ALA - 97/68

Upland Development Programme
in Southern Mindanao (UDP)

STRATEGIES TO OFFSET THE EFFECTS OF DROUGHT AND CONTROL LAND DEGRADATION UNDER COCONUT PLANTATIONS IN SOUTHERN MINDANAO

A report by
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8 April 2005

A partnership programme sponsored by
the European Commission (EC) and the Government of the Philippines (GoP)
and executed by the Department of Agriculture (DA)

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The views expressed in this report are those of the author and do not necessarily reflect those of the European Commission.

Cover photographs:

Top left: Sheet erosion exposing surface roots of coconut tree
Top right: Build up of eroded soil above base of coconut tree and loss of soil below from cultivation. Note severed roots at base of tree
Bottom left: Truncated soil of 40 cm overlying deep excessively drained lahar deposits
Bottom right: Severely moisture-stressed young coconuts, Brgy Dawan Mati, 7 Apr 2005

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INDEX

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SUMMARY

With millions of Filipino farm families directly depending on coconut for their livelihood, it is alarming to find that the soil losses under industrial tree plantations, estimated by the World Bank almost 20 years ago, have continued unabated in parts of the UDP area. Upland farmers report that over the last 20 years erosion has reduced soil depths by more than 50 cm. In some UDP areas, coconut trees are now growing on only 40 to 50 cm, while annual crops are being grown on severely truncated soils with less than 30 cm of soil.

With the onset of El Niño, coconut size and yields of copra have been greatly reduced. This is due to sheet erosion and rilling on steep sloping land reducing soil depths to levels where insufficient moisture can be stored to maintain normal levels of production during extended dry periods. Coconut trees are showing signs of moisture stress and some mortality has resulted in areas that have had no effective rainfall since December 2004.

This paper outlines the significance of soil depth to crop growth, the causes of soil losses under coconut plantations in the uplands, and summarises the effects of drought and water stress on coconut production. *Recommendations,* and the *actions* needed, are given both for *short-term strategies* to offset moisture stress, and for *long-term strategies*, such as multi-storey cropping, to reduce the rate of soil losses, improve the survival of tree crops, and diversify farmer incomes.

A. INTRODUCTION

It has been estimated that, directly or indirectly, the coconut industry supports approximately one third of the national population of the Philippines[1].

Coconut plantations require an equatorial climate with high humidity and well-distributed rainfall of 1300-2300 mm per year. Prolonged dry spells lower the production of coconuts. As the droughts caused by the El Niño phenomenon become more frequent in the Philippines, measures that conserve soil moisture will be increasingly necessary to ensure the survival of coconut trees growing in shallow soils.

Sites selected for coconut plantations generally have well-drained soils not less than 1.5 m deep. Shallow soils with underlying hard rock are avoided, as are low-lying areas subject to water-logging and heavy clay soils. Most of a coconut palm's roots occur in the 30–120 cm soil layer in a 2 m radius around the palm.

In Southern Mindanao, many coconut plantations are on very steep slopes in mountainous terrain. Intercropping under coconuts includes erosion-causing crops such as rice, corn, peanut, cassava, sweet potato, taro, vegetables and pineapple, as well as fruit trees, cacao, coffee, black pepper, and pasture for grazing by livestock.

Under-storey shrubs and grass weeds, if left uncut, compete aggressively for limited soil water and nutrients. Coconut yields and growth can decline drastically when the amount of available soil moisture reaches critical levels during part of the year. On the other hand, under certain circumstances, the cultivation of pasture or other crops in the under-storey can actually increase coconut yields[2], e.g. due to the application of fertilizers.

[1] Ontolan, D.G. (1988) Status report on intercropping and intergrazing in the Philippines. In: Proceedings Workshop on Intercropping and Intergrazing in Coconut Areas, 7-11 September, 1988, Colombo, Sri Lanka.

B. OBSERVATIONS

On the steep slopes found in the uplands of Mindanao, the intercropping of rice, corn, peanut, cassava, sweet potato, taro, and possibly pineapples, under coconut plantations, has resulted in severe reductions in soil depth (see below).

Field visits to farms in Davao del Sur and Davao Oriental (in early 2005) found that soil depths under coconut plantations on steep slopes (40-70%) are as shallow as 30-50 cm (Photo 1). More alarming is the evidence that extensive areas now have shallow soils (<40 cm deep) overlying deep layers of coarse, excessively drained, lahar (see Photo 2).

Skeleton soils are typically formed when most of the humus and fine earth has been washed away by rainfall run-off water on hills and slopes leaving the granular and sandy, gravely or pebbly elements behind. (Due to the continuous cultivation of hill rice and cassava on sloping land, Vietnam now has one million hectares of such soils that are useless for agriculture and cannot be reforested. If a similar situation is allowed to develop in Southern Mindanao, it will be disastrous for the uplands and the local economy.

