocks of the two agroecosystems showing the critical P concentrations in banana and plantain leaves

Phosphorus requirement of *Musa* is not large and deficiency symptoms are rarely seen in the field (MARTIN-PRÉVEL, 1978). According to LAHAV (1996), this can be explained by the facts that *Musa* accumulate the phosphorus they require over an extended period of time and a relatively small quantity of phosphorus is exported with the fruit. Likewise, VORM and DIEST (1982) reported that phosphorus is easily redistributed from old to young leaves, from leaves to the bunch (LAHAV 1974) and from the mother plant to suckers (WALMSLEY and TWYFORD 1968).

3.3.2 Potassium

Potassium is a key element in *Musa* nutrition in general (LAHAV 1996) and abaca in particular (TABORA, JR and SANTOS 1978). The earliest reference to analysis of abaca plant sap (RICHMOND 1906 cited by TABORA, JR. 1978) showed a high concentration of potassium in the plant (about 30.56% K₂O). The same observation was found in banana plant sap (FOURCROY and VAUQUELIN 1807 cited by LAHAV 1996).

In this study, results show that in Caridad site the average potassium concentration in the abaca leaves is 36.1 mg g⁻¹ DM which is higher than in Mailhi site with an average of 25.9 mg g⁻¹ DM (Figure 7). However, the potassium contents in the leaves in both sites are below the critical nutrient

concentration if this will be compared to the value of the banana and plantains' critical potassium concentration in the leaves (Table 10).

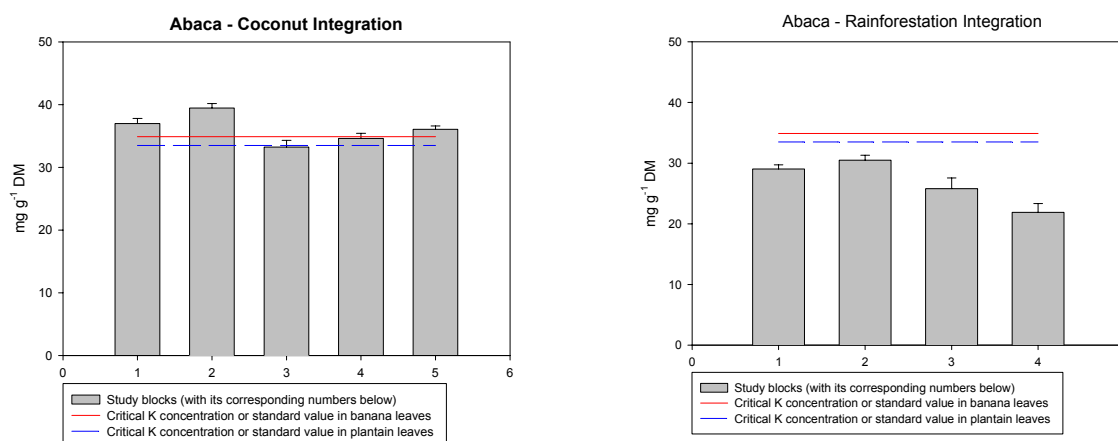


Figure 7: Potassium concentration in abaca leaves in different blocks in the two agroecosystems showing the critical K concentrations in banana and plantain leaves

According to Lahav (1996), the most universal symptoms of potassium deficiency is the appearance of yellow-orange colour in the oldest leaves and their subsequent rapid desiccation, hence, reduced the total leaf area of the plants. In addition, this nutrient deficiency does not only lead to the reduction of leaves sizes but also on the predominant effect of potassium on the longevity of the leaf (LAHAV 1972b; MURRAY, 1960; GARNICA, 1996). Similar symptoms were found in this study where there was a shortening of abaca leaf life span and reduction of cumulative functional leaf area (Figures 15 and 16) particularly in Caridad site. Furthermore, the leaf sheaths of the pseudo stem rotted and gave off an odour of decay and simultaneously the plants became infested with the weevil (Pate 2). A similar result was reported by GARNICA (1996) in plantains. According to Bergmann (1992), K deficiency causes the synthesis of organic compounds to be more inhibited than photosynthesis.



Plate 2: The photo shows a parent plant died and the leaf sheaths of the pseudo stem rotted and gave off an odour of decay and simultaneously the plants became infested with weevil.

3.3.3 Calcium

Uptake of calcium during the course of plant growth is influenced by cultivar and climate and follows dry matter accumulation (LAHAV 1996). TWYFORD and WALMSLEY (1973) reported that further uptake of calcium depends upon the site. The study of LAHAV and TURNER (1983) on Cavendish banana revealed that optimal whole plant calcium uptake as a function of soil calcium availability index ($\text{Ca}/\text{K}+\text{Ca}+\text{Mg}$) was calculated as 0.7 meq per 100 gram soil.

Meanwhile, results show that Caridad site has an average calcium concentration of 4.0 mg g^{-1} DM compared to Mailhi site of 2.3 mg g^{-1} DM (Figure 8). However, both values are lower compared to the critical calcium concentration in both banana and plantains (Table 10).

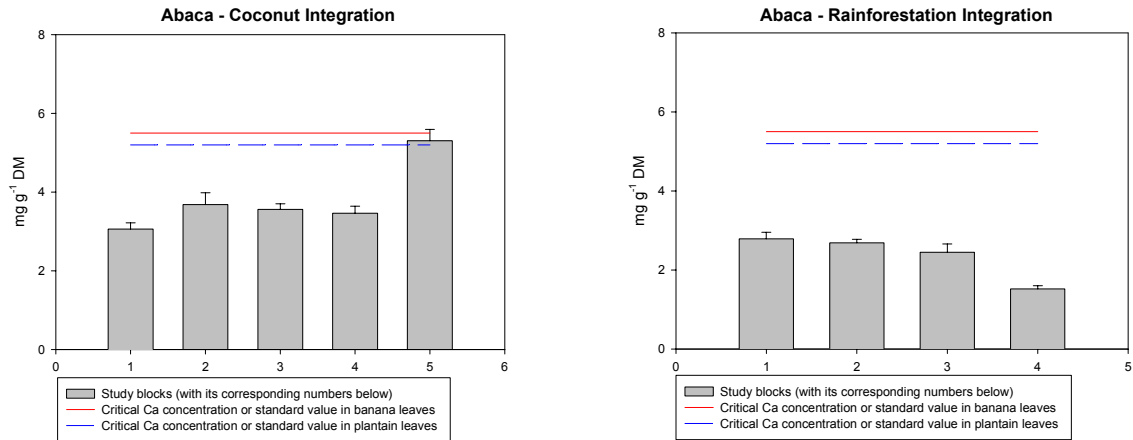


Figure 8: Calcium concentration in abaca leaves in different blocks in the two agroecosystems showing the critical Ca concentrations in banana and plantain leaves

As can be seen in Figure 8, in the abaca – coconut integration, abaca plants that were planted in block 5 contain high amount of Ca in the leaves while the Ca values in block 1 and 4 are more or less comparable. On the other hand, abaca – rainforestation show different results. Like the other nutrients mentioned above, concentration decreases from block 1 to 4. The results from the analysis of variance calculation show that there is a significant difference between block 1 and block 4.

3.3.4 Magnesium

Magnesium is considered to be moderately redistributed in the *Musa* plant (VORM and DIEST 1982). CHALKER and TURNER (1969) reported that deficiencies usually occur where bananas have been grown for 10-20 years without magnesium fertilizer or where high amounts of potassium fertilizer have been given for a number of years (MESSING 1974)

In Caridad site, the average magnesium content in abaca leaves is 3.1 mg g⁻¹ DM while Mailhi site has average magnesium concentration of 2.4 mg g⁻¹ DM. Again, both values are below the critical magnesium concentration in banana and plantain leaves.

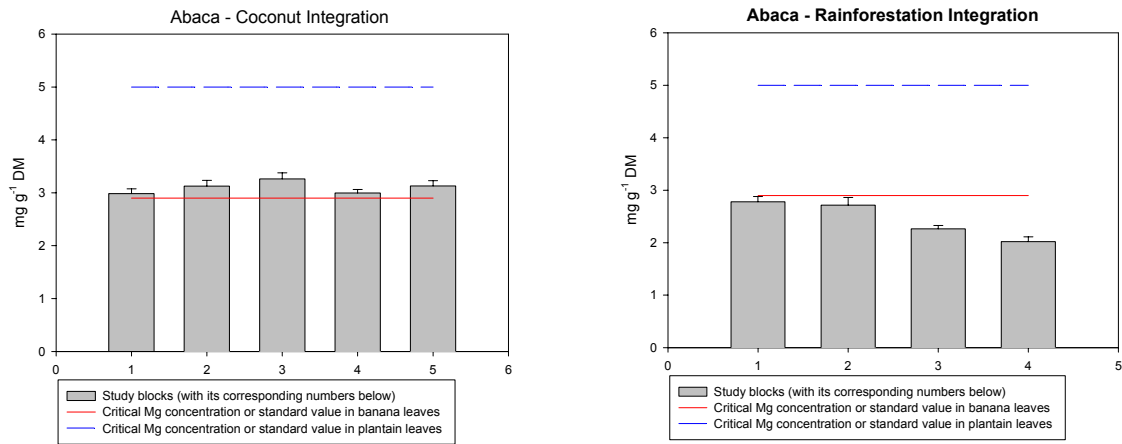


Figure 9: Magnesium concentration in abaca leaves in different blocks in the two agroecosystems showing the critical Mg concentrations in banana and plantain leaves

Figure 9 shows that abaca plants that were planted under the coconut monoculture contains higher amount of Ca in the leaves compared to the abaca plants integrated into the Rainforestation farming system. However, the Ca values in former site (abaca – coconut) from block 1 to 5 do not differ significantly. On the other hand, the abaca – rainforestation integration show the same trend (like other nutrients mentioned above) where magnesium concentration decreases from block 1 to 4. Furthermore, the analysis of variance confirmed that there is a significant difference between block 1 and block 4.

3.3.5 Zinc

The most widely reported minor element deficiency of *Musa* particularly banana is Zinc (CARDENOSA-BARRIGA 1962; JORDINE 1962; MOITY 1954). According to FREIBERG (1966), it has often been confused with virus infection. LAHAV (1996) reported that zinc deficiency is more common on naturally high pH soils or on highly limed soils because zinc ions in the chelate complex can be replaced by calcium ions.

Zinc is moderately distributed from old to young leaves (VORM and DIEST 1982). The characteristic symptoms appear in young leaves which become significantly smaller in size and more lanceolate in shape (JORDINE 1962). The study of GARNICA (1996) on plantains revealed that zinc deficiency caused a

chlorosis of the three youngest leaves which is only visible on the upper leaf surface and the underside of the leaves demonstrated a rose-pink colouring. According to BERGMANN (1992), zinc deficiency inhibits protein synthesis, reduces the number of chloroplasts and causes a decrease in the chloroplast level.

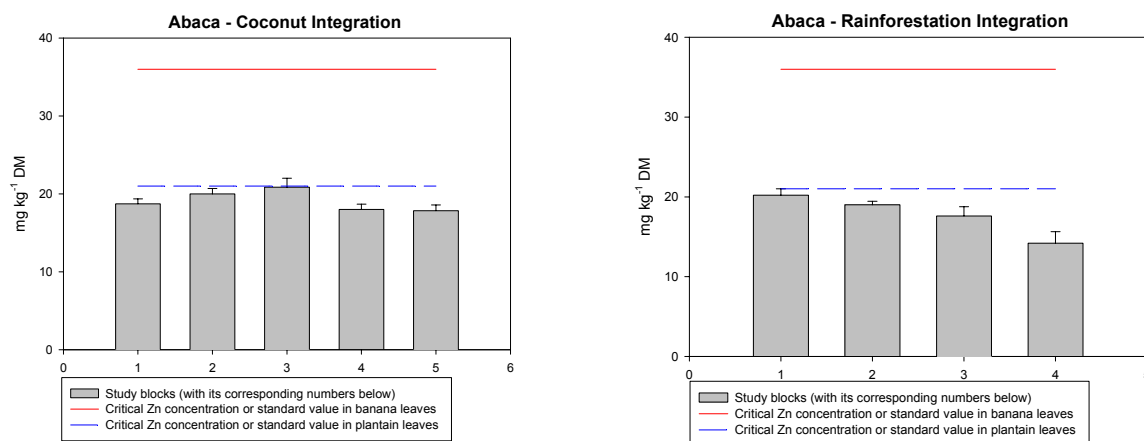


Figure 10: Zinc concentration in abaca leaves in different blocks in the two agroecosystems showing the critical Zn concentrations in banana and plantain leaves

Results show that the average zinc content in Caridad and Mailhi sites are 18.9 mg kg⁻¹ DM and 17.6 mg kg⁻¹ DM, respectively. Again, the values are lower compared to the critical zinc concentration of banana and plantain leaves. Meanwhile, Figure 10 shows that abaca plants that were planted under the coconut monoculture, the Ca values from block 1 to 5 do not differ significantly. However, in the abaca – rainforestation integration, results show the same trend with other nutrients mentioned above (macro nutrients) where zinc concentration decreases from block 1 to 4. Again, result of the analysis of variance confirmed that there is a significant difference between block 1 and block 4.

3.4 Morphological and Physiological Performance

Monthly growth performance was monitored in the two study sites for the period September 2003 until June 2004. The following were measured: (1) site specific climate that include measurements on radiation, temperature, humidity

and wind; (2) canopy structure and light interception; and (3) monthly morphological and physiological changes of abaca plant.

The primary basis for the representation of the results in this section are from data obtained on plant height and diameter increment, leaf area and number of functional leaves from September 2003 to June 2004. Results from the measurement of irradiance are presented as well. Furthermore, like from the previous sections, the results are presented in blocks per study site. This will simplify comparison and discussion of results within the system.

3.4.1 Plant Height and Girth Increment

The measurements of plant height and diameter started immediately after the abaca suckers were planted. These parameters were collected every month to monitor the growth increment (both height and girth) of abaca plants in both sites.

3.4.1.1 Abaca – Coconut Integration

During the farm establishment, the average height and diameter of the abaca suckers (as planting materials) were 100 cm and 6.7 cm, respectively. Results show that after 1 month of planting, the average height was 114 cm with an average diameter of 4.6 cm. This means that the plants grow to an average height increment of 14 cm per month. However, the plant girth shows an opposite trend. Instead of developing, it decreased to an average of 2.1 cm per month. This is attributed to the inability of newly planted suckers to cope up with the evaporative demand due to the removal of roots and old leaves, young leaves were not fully adapted to high radiation and inactive root system which confirmed the work of ECKSTEIN (1994) on the physiological responses of banana. In addition, the decrease in physiological activity was aggravated by a short dry period after planting. Thus, explains higher water use and lower dry matter production of abaca.

Furthermore, after two months of planting, it was observed that both plant height and diameter continued to decline to an average of 111 cm and 4.0 cm, respectively. This is attributed to the delay of new root growth and an efficient

water uptake (ROBINSON and BOWER 1988). A similar result was observed by ECKSTEIN (1994) on the physiological responses of banana on different ontogenetic stage.

Finally, results show that there was an increase in physiological activity after 5-7 months from planting. This is due to root regeneration and an increase in leaf emergence rate. As can be seen in Figures 11 and 12, block 1 to 5 shows similar trend in physiological activity, both height and girth. Therefore, this increase in physiological activity in the latter stage of the study could be attributed to an active root system, a physiologically young leaf area and a high level of photosynthetic activity.

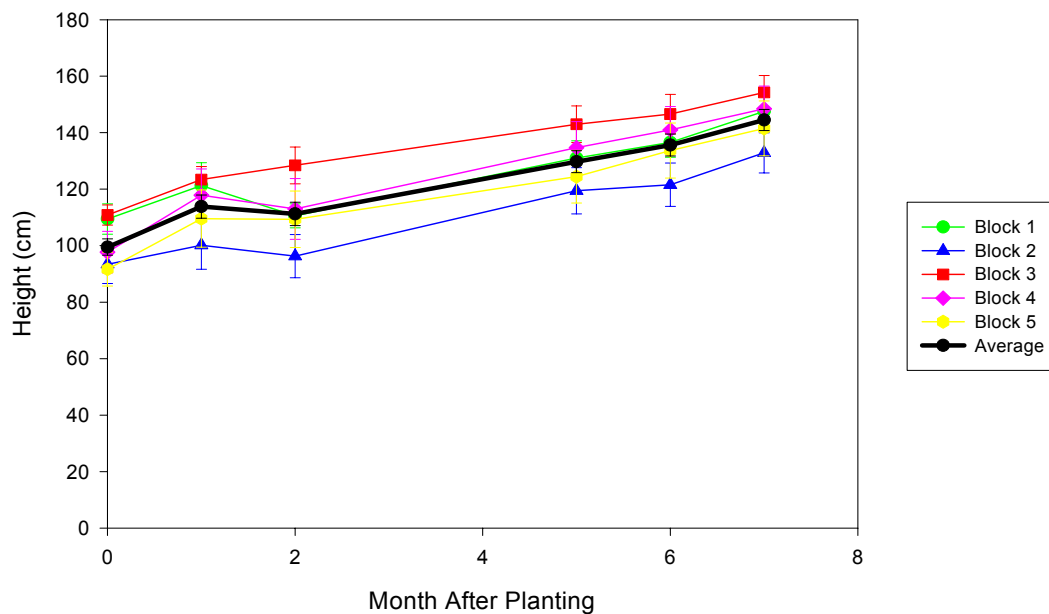


Figure 11: Height increment of abaca in different blocks of the abaca – coconut integration at Barangay Caridad

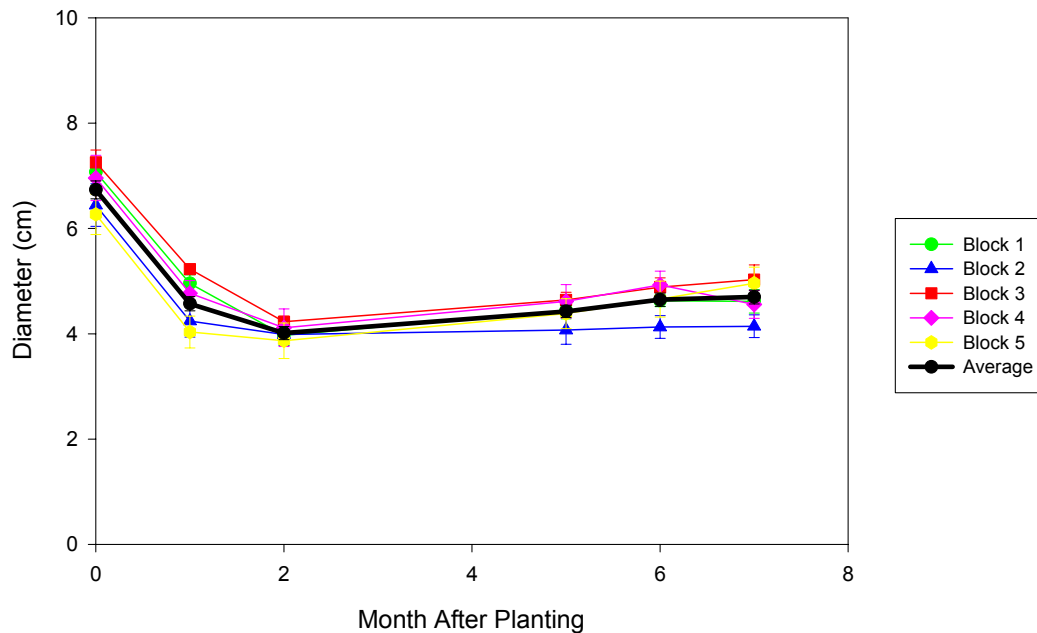


Figure 12: Girth increment of abaca in different blocks of the abaca – coconut integration at Barangay Caridad

3.4.1.2 Abaca – Rainforestation Integration

The average height and diameter of the abaca suckers during the time of planting were 99 cm and 6.7 cm, respectively. Results reveal that plant height increases to an average of 116 cm and 123 cm after 1 and 2 months from planting, respectively. This corresponds to an average height increment of 17 cm during the first month and 7 cm on the succeeding month. On the other hand, plant girth decreases to an average of 4.9 cm on the first month and 4.4 cm on the second month after planting.

However, an increase in physiological activity was observed after 5-7 months from planting due to root regeneration and an increase in leaf emergence rate which lead to the development of an active root system and a physiologically young leaf area. Therefore, a high level of photosynthetic rate.

Meanwhile, Figures 13 and 14 shows that there is a significant difference between block 1 and 4. This is confirmed from the result of analysis of variance. However, there is no significant difference between block 1 to block 2 and 3 as well as block 4 to block 2 and 3. This difference may probably start since beginning of planting the abaca suckers; wherein, block 1 and 4 has an average height of 113 cm and 90 cm, respectively. Likewise, the average diameter was 7.1 cm in block 1 and 6.5 cm in block 4.

One month after planting, block 1 has an average height increment of 16 cm while block 4 has 22 cm. Furthermore, after 5 months from planting, block 1 continued to increase height (from 131 cm to 161 cm). However, block 4 show a decline in height from 116 cm to 107 cm. Field observations show that lodging of leaves and even breaking of pseudo stem due to high wind speed caused this decline in height. According to SIMMONDS (1959), wind speeds of 7-9 m s⁻¹ distort the crown when they are continuous such as in trade winds. Winds of about 18 m s⁻¹ blows down large plants, especially those with bunches (TABORA, JR. 1978; GREEN 1963). Lahav (1998) explained that wind is responsible for the exchange of energy, in the form of momentum, and the gases (i.e. CO₂ and water vapour) between the leaves and the atmosphere immediately above the crop. Therefore, causing both mechanical and physiological effects on the plants.

On the other hand, based on results presented in Table 9, it can be seen that potassium, calcium and magnesium decreases from block 1 to block 4. Hence, this difference in nutrient availability further contributed to the differences of block 1 and block 4 in terms of morphological performance and physiological performance. The results in Table 9 coincide with Figures 5 to 9. This confirmed the results from the study of MARTIN-PRÉVEL and CHARPENTIER (1962) – cited by GARNICA (1997) – on the banana dwarf Cavendish variety. They recorded the following plant heights for bananas: 2.30 m with phosphorus deficiency, 2.00 m with sulfur deficiency, 1.80 m with magnesium deficiency and 1.20 m with nitrogen deficiency.

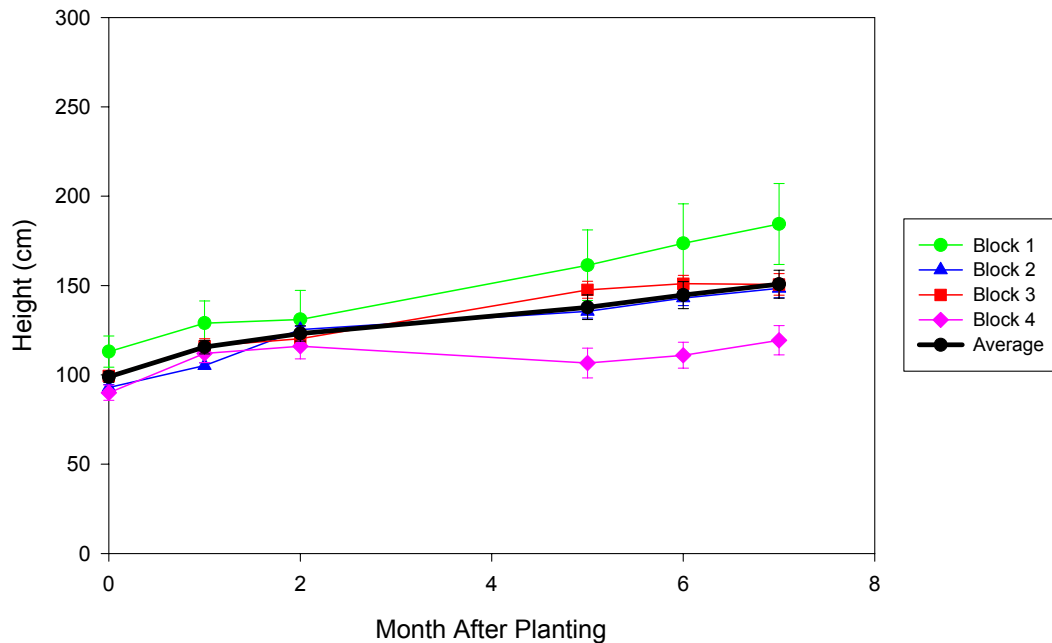


Figure 13: Height increment of abaca in different blocks of the abaca – rainforestation integration at Barangay Mailhi

Figure 14 show that the planting materials in block 1 (an average of 7.1 cm) were bigger in girth than block 4 (an average of 6.5 cm). However, both girth decline one month after planting.

However, a different trend was observed in block 1 after 5-7 months from planting. The abaca plants started to increase girth on an average of 0.25 cm per month. This is due to root regeneration and an increase in leaf emergence rate which lead to the development of an active root system and physiologically young leaf area. On the other hand, block 4 shows a continued decline of girth until the 7th month from planting. This is probably due to wind, since wind modifies the physiological functioning of the plant through its effect on the boundary layer and the temperature of the leaf (LAHAV 1996). This can be explained according to the Penman-Monteith equation which describes the relationship between wind speed and evaporation (MONTEITH 1973) that predicts an increase in evaporation as wind speed increases. Therefore explains higher water use and lower dry matter production of abaca leading to smaller leaf

sheaths and diameter. Finally, the differences in nutrient availability between block 1 and block 4 further contributed to the continuous decline in girth.

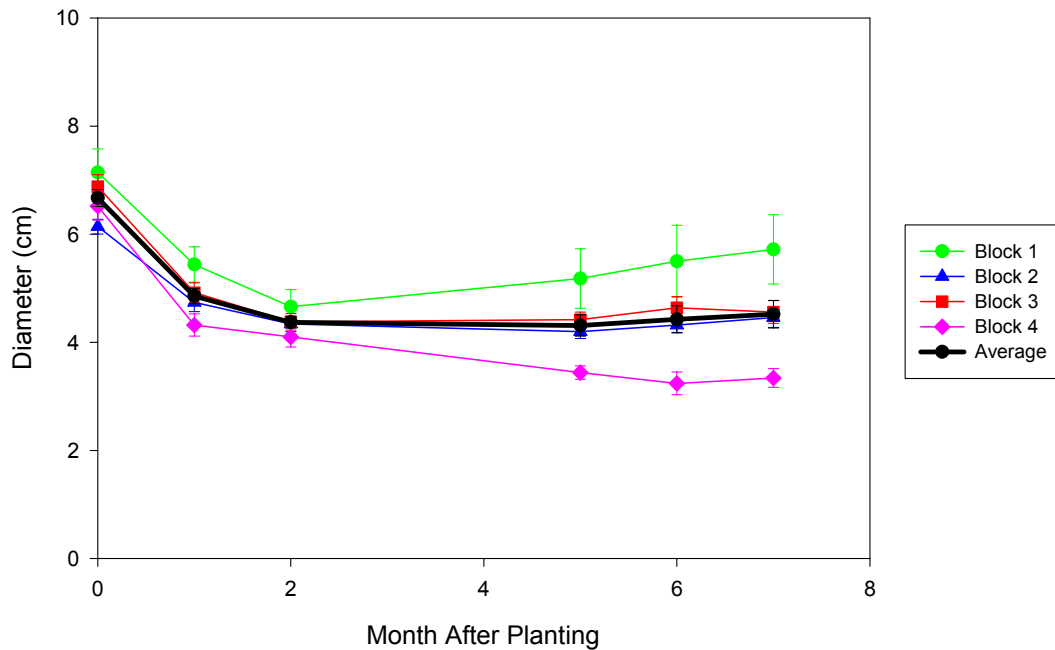


Figure 14: Girth increment of abaca in different blocks of the abaca – rainforestation integration at Barangay Mailhi

3.4.2 Leaf Area and Total Number of Functional Leaves

According to TABORA, JR (1978), the leaf of abaca becomes functional only after its unfurling and when the blade has been fully developed. When the leaf emerges from the cultural stalk, the blade simply starts to unroll. At emergence, the leaf develops chlorophyll and begins to be functional for the plant.

The size of the *Musa* plant and fruit bunch depends directly on the number and size of functional leaves. The formation and development of the leaves is dependent on light, temperature, plant nutrition, water availability and environmental factors, i.e., strong winds and pests (GARNICA 1997).

The leaf of abaca responds very much to diurnal changes. The leaf blade may last for 3 to 5 months before it becomes senile and non-functional (TABORA,

JR. 1978). However, the lifespan indirectly reflects the influence of nutrient deficiencies on the development of phytohormones, especially cytokinin and abscisic acid (GARNICA 1997).

3.4.2.1 Abaca – Coconut Integration

Results show that in Caridad site, the average cumulative leaf area is 1446.33 cm² per plant a month after planting. This continues to increase to an average of 6219.79 cm² per plant until 6th month from planting. Then a slight decrease after 7th month from planting to about 5886.99 cm² per plant (Figure 15). This slight decrease in cumulative leaf area is due to the decline on the number of functional leaves. Meanwhile, Figure 16 show that the average number of functional leaves is 1 per plant after one month from planting and continue to increase to 4.6 per plant after 6 months from planting. However, this decreases to 4.1 per plant after 7 months from planting. This is attributed to the different factors (i.e., plant nutrition and wind speed) where their side effects to abaca growth are cited from the previous section.

As presented in Figure 5-9, the macro nutrient contents in the leaves of Caridad site are within the critical concentration if this will be compared to value of the banana and plantains critical concentrations in the leaves (Table 10). The combined effect of these deficiencies lead to the reduction of leaves sizes as well as the longevity of the leaf. This explains the reduction of cumulative functional leaf area in different blocks due to shortening of leaf lifespan.

Figure 15 and 16 shows that there is no significant difference on the average cumulative functional leaf area and total number of functional leaves between blocks. This is confirmed from the result of the analysis of variance.

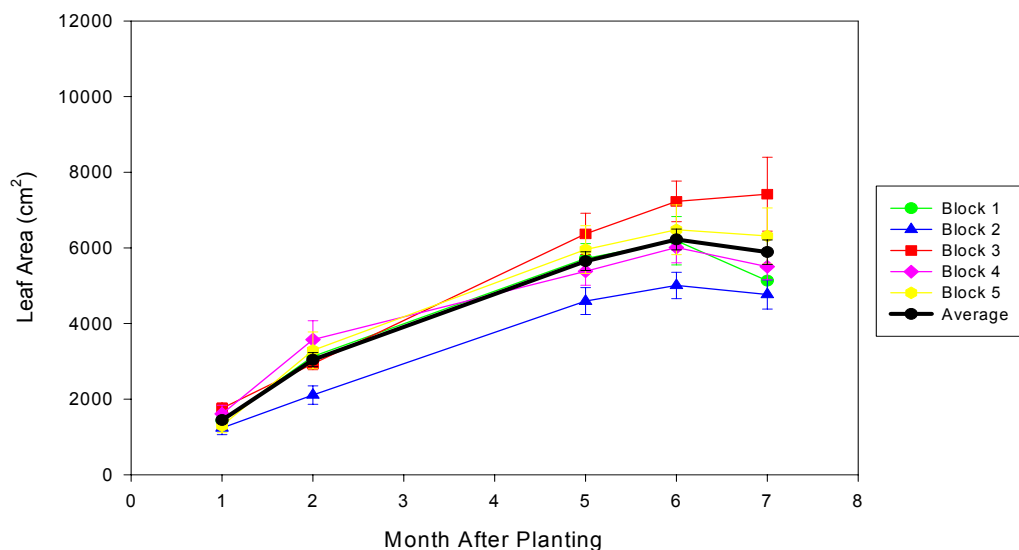


Figure 15: Functional leaf area of abaca in different blocks of the abaca – coconut integration at Barangay Caridad

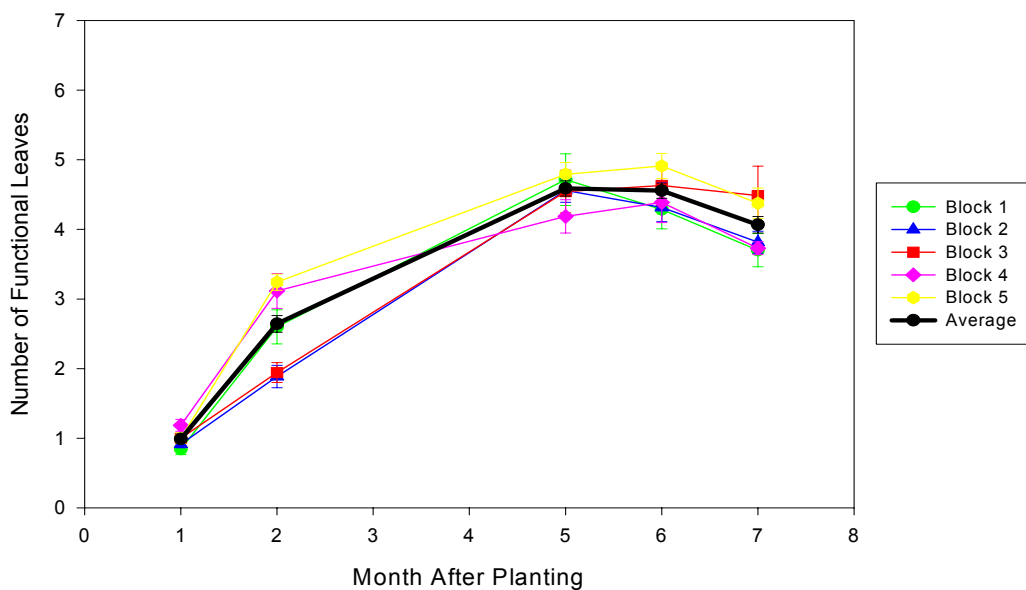


Figure 16: Total number of functional leaves of abaca in different blocks of the abaca–coconut integration at Barangay Caridad

3.4.2.2 Abaca – Rainforestation Integration

Figure 17 show that in Mailhi site, the average cumulative leaf area is 1025.50 cm² per plant a month after planting. This continues to increase to an average of 6453.63 cm² per plant until 7th month from planting. On the other hand, Figure 18 show that the average number of functional leaves is 0.6 per plant after one month and continue to increase to 4.3 per plant after 7 months from planting.

Furthermore, as can be seen in Figures 17 and 18, there is a significant difference between block 1 and 4. This is confirmed from the result of analysis of variance. However, there is no significant difference between block 1 to block 2 and 3 as well as block 4 to block 2 and 3.

Figure 17 show that block 1 has an average cumulative leaf area of 1184.91 cm² after one month and increases to 10433.45 cm² after 7 months from planting. Block 4, on the other hand, has 834.16 cm² during the first month and 3005.22 cm² after 7 months from planting. This means that block 1 has bigger and higher number of functional leaves compared to block 4. Again, this is attributed to the exposure of block 4 to high wind speed which lead to tearing and breaking of leaves. Thus, reducing the functional leaves and cumulative leaf area. Furthermore, the deficiency in the macronutrients aggravated these differences. Finally, the impact of wind on the physiological functioning of the plant. LAHAV (1996) explained that there is an increase in evaporation as wind speed increases. Therefore, explains higher water use and lower dry matter production of abaca leading to smaller number and sizes of leaves.

Meanwhile, Figure 18 show that block 1 has an average of 0.6 leaves per plant after one month from planting. However, after 7-month from planting, results show that there is an increase in leaf emergence rate to an average of 5.3 leaves per plant. The same trend is noticed in block 4, where an average of 0.6 leaves per plant developed after one month and increases to 3.2 leaves per plant after 7 months from the date of planting.

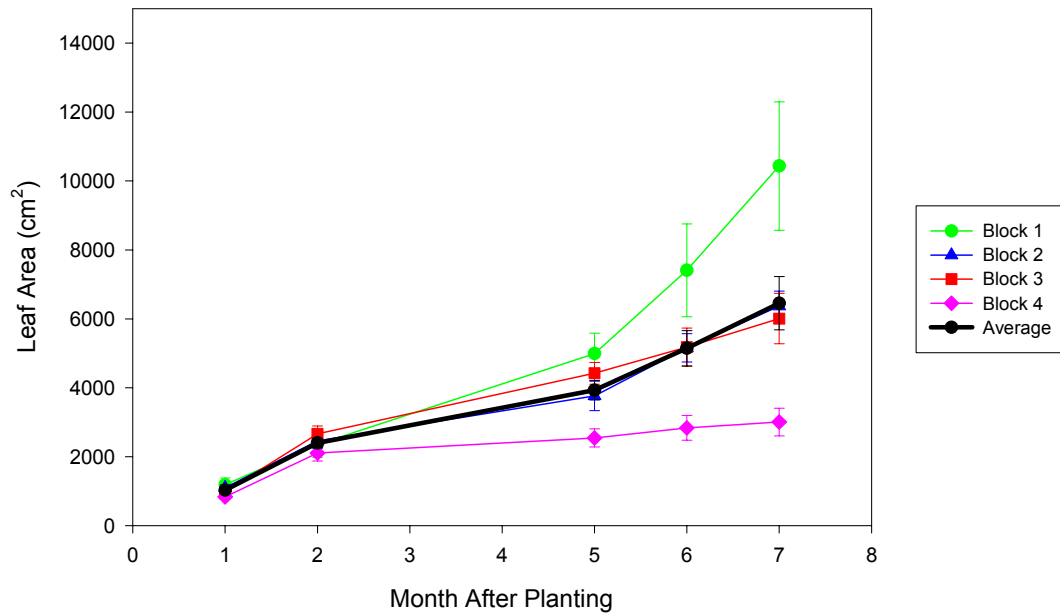


Figure 17: Functional leaf area of abaca in different blocks of the abaca-rainforestation integration at Barangay Mailhi

According to Eckstein (1994), the increase in leaf emergence rate lead to an active root system and a high level of photosynthetic rate. But, the differences in the number of functional leaves between block 1 and 4 has an effect on the level of photosynthetic rate between blocks. Likewise, the formation and development of the leaves is dependent on light, temperature, plant nutrition, water availability and environmental factors, i.e., strong winds and pests (GARNICA 1997). All of these factors affect the morphological and physiological performance of abaca in block 1 and block 4. Therefore explain their differences in the number of functional leaves.

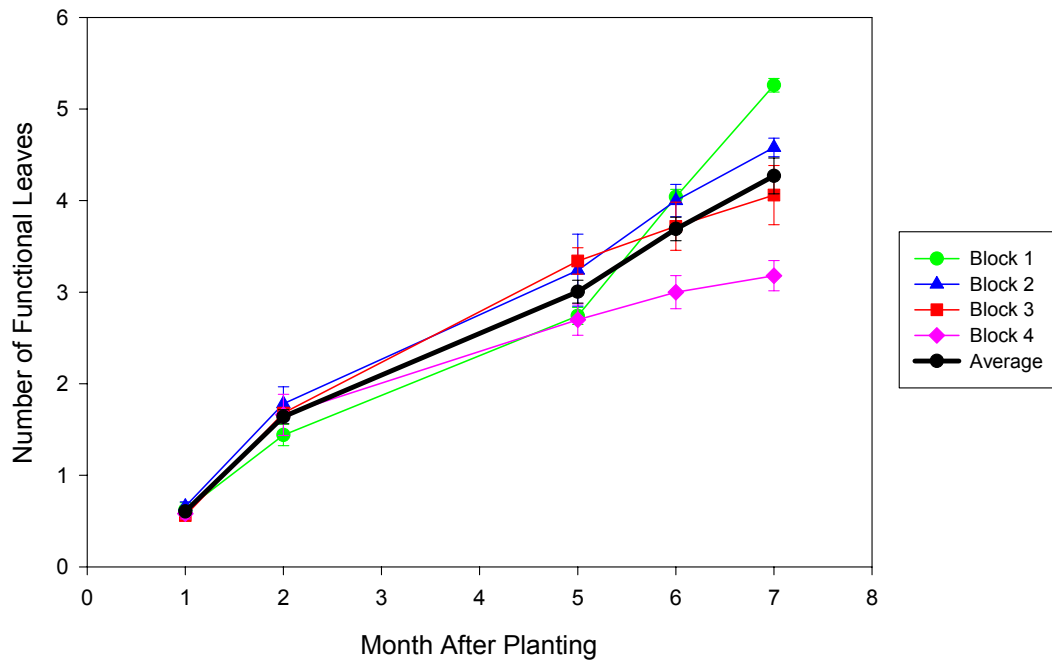


Figure 18: Total number of functional leaves of abaca in different blocks of the abaca – rainforestation integration at Barangay Mailhi

3.4.2 Irradiance Availability

About half of the energy received at the top of a plant canopy arrives as visible light. Leaves used absorbed light to fix carbon dioxide and create the substance of the plant. This together with the mineral nutrients from the soil, forms the dry matter that is partitioned amongst the various plant organs (LAHAV 1996). However, NOBEL and LONG (1985) cited that absorption of photosynthetically active photon flux (PAR) by the canopy depends on leaf angle, sun elevation in the sky, the finite width of the sun's disc, changes in spectral distribution of PAR through the canopy, multiple reflections of PAR within the canopy and the arrangement of leaves in the canopy.

Measurements of visible light above and below the abaca canopy per individual plant in each plot were conducted from September 2003 to June 2004 at different time interval by using a light sensor. The measurement was

conducted between 9:00-10:00 AM, 11:00 AM-12:00 PM and 14:00-15:00 PM. Hence, the primary basis for results representation in this section.

3.4.2.1 Abaca – Coconut Integration

The orientation of the coconut's long leaves at the top of the trunk, with the structure of leaves resembling Venetians blinds, permit part of the solar radiation incident on the foliage to pass through the lower profiles and the grounds. NAIR (1979) cited that the magnitude of radiation transmitted and the shade cast by the coconut canopy vary depending upon the age of palms. According to the study of NELLIAT et al (1974) on light availability in coconuts. He reported that when palms are about 8-10 years old, the percentage of sunlight transmitted is only about 20% and this remains almost constant until the palms are about 25 years of age. Subsequently, the percent light transmission increases progressively and the canopy coverage of ground decreases inversely. By the time the palms are about 40 years old, the light transmission increases to about 50%. This high transmission through the canopy of older palms is caused by the position of leaves and height of trunk. NAIR (1979) explained, as the palms get older, about a third of the total number of leaves in the crown bend downward, whereas in the younger palms, the leaf reaches only an angle up to 90° before it ripens and sheds off. The dropping of leaves will intercept less radiation and may probably reflect more light to the ground, than the horizontal or upright leaves (NAIR 1979). Likewise, as the trunk height increases, the magnitude of slant rays falling to the ground increases.

In this investigation, the irradiance availability above and below the abaca canopy in different plots varies significantly (Figure 19). This is attributed to the number of coconuts within plots and the differences on leaf angle, sun elevation in the sky, the finite width of the sun's disc, changes in spectral distribution of PAR through the canopy, multiple reflections of PAR within the canopy and the arrangement of leaves in the canopy. Results from the field measurements confirmed that clouds further contributed this variability.

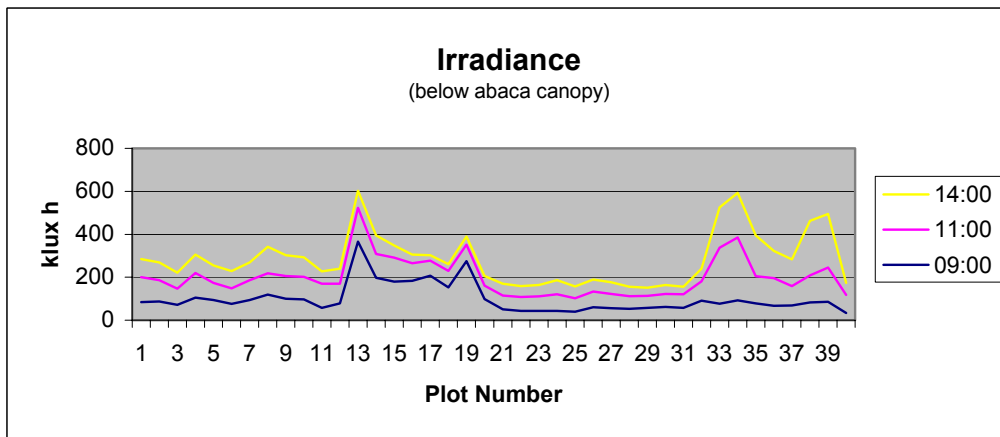
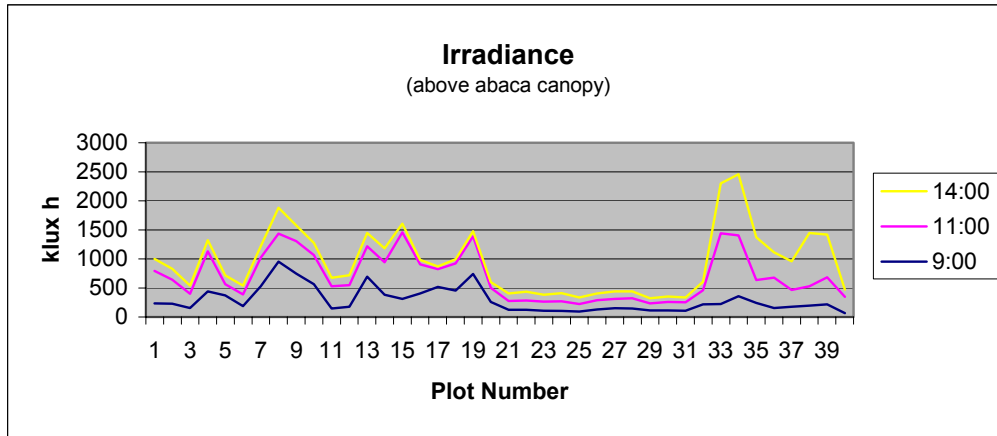


Figure 19. Irradiance availability in different study plots of the abaca – coconut integration at Barangay Caridad

Results show that plants received high irradiance in both above and below abaca canopy at 14:00 PM. Furthermore, computation of the light transmission ratio shows that the LTR1 (above the abaca canopy) and LTR2 (below the abaca canopy) are 33% and 11%, respectively (Figure 20). According to NAIR (1979), the high reflectance of the thick-cuticled coconut leaves and the position of leaflets cause shattering of incident radiation in all direction. As a result, the light intensity at the plantation floor, even directly under the canopy shade of coconuts, could be higher than would be expected, and maybe sufficient for the growth of some plant species.

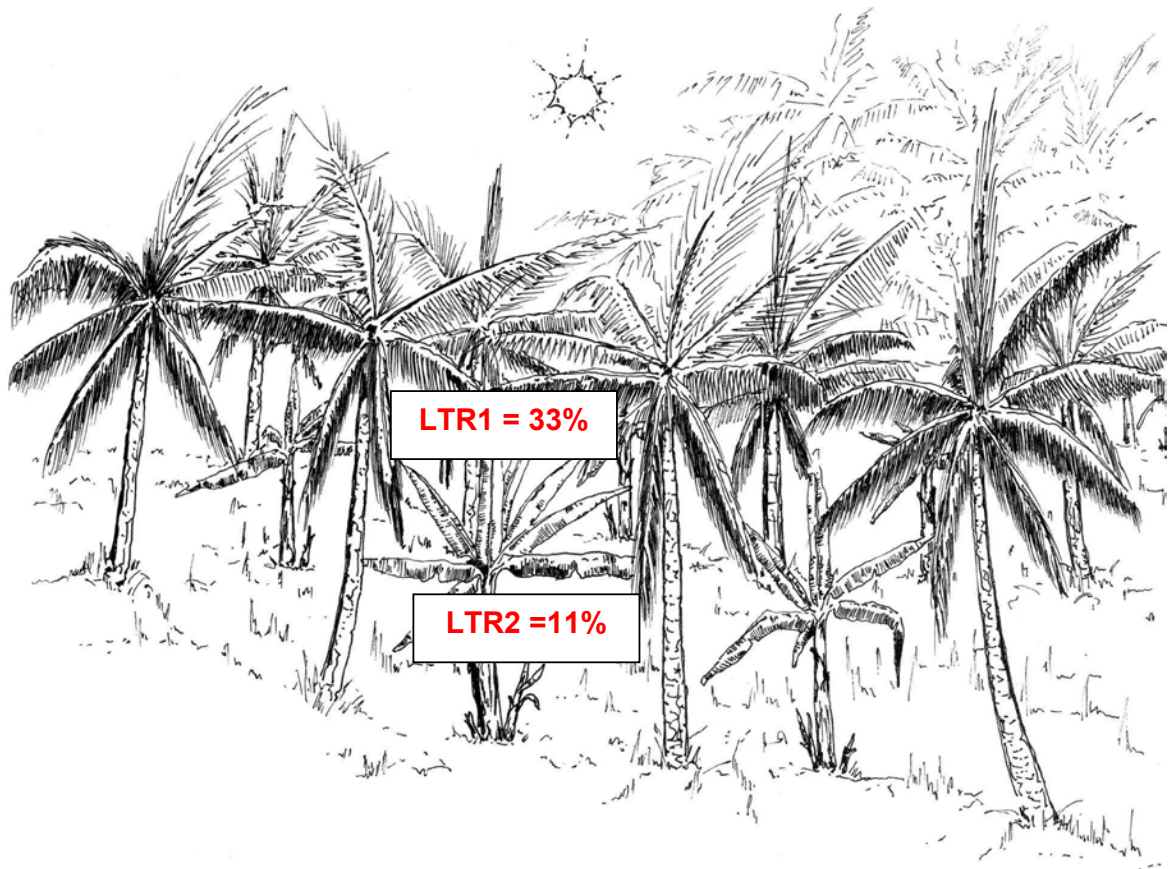


Figure 20. Light transmission ratio (LTR) above and below abaca canopy in an abaca – coconut integration at Barangay Caridad

3.4.2.2 Abaca – Rainforestation Integration

Figure 21 show that in Abaca – Rainforestation Integration, the irradiance availability above and below the abaca canopy also varies significantly. This is due to the differences on the number of shade trees between the plots and the differences on leaf angle, sun elevation in the sky, the finite width of the sun’s disc, changes in spectral distribution of PAR through the canopy, multiple reflections of PAR within the canopy and the arrangement of leaves. Furthermore, it is observed that the amount of clouds during the measurement significantly affects the reading that lead to variability of results. Finally, results from the computation of the light transmission ratio under such as system. Result show that LTR1 is 36% (above the abaca canopy) and LTR2 is 9% (below the abaca canopy). Figure 22 shows the light transmission ratio under abaca-rainforestation integration.

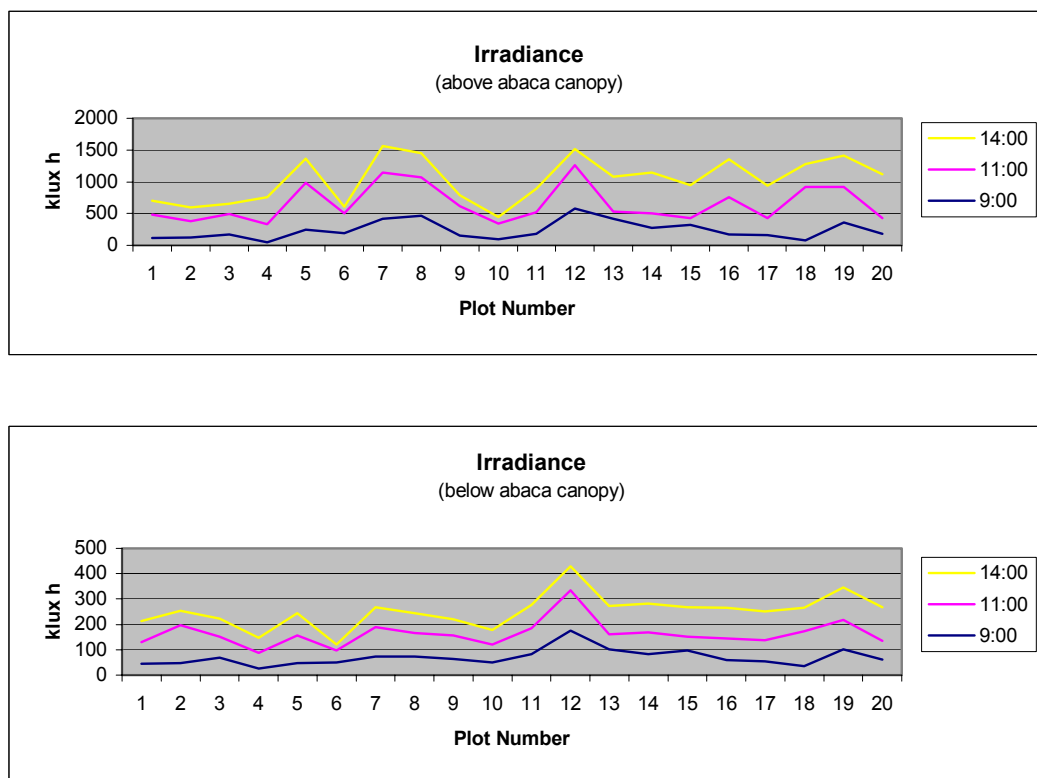


Figure 21. Irradiance availability in different study plots of the abaca – rainforestation integration at Barangay Mailhi

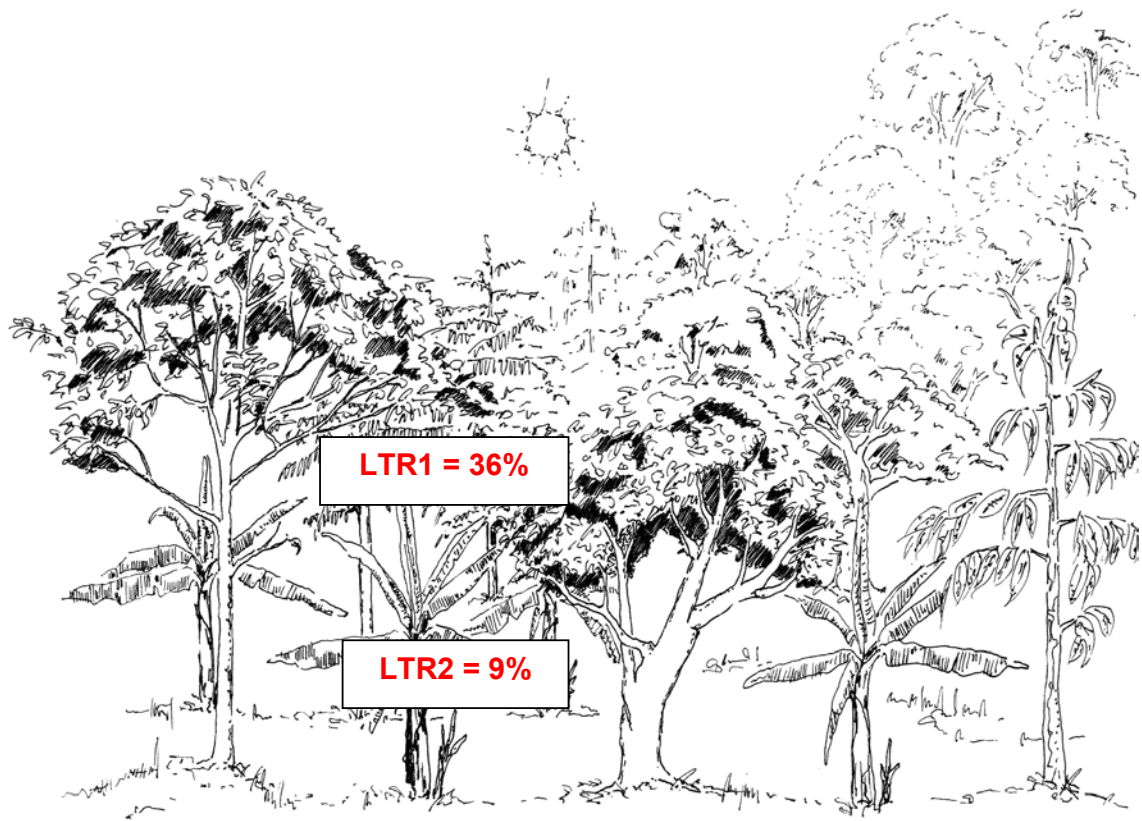


Figure 22. Light transmission ratio (LTR) above and below the abaca canopy in an abaca-rainforestation integration at Barangay Mailhi

4. Discussion

This section deals with the results derived from the specific site nutrient status, plant nutrient uptake and morphological and physiological performance of abaca plants that are integrated in the coconut monoculture and rainforestation concept. In this investigation, it is not possible to compare the results and draw conclusions immediately since both systems differ from various factors i.e., soil type, topography, land use and species composition, management practices and climatic factors to some extent (e.g. wind speed).

Thus, the primary basis for the discussion in this section is the results from the different blocks in each study site considering their differences in specific site nutrient status, plant nutrient uptake, and morphological and physiological performance of abaca plants. Then, conclusions will be generated which will be the basis for comparing the two different agroecosystems.

4.1. Abaca – Coconut Integration

4.1.1 Site Nutrient Status

In this particular agroecosystem, results show (Table 8) that availability of macronutrients from different blocks demonstrates some degree of spatial variability. This variability can be attributed to the history of land uses and farmer's management practice.

The variability of total nitrogen in the different blocks is probably due to the burning of coconut husk during copra harvesting and the presence of kudzu as cover crop which could have an effect on the amount of total nitrogen in the soil profile. However, available phosphorus was very low compared to the other nutrients. According to ASIO (1996), these results can be expected considering the mineralogical characteristics of the soil. Wherein, in this particular site, the soil is classified as Alisol according to FAO-World Reference Base. ASIO et al (1998) explained that Alisol is dominated by kaolinite and halloysite and contains significant amounts of goethite and hematite with more than 60% P retention capacity.

Furthermore, the variability of exchangeable K in the surface horizon of the different blocks could have been caused by the history of land uses and periodic burning and decomposition of coconut husk. The high availability of

exchangeable Ca and Mg, on the other hand, could be contributed from the ash produced during the burning of coconut husk.

Therefore, under such type of an agroecosystem, it can be concluded that site nutrient status depends upon the type of land use, management practice (i.e. periodic burning of coconut husk) and soil type.

4.1.2 Nutrient Uptake

According to LAHAV (1996), interpreting soil analysis for determining nutrient needs is difficult as nutrient uptake depends not only on nutrient concentration in the soil solution but also on rooting characteristics. Though concentrations in soils and leaves may be poorly related (TWYFORD and WALMSLEY 1974; TURNER et al 1989; LAHAV 1996), using both soil and plant tests may help in assessing critical values when clear nutritional contrasts appear (DELVAUX et al 1986).

As can be seen in Figure 5, a low nitrogen concentration in abaca leaves can be a result of low nitrogen supply. However, GARNICA (1997) explained that a low leaf nitrogen concentration does not necessarily caused by a pronounced soil nitrogen deficiency, it may have other causes. Wherein, in this case, the low concentration maybe aggravated by the competition between the abaca and coconut since both crops has an adventitious roots. TABORA JR (1978) reported that 70 to 90% of the abaca roots are at one-foot depth from the ground surface and extend laterally up to 8 feet (for an eight-month old plant). While, the active root zone (with maximum concentration and activity of roots) of coconut confined laterally within a radius of 2 meters from the base and vertically within 30-120 cm depth (NAIR 1979).

With regards to phosphorus, results reveal a very low concentration in abaca leaves. This confirmed to the result of the soil analysis that show very limited supply of available phosphorus in the soil solution which is according to ASIO (1996) is due to the mineralogical characteristics of the soil. GARNICA (1997) reported that a low phosphorus supply from the soil solution appears to be safely detected by leaf analysis giving low phosphorus concentration in the leaves.

However, for antagonistic cation such as potassium and magnesium. GARNICA (1997) reported that when potassium supply is low, its leaf concentration is also low. He further explained that a high potassium leaf concentration does not necessarily a result of high soil potassium supply. It can be due to magnesium deficiency, allowing a preferential uptake of potassium. But, in this case, Table 8 show that the high potassium concentration in abaca leaves is due to high supply of available potassium in the soil solution not due to magnesium deficiency.

As a result, it is not enough and safe to conclude that the low nutrient concentration in abaca leaves is due to low nutrient stocks in the soil solution. Moreover, the information on the concentration of nutrients in abaca leaves is insufficient in diagnosing nutrient deficiencies since the standard values for abaca is still unknown. However, by comparing these results to the critical nutrient concentration on other *Musa* species will help us in understanding the effect of nutrient deficiencies to the morphological and physiological performance of abaca under such as system.

4.1.3 Morphological and Physiological Performance of Abaca

The abaca plants show an opposite trend between height and girth increment after one month from planting (Figure 11). This is probably attributed to the following factors: a) inability of newly planted suckers to cope up with the evaporative demand due to the removal of roots and old leaves during planting, b) the newly developed or young leaf were not fully adapted to high radiation, c) inactive root system of the planting materials due to root damage caused during the separation from the mother plant, and d) short dry period after planting.

Two month later, it was observed that both plant height and diameter declined. This may be attributed to the delay of new root growth and an efficient water uptake. However, both height and girth tend to increase after 5-7 months which is due to root regeneration and an increase in leaf emergence rate leading to the development of an active root system and a physiologically young leaf area.

With regards to cumulative leaf area, results reveal an increase from the 1st to 6th month and a slight decrease after 7th month from planting (Figure 15). On the other hand, the number of functional leaves increased from the 1st to 6th month and decreased after 7th month from planting. Hence, the slight decrease in cumulative leaf area is due to the decline on the number of functional leaves. This is due to the combined effect of different factors such as plant nutrition, wind speed and mechanical damage caused by falling of coconut leaves either naturally or during copra harvesting. Thus, lead to the reduction of leaf sizes as well as the longevity of the leaf.

Therefore, under such type of a system, it can be concluded that the morphological and physiological performance of abaca depends upon on the following factors: a) type of planting materials that exhibit fast recovery of its root system and increase in leaf emergence rate (e.g. tissue cultured seedlings), b) plant nutrition, c) climatic and environmental factors (i.e., strong winds and pests), d) water availability during planting, and e) farm management and practices.

4.2 Abaca – Rainforestation Integration

4.2.1 Site Nutrient Status

As can be seen in Table 9, results demonstrate some degree of spatial variability on the availability of macronutrients from different blocks. The variability of available and total nitrogen in the different blocks is probably due to the contribution of leguminous trees planted within the blocks under the Rainforestation concept. Likewise, the amount of easily decomposable material coming from the tree biomass may further enhance N mineralization in the soil profile. Available phosphorus, on the other hand, is very limited in this type of soil which is Andosol due to its mineralogical characteristics. ASIO et al 1998 reported that Andosol contains high amounts of gibbsite, imogolite, and amorphous compounds with very high (90%) P retention capacity.

Meanwhile, the variability of exchangeable potassium might be due to the tree species composition within blocks where trees function as “potassium-pumps”. However, the differences of exchangeable Calcium and Magnesium

between blocks maybe due to soil erosion, human disturbance and litter accumulation.

Therefore, it can be concluded that the trees planted under the Rainforestation concept plays a significant role in the nutrient fluxes and the improvement of soil acidity. This is due to the fact that trees function as “nutrient-pumps”. However, the sustainability of the soil nutrient stocks depends on the type of management practice that farmer will adopt (either to cut trees for more abaca or to preserve them) which on the other hand a crucial factor for improving soil acidity and preventing aluminium toxicity under such type of soil.

4.2.2 Nutrient Uptake

As can be seen in Figure 5, there is a low concentration in abaca leaves which could be a result of low nitrogen supply in the soil solution. Results from the analysis of variance show a significant difference between Block 1 and Block 4. But, no significant difference between Block 1 to Block 2 and 3 and between Block 4 to Block 2 and 3. This difference is due to contribution of leguminous trees planted within each block under the Rainforestation concept. In addition, the amount of easily decomposable material coming from the tree biomass may enhanced N mineralization where topography and wind velocity play a significant role. The study of CUEVAS and SAJISE (1978) cited by ASIO (1996) in Mt. Makiling, Philippines concluded that topography and wind velocity influences very significantly the amounts of litter produced in the forest.

On the other hand, the average phosphorus concentration in abaca leaves is low, but varies between different blocks (Figure 6), but their is a significant difference between Block 1 and Block 4. GARNICA (1997) reported that a low phosphorus supply from the soil solution appears to be safely detected by leaf analysis giving low phosphorus concentration in the leaves. However, he added that the high phosphorus concentration in the leaves does not necessarily indicate an adequate phosphorus supply from the soil as it can be induced by nitrogen deficiency. Hence, in this case, the low supply of available nitrogen in the soil solution in Block 1 (Table 9) lead to a preferential uptake of phosphorus.

As a result, under such a system and soil type (Andosol), information on the concentration of nutrients in abaca leaves is insufficient in diagnosing nutrient deficiencies. Likewise, the knowledge between the interaction of native trees on both soil nutrients and its properties are very limited. Thus, it is not enough and safe to conclude that the low nutrient concentration in abaca leaves is due to low nutrient stocks in the soil solution. It maybe due to the soil cation balance and level, in the case of phosphorus-nitrogen interaction in block 1 and 4. Interestingly, result show that native trees play a significant role in the nutrient fluxes and the improvement of soil acidity. Therefore, contributing to a high degree of nutrient uptake in the abaca leaves considering the negative features of the type of soil under such a system. Finally, it can be concluded that the differences between Block 1 and Block 4 in all the nutrients being analysed (N, P, K, Ca, Mg and Zn) is due to topography and tree species composition under the rainforestation concept.

4.2.3 Morphological and Physiological Performance of Abaca

Figures 17 and 18 show that cumulative leaf area and the number of functional leaves continue to increase from the 1st until 7th month from planting. Likewise, as can be seen in both figures that there is a significant difference between block 1 and 4. However, there is no significant difference between block 1 to block 2 and 3 as well as block 4 to block 2 and 3. This is confirmed from the result of analysis of variance.

This difference is due to the exposure of block 4 to high wind speed which lead to tearing and breaking of leaves. Thus, reducing the functional leaves and cumulative leaf area. Likewise, the impact of wind on the physiological functioning of the plant where there is an increase in evaporation as wind speed increases causing a higher water use and lower dry matter production of abaca leading to smaller number and sizes of leaves.

5. Conclusion

One of the major objectives of this study was to evaluate the two multi-strata abaca production systems based on site and plant nutrient status, site adaptability and biological productivity. In this investigation, the site and plant nutrient status was evaluated based on soil nutrient stock and plant nutrient uptake. On the other hand, site adaptability and biological productivity was evaluated based on the morphological and physiological performance of abaca.

In abaca –coconut integration, site nutrient status depends upon the type of land use, management practice i.e. periodic burning of coconut husk and soil type. While, in plant nutrient uptake, results show that nutrient concentration of abaca leaves are below the critical nutrient concentrations of banana and plantains. However, it is not enough and safe to conclude that the low nutrient concentration is in critical condition since the standard values for abaca is still unknown. Thus, using the results for diagnosing nutrient deficiencies is insufficient. Likewise, it is inadequate and undefended to bring into conclusion that the low concentration of nutrients in abaca leaves is due to low nutrient stocks in the soil solution. It may be due to some other factors like nutrient competition between the two crops or cation balance in the soil solution. All these factors have an effect on the morphological and physiological performance of abaca. However, in the case of this study, morphological and physiological performance of abaca depends mainly on the type of planting materials that exhibit fast recovery of its root system and increase in leaf emergence rate. Another is the farmer's practice towards the management of coconut plantation.

While, in abaca – rainforestation integration, results reveal that the trees planted under the Rainforestation concept plays a very significant role in the nutrient fluxes and the improvement of soil acidity in the surface horizon. This is due to the fact that trees function as “nutrient-pumps”. Therefore, contributing to a high degree of nutrient uptake in the abaca leaves considering the negative properties (e.g. high exchangeable acidity and aluminium saturation) of the type of soil under such a system. However, the sustainability of the soil nutrient stocks depends also on the type of management practice that farmer will choose, either to cut or harvest the trees for more abaca or to

preserve them. Meanwhile, under such as system, topography is one of the major factors that affect nutrient availability in the soil and plant uptake leading to poor growth performance of abaca. Another factor is wind speed which has a direct impact on the physiological functioning and mechanical damage of the plant.

Another objective was to identify possible pathways for a sustainable abaca production scheme in the Philippines. Based on the results, the integration of abaca in the coconut monoculture is an impressive idea in preventing the cutting down of old coconut trees. However, result show that additional input, i.e. fertilizer, must somehow be considered to attain better morphological and physiological performance of abaca. Additionally, the type of planting materials must be taken into consideration by using tissue-cultured seedlings than suckers. However, all of these means, additional cost and this will trickle down to the target clientele who will make the final decision at the end.

Thus, integrating abaca under the rainforestation concept is a best option. This may provide additional income to the farmer adopters while maintaining the trees for biological purposes. In this investigation, results revealed that rainforestation farming appeared to be an effective way in restoring the functions of an agroecosystem and improving soil quality. However, the sustainability of such as system always lies on the hands of the farmer's, either to cut or harvest the trees for additional income or to preserve them for ecological purposes.

Therefore, it can be concluded that both sites are suitable for abaca production in terms of soil type and nutrient reserves. However, due to high planting density, additional inputs are needed to improve the crop's growth performance, like fertilizer and high quality planting materials that exhibit fast recovery of its root system and increase in leaf emergence rate. Likewise, topography and wind speed must be considered during site selection. Finally, integrating abaca into coconut monoculture maybe a good idea, but under such type of an acidic soil, integrating abaca into the Rainforestation concept is the best option. If sustainability of the whole agroecosystem functions is taken into account.

6. Summary

The establishment of an agroecosystem, as exemplified by clearing and cultivation, is primarily intended to serve human needs for agricultural products (KOCH et al 1990 cited by DARGANTES 1996). Once established, the agroecosystem is then geared towards the attainment of high crop yields. According to DARGANTES (1996), stability, which may only be maintained in special and exceptional cases and only within short periods, usually assumes a subordinate role to the objective of producing outputs with immediate economic value. Under these conditions, the interactive influences of the ecosystem and the socio-economic system exert undue influence over the ecosystem and subdue the elements and processes which maintain this equilibrium. And in Leyte, this is manifested by the loss of 163,000 hectares of the islands' forest lands to agriculture (ACOSTA 1991 cited by DARGANTES 1996).

GROETSCHHEL et al (2001) stressed that the amount of remaining forest cover can be used as an indicator of the critical situation regarding land access for the increasing number of people dependent on agriculture. The decreasing productivity and increasing instability of the island upland resource base is reflected in the increasing poor economic status of the upland population (STARK 2000). Therefore, a combined effort (i.e., government, research institutions and forest occupants) is required to propagate ecological technologies to stop environmental degradation (PASCUAL 1998) since the extent and severity of soil degradation upon clearing tropical forest for agriculture would depend on the cultivation system being imposed and how the soil is being managed (THENG 1991). Thus, a development of a sustainable environmentally sound agroecosystem must be in placed within the framework of a holistic community-based rainforestation farming in order to rehabilitate the degraded lands as well as to overcome the distinct economic inequalities of the upland population in Leyte.

Despite the importance of abaca to the national economy in general and to Leyte's economy in particular, its potential as a source of greater income to upland farmers while serving as a crop that may actually help in slowing down deforestation, is given little research and policy attention (LACUNA-RICHMAN

2002). Planting abaca give *de facto* rights to the land it is planted on, and reforestation efforts should take this into account as more families are forced by circumstances to settle on areas designated as forest land. LACUNA-RICHMAN (2002) reported that abaca is frequently the only source of cash income of poorer households in Leyte, who have only abaca as a single cash crop, and various subsistence crops as supplement of their household.

Hence, abaca is a very suitable crop for integration in both rainforestation farming system and monoculture coconut plantations, by creating a diversified multi-strata agroecosystem. The integration of abaca in the rainforestation farming concept will serve as a guide for transforming the actual subsistence-level single-species systems into a holistic community-based rainforestation farming. The produce from fruit and forest trees could allow abaca-producing households to earn an income when their abaca crops become less productive, or when harvesting the fiber become close to impossible for particular households, for example, due to the lack of able-bodied family members to maintain the plot and harvest the crop. Thus, helping to rehabilitate the degraded land as well as to overcome the distinct economic inequalities of the upland population in Leyte. On the other hand, utilizing the open space between monoculture coconuts (which is about 21.4% of the island's area) will minimize further forest encroachment and clearing of tropical forest for agriculture.

The objectives of this study are: a) to evaluate two multi-strata abaca production systems based on site and plant nutrient status, site adaptability and biological productivity and b) to identify possible pathways for a sustainable abaca production scheme in the Philippines. In addition, these objectives may point to possible areas of concern in promoting the use of abaca as an agroforestry crop for reforestation purposes.

In September 2003, two study sites were established at two different areas near Baybay, Leyte, Philippines. The first site (Barangay Caridad) is located about 14 km northeast of Baybay town at an elevation of 122 amsl. The second site (Barangay Mailhi) is about 23 km southwest of Baybay at 351 amsl elevation. The two research sites are comparable in terms of soil physiography and geology. This was accomplished by a very detailed survey using auger to

make sure that the soils were comparably similar as indicated for example, by morphological features such as color, texture and horizonation.

The data collection was carried out from September 2003 to June 2004 with the cooperation of the Institute of Tropical Ecology of the Leyte State University, Baybay, Leyte, Philippines. The study involved data collection on the following aspects: site nutrient status, plant nutrient uptake, and morphological and physiological performance of abaca plants.

In abaca –coconut integration, site nutrient status depends upon the type of land use, management practice i.e. periodic burning of coconut husk and soil type. While, in plant nutrient uptake, results show that nutrient concentration of abaca leaves are below the critical nutrient concentrations of banana and plantains. However, it is not enough and safe to conclude that the low nutrient concentration is in critical condition since the standard values for abaca is still unknown. Thus, using the results for diagnosing nutrient deficiencies is insufficient. Likewise, it is inadequate and undefended to bring into conclusion that the low concentration of nutrients in abaca leaves is due to low nutrient stocks in the soil solution. It may be due to some other factors like nutrient competition between the two crops or cation balance in the soil solution. All these factors have an effect on the morphological and physiological performance of abaca. However, in the case of this study, morphological and physiological performance of abaca depends mainly on the type of planting materials that exhibit fast recovery of its root system and increase in leaf emergence rate. Another is the farmer's practice towards the management of coconut plantation.

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Therefore, it can be concluded that both sites are suitable for abaca production in terms of soil type and nutrient reserves. However, due to high planting density, additional inputs are needed to improve the crop's growth performance, like fertilizer and high quality planting materials that exhibit fast recovery of its root system and increase in leaf emergence rate. Likewise, topography and wind speed must be considered during site selection. Finally, integrating abaca into coconut monoculture maybe a good idea, but under such type of an acidic soil, integrating abaca into the Rainforestation concept is the best option. If sustainability of the whole agroecosystem functions is taken into account.

7. References

- Acosta, R.T., 1991. Leyte Island: Ecosystems in peril. Paper presented during the Symposium on Environmental Management held at the Visayas State College of Agriculture, Baybay, Leyte on 25 September 1991, 21 pp.
- Alzina, F.I., 1868. On another kind of Banana (Translated by Leopoldo B. Uichanco). *Philippine Agriculture* 20 (8), 455-499
- Asio, V. B., 1996. Characteristics, Weathering, Formation and Degradation of Soils from Volcanic Rocks in Leyte, Philippines. Dissertation, Universität Hohenheim, 209 pp.
- Asio, V. B., Jahn, R., Stahr, K. and Margraf, J., 1998. Soils of the tropical forests of Leyte, Philippines II: Impact of different land uses on status of organic matter and nutrient availability. *In*: A. Schulte and D. Ruhayat (eds.) *Soils of tropical forest ecosystems: characteristics, ecology and management*. Berlin, Springer, 1998, 44: 37-44
- Asio, V.B. and Milan, P.P., 2002. Improvement of Soil Quality in Degraded Lands Through Rainforestation Farming. Paper presented during the International Symposium in Sustaining Food Security and Managing Natural Resources in Southeast Asia: Challenges for the 21st Century. Chiang Mai, Thailand on 8-11 January 2002
- Ashman, M.R., and Puri, G., 2002. *Essential Soil Science: A clear and concise introduction to soil science*. Blackwell Science Ltd. 191 pp.
- Baloloy, A. and Atienza, R.N., 1992. Soils, Land Resources, Technology and DOST Findings. *In*: *Proceedings of the Symposium on Disaster Planning and Management for Agriculture*, Quezon City, Philippines, on 24-26 March 1992, 19-24
- Balzer, P. and Margraf, J., 1994. Recent rainfall trends in ViSCA, Baybay, Leyte, Philippines. *Annals of Tropical Research* 16 (4), 32-42
- Barrera, A., Aristorenas, I., and Tingzon, J., 1954. *Soil Survey of Leyte Province, Philippines*. Bureau of Print, Manila, 103 pp.
- Bauer, A., and Black, A.L., 1994. Quantification of the effect of soil organic matter content on soil productivity. *Soil Sci. Soc. Am. J.* 58:185-193
- Bergmann, W., 1988. *Ernährungsstörungen bei Kulturpflanzen. Entstehung, visuelle und analytische Diagnose*. Fischer, Stuttgart, New York. 762 pp.
- Black, C.A. (Editor), 1965. *Methods of Soil Science Analysis. Part 2. Chemical and microbial properties*. Amer. Soc. Of Agron. Monograph No. 9, Madison, Wisconsin, 1572 pp.
- Bremner, J.M., 1986. Total nitrogen. *In*: D.L. Sparks (ed) *Methods of soil analysis. Part III. Chemical methods*. Amer. Soc. Agron. Inc. and Soil Sci. Soc., Amer., Madison, Wisconsin 1085-1121 pp.
- Buol, S.W., Hole, F.D. and McCracken, R.J., 1980. *Soil Genesis and Classification*. (2nd ed.). Iowa State University Press, Ames, 406 pp.

- Cabrido, C.A., Jr., 1985. An Assessment of National Soil Erosion Control Management Programs in the Philippines. In: Crawswell, E.T., Remenyi, J.V., Nallana, L.G. (eds.): Soil Erosion Management. ACIAR Proc. Series No. 6, Canberra, Australia: ACIAR, 13-20
- Caliente, A.C., 1993. Hydrobiology of Baybay Waters. ViSCA-GTZ Ecology Program, Terminal Report, Leyte, Philippines, 129 pp.
- Capistrano, A.D., and Marten, G.G., 1986. Agriculture in Southeast Asia. In: Marten (Editor), Traditional Agriculture in Southeast Asia: A Human Ecology Perspective, Western Press, Boulder, pp. 6-19
- Cardenosa-Barriga, R., 1962. La 'rayadilla' del platano en Colombia. Turrialba, 118-127
- Celestino, A.F. and Elliot, F.P., 1986. Hillyland Farming Systems in the Philippines: An Assessment. Farming Systems and Soil Resources Institute, University of the Philippines, Los Baños, Philippines
- Chalker, F.C. and Turner, D.W., 1969. Magnesium deficiency in bananas. Agric. Gaz. NSW, 474-476
- Constantino, R., 1980. The Philippines: A Past Revisited (Pre-Spanish-1941) Copyright 1975 Vol. 1pp. 121-122
- Coombs, J. et. al., 1985. Techniques in Bioproductivity and Photosynthesis 2nd Edition. Pergamon Press, Oxford.
- Corona, J., 1920. The Climate and Weather of the Philippines, 1903 to 1918. Bureau of Print, Manila, 189 pp.
- Dargantes, B.B., 1996. Socio-ecological Case Studies on Forest Lands Cultivation in Leyte, Philippines. Dissertation, Universität Hohenheim, 191 pp.
- Dargantes, B.B. and Koch, W., 1995b. Breakdown in the Sustainability of Shifting Cultivation: Case Studies of Forest Farming in Leyte, Philippines. Paper presented during the 16th Congress of the European Society for Rural Sociology held in Prague on 31 July to 4 August 1995, 31 pp.
- Department of Agriculture - Agribusiness and Marketing Assistance Service (DA-AMAS) 2002. Abaca Industry Situationer Report, Manila (On-line) Available: http://www.da.gov.ph/agribiz/abaca_new.html
- Edwards, H.T., 1945. The Introduction of Abaca (Manila hemp) into the Western Hemisphere. Annu Rep Smithson Inst., 327-350
- Eckstien, K., 1994. Physiological Responses of Banana (Musa AAA: Cadavish subgroup) in the Subtropics. Inaugural Dissertation. Rheinischen Friedrich-Wilhelms-Universität Bonn, 203 pp.
- Escandor, J., 2001. Bicol gears up for rising abaca exports': Philippine Daily Inquirer, October 7, 2001 Issue (On-line). Available: <http://www.inq.net/bus/2001/oct/07/text/bus-2-1p.htm>
- Environmental Research Division – Manila Observatory (ERD-MO), 1991. Leyte Island Drainage and Forest Cover Map. Ateneo de Manila University, Quezon City

- Food and Agriculture Organization (FAO), 1990. Guidelines for Soil Profile Description (3rd ed.). Rome
- FAO-UNESCO, ISRIC, ISSS-AISS-IBG, 1994. World Reference Base for Soil Resources. Draft. Wageningen, The Netherlands
- Freiberg, S.R., 1966. Banana nutrition. *In* Childers. N.F. (ed) Fruit Nutrition. Horticultural Publications, New Brunswicks, NJ
- Garnica, A.M., 1997. Mineral Nutrient Deficiency in Plantain. Margraf Verlag, Germany, 112 pp.
- Gonzal, L.R., Guarte, R. and Mühlbauer, W., 2003. Using Abaca Fiber as Industrial Raw Material. *In*: Hutter, C.P., Göltenboth, F. and Hanssler, M. (eds.), 2003: Path to Sustainable Development New Experiences in the Philippines. S. Hirzel Verlag Stuttgart, Leipzig, 25-30
- Göltenboth, F. and Milan, P.P., 2003. Challenge and Goal: Mt. Pangasugan on Leyte as a World Natural Heritage Site. *In*: Hutter, C.P., Göltenboth, F. and Hanssler, M. (eds.), 2003: Path to Sustainable Development New Experiences in the Philippines. S. Hirzel Verlag Stuttgart, Leipzig, 31-34
- Green, G.C., 1963. Fungi associated with crown rot of boxed bananas. *Phytopathology*, 271-275
- Groetschel, A., Aquino, R.R., Buchholz, I., Mazo, T.E., Ibkendanz, A., Sales, N.A. and Vicentuan, K.C., 2001. Natural Resource Management Strategies on Leyte Island, Philippines. SLE Center for Advanced Training in Rural Development, Humboldt-Universität zu Berlin, Germany, 230 pp.
- Hoffmann, G., 1991. Methodenbuch. Band 1. Die Untersuchung von Boden. Darmstadt, Germany
- IIRR, DENR and Ford Foundation, 1992. Agroforestry Technology Information Kit (ATIK). Silan, Cavete, Philippines: IIRR (International Institute for Rural Reconstruction), DENR (Department of Environment and Natural Resources) and Ford Foundation
- Jahn, R., Hädrich, and Stahr, 1994. Bodenminerale in Raum und Zeit. Exkursionsführer zur Tagung der Kommission VII – Bodenmineralogie der Deutschen Bodenkundlichen Gesellschaft, *In* U. Babel, W.R. Fischer, K. Roth, K. Stahr, R. Jahn (Hrsg.) Hohenheimer Bodenkundliche Hefte. Nr. 20-II, University of Hohenheim, Stuttgart, Germany.
- Jahn, R., Asio, V.B., and Stahr, K., 1995. Soils of the tropical forest in Leyte, Philippines I: Weathering, characteristics, classification and site qualities. *In* Proc. Intern. Congr. Soil Trop. Forest Ecosystem. Vol. 1, Mulawarman Univ. Press, Samarinda, Indonesia, pp. 79-91
- Jahn, R., 1998. Böden Lanzarotes. Vorkommen, Genese and Eigenschaften von Böden aus Vulkaniten im semiariden Klima Lanzarotes (Kanarische Inseln). PhD Dissertation. *In* Hohenheimer Arbeiten, Eugen Ulmer, Stuttgart, Germany. 257 pp.

- Jahn, R., Blume, H.P. and Asio, V.B., 2003. Students Guide for Soil Description, Soil Classification and Site Evaluation. Teaching Materials, Halle/Saale, Germany, 120 pp.
- Jenny, H., 1950. Causes of high nitrogen and organic matter content of certain tropical forests soils: *Soil Science* 69: 63-69
- Jordine, C.G., 1962. Metal deficiencies in banana. *Nature*, 1160-1163
- Kolb, M., 2002. First Silvicultural Evaluation of Rainforestation Farming Plots on Leyte, Philippines. Unpublished Msc. Thesis manuscript,
- Lacuna-Richman, C., 2002. The Role of Abaca (*Musa textilis*) in the Household Economy of a Forest Village. In: Small-Scale Forest Economics, Management and Policy. Faculty of Forestry, University of Joensuu, Finland, 1(1) 93-101
- Lal, R., 1990. Soil Erosion in the Tropics: Principles and Management. McGraw-Hill, Inc., London
- Lal, R., Kimble, J., and Follett, R., 1997. Soil quantity management for carbon sequestration. P. 1-8. In R.Lal et al (ed). Soil properties and their management for carbon sequestration. United States Department of Agriculture, Natural Resources Conservation Services, National Soil Survey Center, Lincoln, NE.
- Lahav, E., 1996. Banana nutrition. In S. Gowen (ed). Banana and Plantains. Published by Chapman and Hall, 2-6 Boundary Row, London, SE1 8HN UK, 316: 258-316
- Lahav, E., 1974. The influence of potassium on the content of macro-elements in the banana suckers. *Agrochimica* 319-325
- Lahav, E., 1972b. Effects of different amounts of potassium on the growth of banana. *Trop. Agric. Trinidad*, 321-335
- Lahav, E. and Turner, D.W., 1983. Banana Nutrition, Bull. 7. International Potash Institute, Worblaufen-Bern, Switzerland.
- Leones, J.P., 1987. The Impact of an Agroforestry Project on Upland Farming in San Francisco, Cebu, Philippines. Cornell International Agriculture Mimeograph 116, New York, USA
- Margraf, J. and Milan, P.P., 1996. Ecology of Dipterocarp Forests and its Relevance for Island Rehabilitation in Leyte, Philippines. In: Schulte, A. and Shöne, D. (eds.). Dipterocarp Forest Ecosystems: Towards Sustainable Management. World Scientific, Singapore, New Jersey, London: 124-154
- Martin-Prével, P. and Montagut, G., 1966b. Essais sol-plante sur bananier. 8. Dynamique de l'azote dans la croissance et al développ. ement du végétal. 9. Fonctions des divers organes dans l'assimilation de P, K, Ca, Mg. *Fruits*, 21, 283-294 and 395-416
- Martin-Prével, P., 1977. Echantillonnage du bananier pour l'analyse foliare, consequences des differences de techniques. *Fruits*, 32. 151-166
- Martin-Prével, P., 1978. Effects of magnesium and potassium nutrition on phosphorus uptake and redistribution in a cultivated plants. *Musa sp.* In Plant Nutrition

- 1978: Proc. 8th Int. Colloq. On Plant Analysis and Fertilizer Problems, pp. 329-338. Auckland NZ.
- Mekaru, T. and Uehara, G., 1972. Anion adsorption in ferruginous tropical soils. Soil Sci. Soc. Ame. Proc. 36:296-300
- Messing, J.H.L., 1974. Long term changes in potassium, magnesium and calcium content of banana plants and soils in the Windward Islands. Trop. Agric. Trinidad, 154-160
- Milan, P.P. and Margraf, J., 1990. Synecological Approach to Island Development in the Philippines. Paper presented at the Int. Symp. On agroecology and conservation issues in temperate and tropical regions, Padova, Italy, on 26-29 September 1990
- Milan, P.P. and Margraf, J., 1994b. Rainforestation Farming, an Alternative to Conventional Concepts. Proc. Sustainable Alternative Livelihood Project Symp., Quezon City, Philippines on 10-11 November 1994, 12 pp.
- Moity, M., 1954. La carence en zinc sur le bananier. Fruits, 334
- Montagut, G., Martin-Prével, P., 1965. Essais sol-plante sur bananiers. 1 Besoins en engrais des bananeries antillaises. Fruits. 20, 265-273
- Montient, J.L., 1973. Principles of environmental physics. Edwards Arnold, London.
- Murray, D.B., 1959. Deficiency symptoms of the major elements in the banana. Trop. Agric. Trinidad, 100-107
- Murray, D.B., 1960. The effects of the deficiencies of the major nutrients on the growth and leaf analysis of the banana. Trop. Agric. Trinidad, 97-106
- Nair, P.K.R., 1979. Intensive multiple cropping with coconuts in India, Principles, programmes and prospects. Advances in Agronomy and Crop Science. Verlag Paul Parey, Berlin und Hamburg, 147 pp.
- National Statistic Coordination Board (NSCB), 1997. Philippine Statistical Yearbook. NSCB, Manila, Philippines
- Nelson, R.A., Cramb, R.A., Menz, K. and Mamicmic, M., 1998a. Gliricidia, Napier and Natural Vegetation Hedgerows. In: Menz, K., Magcale-Macandong, D. and Rusastra, I.W. (eds.): Improving Smallholder Farming System in Imperata Areas of Southeast Asia: Alternative to Shifting Cultivation. Canberra, Australia: ACIAR, 95-112
- Nelliat, E.V., Bavappa, K.V.A. and Nair, P.K.R., 1974. Multistoreyed cropping – new dimension of multiple cropping in coconut plantation. World crops 26, 262-266
- Nishimura, S., 1996. Agricultural Development in Western Visayas: Pawned Lands, Overseas Worker and *Porsiyentuhan*. In: Ushijima, I. and Zayas, C.N. (eds.). *Binisaya nga Kinabuhi* (Visayan Life), Visayas Maritime Anthropological Studies, University of the Philippines Press, Diliman, Quezon City, pp. 59-72
- Nobel, P.S. and Long. S.P., 1985. Canopy structure and light interception. In: Coombs, J. et. al. (eds). Techniques in Bioproductivity and Photosynthesis 2nd Edition. Pergamon Press, Oxford.

- Oliver, A., 2004. Going Bananas. DaimlerChrysler – Environmental Report 2004 Magazine (On-line) Available : <http://www.daimlerchrysler.com/dccom/0..05-187315-1-198390-1-0-0-187343-0-0-135-7166-0-0-0-0-0-0-00.html>
- Olofson, H., 1983. Indigenous Agroforestry Systems. Philippine Quarterly of Culture and Society, 11 (2/3) 149-174
- Otsuka, H., Briones, A.A., Daquiado, N.P., and Evangelio, F.A., 1988. Characteristics and genesis of volcanic ash soils in the Philippines. Technical Bulletin No. 24, Trop. Agric. Res. Center, Minist. Agric. Forest and Fish, Japan, 122 pp.
- Pagel, H., 1982. Pflanzennährstoffe in tropischen Böden – ihre Bestimmung und Bewertung. VEB Deutscher Landwirtschaftsverlag, Berlin. 272 pp.
- Paningbatan, E.P., 1993. Management of soil erosion for sloping uplands in the Philippines. Paper presented at the Third International Forum on Soil Taxonomy and Sustainable Land Management. Diliman, Quezon City, Philippines; 17-28 May 1993. (Unpublished mimeograph).
- Pascual, F.G., 1998. Sustainable Agriculture, Landlessness, and Food Security. International South Group Network, Monograph No. 1, January 1998 (On-line) Available: <http://www.philsol.nl/AOOa/ISGN-Fpascual-jan98.htm>
- Philippine Council for Agriculture, Forestry and Natural Resources Research and Development (PCARRD), 1971. The Philippines Recommends for Abaca. Los Baños, Laguna, Philippines
- Philippine Upland Resource Center (PURC), 1980. Soil Erosion Control Measures for the Uplands. Manila, Philippines
- Reaves, D.W., 1997. The role of soil organic matter in maintaining soil quality in continuous cropping systems. Soil Tillage Res. 43: 131-167
- Richmond, G.E., 1907. Philippine Fibers and Fibrous Substances: Their Suitability for Papermaking. III. Conclusions. Philipp J. Sci. 2(2) 81-122
- Ruthenberg, H., 1980. Farming Systems in the Tropics (3rd eds.). Clarendon Press, Oxford
- Römheld, V., 2003. Plant Nutrition in Tropics and Subtropics. Lecture notes, M.Sc. Programme in Agricultural Science, Food Security and Natural Resource Management, Tropenzentrum, University of Hohenheim
- Robinson, J.C. and Bower, J.P., 1988. Transpiration from banana leaves in the subtropics in response to diurnal and seasonal factors and high evaporative demand. Scientia Horticultura, 129-143
- Sanchez, P.A., 1976. Properties and management of soils in the tropics. Wiley and Sons, New York, 617 pp.
- Sajise, P., 1980. Alang-alang (*Imperata cylindrica* (L) BEAUV.) and Upland Agriculture. Biotrop Spec. Publ. No. 5, pp. 35-46

- Sajise, P.E., 1983. Effects of Intercropping and Tillage Practices on Crop Productivity and Soil Conservation Unpub. M.Sc. Thesis, UPLB, College, Laguna, Philippines.
- Sajise, P.E., 1986. The Changing Upland Landscape. In: Fujisaka, S., Castillo, R., Sajise, P.E. (eds.), 1986: Man, Agriculture and the Tropical Forest: Change and Development in the Philippine Uplands. Bangkok, Thailand, Winrock International, 13-41
- Sajise, P.E. and Briones, N.D., 1986. Environmentally Sustainable Rural and Agricultural Development Strategies in the Philippines: Lessons from six case studies. Los Baños, Philippines: SEARCA
- Simmonds, N.W., 1959. Ensete cultivation in the southern highlands of Ethiopia, a review on Tropical Agriculture, Trinidad, 302-7
- Schachtschabel, P., 1992. Lehrbuch der Bodenkunde. Enke, Stuttgart.
- Scheffer, F., and Schachtschabel, P., 1992. Lehrbuch der Bodenkunde. Durchgesehene Auflage. Ferdinand Enke Verlag, Stuttgart, Germany, 491 pp.
- Schlichting, E., Blume, H.P. and Stahr, K. , 1995. Bodenkundliches Praktikum. (2. Auflage) Blackwell, Berlin, 295 pp.
- Schulte, A., 2002. Rainforestation Farming: Option for Rural Development and Biodiversity Conservation in the Humid Tropics of Southeast Asia: A review of the major issues on community-based rehabilitation silviculture and guide to recommended native species for the Visayas, Philippines. Shaker Verlag GmbH, Germany, 312 pp.
- Seidenschwarz, F., 1994. Plant World of the Philippines. University of San Carlos Press, Cebu City, Philippines
- Shoji, S., Nanzyo, M., and Dahlgren, R.A., 1993. Volcanic ash soils. Genesis, properties and utilization. Developments in Soil Science 21, Elsevier, Amsterdam, 288 pp.
- Stark, M., 2000. Soil Management Strategies to Sustain Continuous Crop Production between Vegetative Contour Strips on Humid Tropical Hillside. Technological development and dissemination based on farmers' adaptive field experimentation in the Philippines. International Center for Research in Agroforestry. Southeast Asia Regional Research Programme, 225 pp.
- Sumner, M.E., and Miller, W.P., 1996. Cation exchange capacity and exchange coefficient. In D.L. Sparks (ed) Methods of soil analysis. Part III. Chemical methods. Amer. Soc. Agron. Inc. and Soil Sci. Soc. Amer., Madison Wisconsin, pp. 1201-1229
- Tabora, P.C., Jr., 1978. Historical Background. In: The Abaca. International Documentation Center on Abaca, University of the Philippines at Los Baños Library College, Laguna, Philippines, 135 pp.
- Tabora, P.C., and Santos, R., 1978. Soil and climate for abaca production. In: The Abaca. International Documentation Center on Abaca, University of the Philippines at Los Baños Library College, Laguna, Philippines, 63: 60-63

- Tiessen, H., 1998. Resilience of phosphorus transformation in tropical forest and derived ecosystem. *In*: A. Schulte and D. Ruhayat (eds.) Soils of tropical forest ecosystems: characteristics, ecology and management. Berlin, Springer, 1998, 98: 92-98
- Theng, B.K.G., 1991. Soil Science in the Tropics – the next 75 years. *Soil Science* 151: 76-89
- Thomas, G.W., 1996. Soil pH and soil activity. *In* D.L. Sparks (ed) Methods of soil analysis. Part III. Chemical methods. Amer. Soc. Agron. Inc. and Soil Sci. Soc. Amer. Madison, Wisconsin, pp. 475-489
- Twyford, I.T., 1967. Nutrition, a review of principles and practice. *J. Sci Food Agric.*, 18, 177-183
- Twyford, I.T. and Wamsley, D., 1973-74. The mineral composition of the Robusta banana plant 1. Methods and plant growth studies. 2. The concentration of mineral constituents. 3. Uptake and distribution of mineral constituents. 4. The application of fertilizer for high yields. *Plant and Soil* 227-243, 459-470, 471-491, 493-508
- Vorm, P.D.J. van der and Diest A., van, 1982. Redistribution of nutritive elements in a 'Gors Michel' banana plant. *Neth. J. Agric. Sci.* 286-296
- Walmsley, D. and Twyford., 1968. The uptake of ^{32}P by Robusta banana. *Trop. Agric. Trinidad*, 223-228
- West, T.O. and Post, W.M., 2002. Soil organic carbon sequestration rates by tillage and crop rotation: A global data analysis. *Soil Sc. Soc. Am. J.* 66 :1930-1946
- Yambot, E., (ed.), 1975. Philippine Almanac and Handbook of Facts. Philippine Almanac Printers, Inc., Quezon City
- Zikeli, S., 1998. Nutrient Status and Nutrient Cycles of the Tropical Rainforest, Mt. Pangasugan, Leyte, Philippines. Unpublished MSc. Thesis. Thesis manuscript.

APPENDICES

Appendix A

Procedure for Soil Analysis

Sample Preparation

Right after sampling, soil samples were air-dried, freed of large plant residues as well as rock fragments, ground, sieved to pass a 2mm sieve and were stored in plastic containers. For organic carbon analysis, enough amount of 2mm sample was ground to pass a 0.5mm sieve. This procedure is generally that of ISRIC (1986).

pH. 10g air-dried <2mm samples with water and 1M KCl (for profile samples) using a ratio of 1:2.5 according to Jackson (1958) and Schlichting et al. (1995).

Organic Carbon. By Walkley-Black method (Nelson and Sommers, 1982) which involved organic carbon oxidation with 1M $K_2Cr_2O_7$ in the presence of concentrated H_2SO_4 . Titration was done with standardized 0.5M $FeSO_4$ solution.

Total Nitrogen. By Kjeldahl procedure of ISRIC (1986) with slight modification such as the use of 40% NaOH and standardized 0.1M HCl during distillation and titration, respectively.

Cation Exchange Capacity. By NH_4OAc (pH 7.0) Black (1965) which involved ordinary filtration method of sample using NH_4OAc to remove exchangeable cations and saturate the exchange material with ammonium. The sample is leached with 10% KCl solution to remove exchangeable ammonium, after removing with 80% ethanol the excess ammonium acetate. Distillation was done in Buchi 315 distillation unit and samples were titrated with standardized 0.1M HCl.

Exchangeable Acidity and Aluminum. By Thomas (1982). A neutral 1M KCl solution is used to leach sample of exchangeable H and Al ions. The leachate which is acidic is titrated with standardized 0.1M NaOH. Exchangeable Al is measured by titrating the released Alkali with standardized 0.1M HCl.

Appendix B

Procedure for Plant Tissue Analysis

I. Solutions

1. 1:3 diluted Nitric Acid: 1 part HNO_3 , 65% parts deionised H_2O
2. 1:3 diluted HCl: 1 part HCl 37% + 2 parts parts deionised H_2O
3. Cs/La-buffer solution according to Schinkel (Merck No. 167555), especially for Mn and Fe
4. Molbdate-Vanadate-Solution (only for P analysis)
 - a. Diluted 1:3 HNO_3
 - b. Ammonium vanadate solution 0.25%: solve 2.5 g Ammonium monovanadate in 600ml boiling deionised water, after cooling add 80 ml concentration HNO_3 and add deionised H_2O to fill to 1 liter
 - c. Ammonium molybdate solution 5%: solve 50 g ammonium-heptamolybdate-tetrahydrate in 800 ml deionised water at 60 °C and bring to 1 litter with deionised H_2O after cooling.
 - d. The solution a and c then mix to a 1:1:1 ratio

II. Preparation of Ash Solution

500 mg dried substance is weighed out in a porcelain crucible and placed in the furnace. This is then heated at 500°C for at least 4 hours. If after this treatment the ash is not light coloured, it should be cooled, wetted with some drops of deionised H_2O and then with some drops of 1:3 dil. HNO_3 (or 3% H_2O_2) and evaporated on a heat plate. The crucible are placed back in the furnace for at least 1 hour. After cooling, the ashes should be wetted with some drops of deionised H_2O and evaporated with 5 ml HNO_3 1:3. Repeat this process to clear the substance of SiO_2 . The sample is then solved with 5 ml HCl (1:3). Transfer the solution to a 50 ml volumetric flask and rinse the crucible with ca. 25 ml hot water. The solution should be boiled for 2 minutes (boiling chips) to change meta and pyrophosphates (formed during the evaporation of HNO_3) back to orthophosphates. After cooling to room temperature, the solution is filled with H_2O up to 50 ml, to mix H_2O with acid and filtered through blue band filter paper.

For P analysis an aliquot (0-5-7ml) of the ash solution is mixed with 3 ml molybdat-vanadat-solution and brought to a volume of 10 ml with 1:30 diluted HCl. The colour intensity of the solution is after 2 hours almost constant, after 20 hours about 2% higher and then constant for several months.

III. Measurement of Samples

These elements can be measured directly from ash-solution:

- K, Ca and Na with the flame-photometer
- Mg, Cu, Zn with the atomic-absorbion-spectrophotometer
- Concerning P-measurement requires the spectrophotometer set to wavelength 436 nm

Appendix C

Soil Profile

Caridad Site

Land Information and factors of soil formation:

Profile:	1
Location:	Sitio Manukot, Barangay Caridad, Baybay, Leyte
Altitude:	127 m asl
Latitude:	124° 46' 03"
Longitude:	10° 15' 32.4"
Annual mean temperature:	27.4°C
Annual mean rainfall:	2600 mm
Length of growing period:	throughout the year
Present weather condition:	Overcast
Major landform:	volcanic mountain
Slope position:	Upper slope
Slope form:	Straight
Local landform:	Medium-gradient mountain footslope
Gradient:	20%
Orientation:	75°N
Land use:	Mixed farming (coconut-abaca)
Crops and vegetation:	Coconut, abaca, kudzu, herbs
Human influence:	Cultivation (upland farming)
Parent material:	Basaltic and andesitic volcanic rocks
Age of land surface:	Quaternary
Drainage:	Good
Soil classification:	Alisol
Date examined :	22 April 2004

Profile description:

Ah	0-11 cm. Dark brown (10YR 4/3) silty clay loam; moderate coarse granular structure; common fine and coarse roots; common pores; no rock fragments; charcoal, ants, centipedes, termites observed; pH 5.5; clear to gradual irregular boundary.
Bw	11-35 cm. Dark yellowish brown (10YR 3/6) clay loam; moderate, medium to coarse granular structure; very few fine and coarse roots; few pores; very few rock fragments; termite larvae observed; pH 5.5; diffuse boundary.
Bt ₁	35-53cm. Dark yellowish brown (10YR 3/6) clay loam; moderate medium to coarse sub-angular blocky; very few roots; few pores; very few rock fragments; termites observed; pH 5.6; gradual irregular boundary.
Bt ₂	53-70cm. Dark yellowish brown (10YR 4/6) clay loam; moderate to strong very coarse sub-angular blocky structure; very few roots, few pores; no rock fragments; pH 5.6; gradual boundary.
Bt ₃	70-100cm. (10YR 4/6) clay loam; moderate to strong very coarse sub-angular blocky structure; plastic and sticky; very few roots; very few pores; no rock fragments; pH 5.9.

Profile: 2
Altitude: 121 m asl
Latitude: 124° 46' 02.1"
Longitude: 10° 15' 32.2"
Present weather condition: Sunny (25% cloudy)
Slope position: Middle slope
Slope form: Concave
Gradient: 24%
Orientation: 75°N
Date examined: 22 April 2004

Profile description:

- Ah 0-11 cm. Dark brown (10YR 3/3) clay loam; strong coarse granular structure; few fine and coarse roots; few pores; no rock fragments; charcoal, ants, centipede observed; pH 5.2; clear irregular boundary.
- Bw 11-32 cm. Dark yellowish brown (10YR 4/4) clay loam; moderate, medium to coarse granular structure; few fine and coarse roots; few pores; no rock fragments; termites observed; pH 5.1; diffuse boundary.
- Bt₁ 32-80cm. Dark yellowish brown (10YR 4/6) silty clay loam; moderate medium to coarse sub-angular blocky structure; very few roots; few pores; very few rock fragments; small black concretions (Mn) observed; pH 5.3; diffuse boundary.
- Bt₂ 80-100cm. Dark yellowish brown (10YR 4/6) silty clay loam; weak to moderate sub-angular blocky structure; very few roots, few pores; very few rock fragments; some white fragments (saprolite) observed; pH 5.5.

Profile: 3
Altitude: 118 m asl
Latitude: 124° 46' 00.9"
Longitude: 10° 15' 32.6"
Present weather condition: Sunny (25% cloudy)
Slope position: Lower slope
Slope form: Concave
Gradient: 22.22%
Orientation: 75°N
Date examined: 22 April 2004

Profile description:

- Ah 0-5cm. Dark brown (10YR 3/3) silty clay loam; strong coarse granular structure; very few roots; common pores; no rock fragments; charcoal and ants observed; pH 5.4; gradual irregular boundary.
- Bw 5-23 cm. Dark yellowish brown (10YR 3/6) silty clay loam; moderate to strong coarse granular structure; slightly very few fine and coarse roots; common pores; no rock fragments; pH 5.1; clear irregular boundary.
- Bt₁ 23-76cm. Dark yellowish brown (10YR 3/6) silty clay; strong sub-angular blocky structure; very few roots; few pores; abundant fragments; termites observed; pH 5.1; gradual irregular boundary.

Bt₂ 76-100cm. Dark yellowish brown (10YR 3/6) silty clay; moderate to strong very coarse sub-angular blocky structure; very few roots, few pores; abundant rock fragments; pH 5.1

Mailhi Site

Land Information and factors of soil formation:

Profile: 1
Location: Sitio Tinago, Barangay Mailhi, Baybay, Leyte
Altitude: 380 m asl
Latitude: 124° 54' 29.3"
Longitude: 10° 38' 07.8"
Annual mean temperature: slightly lower than 27°C (lowland average)
Annual mean rainfall: slightly higher than 2600 mm (lowland average)
Length of growing period: throughout the year
Present weather condition: 100% cloudy
Major landform: Volcanic mountain
Slope position: Upper slope
Slope form: Straight
Local landform: Medium-gradient mountain backslope
Gradient: 67%
Orientation: 65°N
Land use: Mixed farming (rainforestation-abaca)
Crops and vegetation: Coconut, abaca, forest/fruit trees, pineapple, ferns
Human influence: Cultivation (upland farming) in the past
Parent material: Andesitic volcanic rocks
Age of land surface: Quaternary
Drainage: Good
Soil classification: Andosol
Date examined: 18 June 2004

Profile description:

Ah 0-8 cm. Dark yellowish brown (10YR 3/4) sandy clay loam; moderate medium to coarse granular structure; common fine roots; abundant pores; no rock fragments; charcoal, ants, earthworms observed; pH 4.6; clear irregular boundary.

Bw₁ 8-24 cm. Dark yellowish brown (10YR 4/4) sandy clay loam; moderate coarse to very coarse granular structure; few fine roots; abundant pores; no rock fragments; earthworms and centipede observed; pH 4.8; diffuse irregular boundary.

Bw₂ 24-72cm. Yellowish brown (10YR 5/6) silty clay; moderate to strong medium to very coarse granular structure; very few medium roots; common pores; no rock fragments; pH 4.8; diffuse boundary.

Bw₃ 72-100cm. Yellowish brown (10YR 5/6) sandy clay; moderate medium to very coarse granular structure; very few medium roots, common pores; no rock fragments; pH 4.8.

Profile: 2
Altitude: 348 m asl
Latitude: 124° 54' 28.3"
Longitude: 10° 38' 06.9"
Present weather condition: 100% cloudy
Slope position: Middle slope
Slope form: Concave
Gradient: 56%
Orientation: 50°N
Date examined: 19 June 2004

Profile description:

- Ah 0-6 cm. Dark yellowish brown (10YR 4/4) sandy clay; moderate medium to coarse granular structure; few fine roots; few pores; about 10% rock fragments; ants observed; pH 4.9; diffuse boundary.
- Bw₁ 6-66 cm. Dark yellowish brown (10YR 4/4) sandy clay; moderate medium to very coarse granular structure; few medium roots; common pores; few rock fragments; pH 4.7; clear irregular boundary.
- Bw₂ 66-100cm. Yellowish brown (10YR 5/6) sandy clay; moderate, medium to very coarse granular structure; very few medium roots; abundant pores; abundant rock fragments; pH 4.7.

Profile: 3
Altitude: 326 m asl
Latitude: 124° 54' 26.9"
Longitude: 10° 38' 05.1"
Present weather condition: 100% cloudy
Slope position: Lower slope
Slope form: Concave
Gradient: 7%
Orientation: 10°N
Date examined: 18 June 2004

Profile description:

- Ap 0-9 cm. Dark yellowish brown (10YR 3/4) clay loam; strong very coarse granular structure; common fine roots; few pores; few rock fragments; ants, earthworms observed; pH 5.3; gradual irregular boundary.
- Bw₁ 9-27 cm. Dark yellowish brown (10YR 4/4) clay loam; moderate to strong medium granular structure; very few medium roots; common pores; common rock fragments; earthworms observed; pH 5.2; clear irregular boundary.
- Bw₂ 27-100cm. Dark brown (10YR 4/3) sandy clay loam; moderate to strong medium sub-angular blocky structure; very few medium roots; few pores; abundant rock fragments; pH 4.8.