Photo 1. Truncated soil profile of 30 cm over fractured rock. (Pen is 14 cm long)

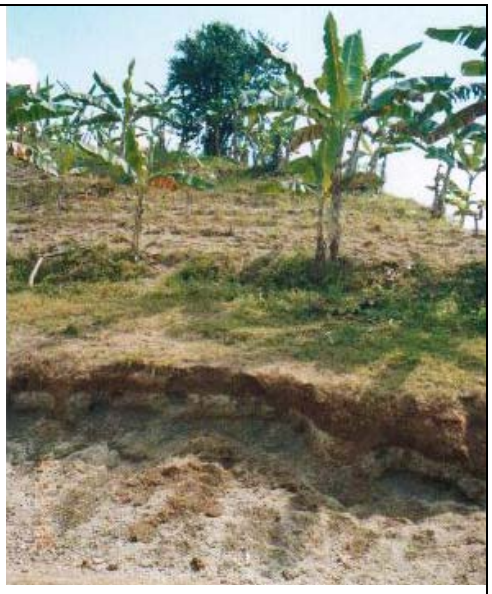

Photo 2. Truncated soil profile of 40 cm over excessively drained lahar deposits.

Upland farmers in some areas, remember soil depths being in the region of 100 cm or more 20 years ago. In the worst cases found so far, farmers in the uplands of San Isidro, Municpality of Mati, indicated that soil depths were only knee high (i.e. 50 cm deep) 20 years ago, but are now less than ankle deep (15 cm).

Investigations in October 2004 by the UDP's Upland Farming/ Soil & Water Conservation Consultant confirmed that higher rates of soil losses are occurring on sloping lands (30-70% slope) where corn and cassava have been grown almost continuously[3]. Soil depths of just 22-50 cm were recorded on land cultivated for corn, or lying idle. Yet 50 metres away,

[2] Winrock International (1993). *Cattle under coconuts – a practical Pacific tradition*. Agroforestry for the Pacific Technologies. July 1993, Number 7. A publication of the Agroforestry Information Service. Winrock International. Forestry and Natural Resource Management Program

[3] *Problems with cassava production in the uplands of Southern Mindanao.* A report by for the Upland Development Programme in Southern Mindanao by Kenneth R S Proud, Upland Farming Systems/Soil and Water Conservation Consultant, & Ben-Hur Viloria, Sustainable Agriculture Development Coordinator. 25 October 2004

on slopes as steep as 85% but protected by a multi-storey cover of old fruit trees, ipil ipil, coconuts etc, soils were 70-85 cm deep[4].

The soil depths observed on very steep slopes under established multi-storey cover suggest the original depths would have been 90-150 cm. This view is supported (a) by soil pits over 1.5 m deep, dug for latrines on hill crests in San Isidro and Laak, and (b) by a survey of 16 naturally forested mountainous land systems in Indonesia, which had soil depths of 90-150 cm on slopes >60%, which account for nine-tenths of the landscape[5].

Coconut trees on the steeper slopes are often perched on "pillars" of soil due to cultivation of intercrops eroding soil from below the tree, while intercepted soil builds up on the upslope side of the trunk. As Photo 3 shows, the roots on the downslope side of the palm have been severed by ploughing or cultivation for short season crops.

C. SIGNIFICANCE

1. Importance of soil depth

- Soil stores the moisture and nutrients needed for crop growth. The deeper the soil, the more moisture and nutrients that can be stored. With a reduced depth of soil less moisture is available to sustain a crop during prolonged gaps between rainstorms. Shortages of moisture for just a few days during critical stages in a crop's cycle (e.g. at flowering or seed setting), can lead to a total crop failure.

- Unlike annual crops, which only require soil moisture during the 3-4 months of the growing season, trees require moisture in the soil throughout the year. As soil profiles erode away and become shallower, their ability to store sufficient moisture for trees to survive dry spells of several weeks is diminished. A fruit tree that has experienced severe moisture stress can take several years to regain its former productivity. As a rough guide, the amounts of water available to plants in 50 cm depth of soil are:

  Sandy soils: 25-35 mm. Loams: 75-90 mm. Clays: 125-140 mm.

- Coconuts are usually planted in pits ranging in size from 60 x 60 x 60 cm in sandy soils to 100 x 100 x 100 cm in loamy soils, on sites with at least 150 cm depth of well-drained soil.

2. Soil losses under coconut plantations and their causes

- The World Bank (c. 1989)[6] estimated soil losses under industrial tree plantations such as coconuts in the Philippines to be 360 t/ha/yr (equivalent to a reduction in soil depth of 2.5-3.0 cm/year). By comparison, soil losses of only 6 tons/ha/yr occur under undisturbed tropical rain forest.

[4] *The reduction in soil depths of upland soils in Southern Mindanao, their causes and consequences*. A report by for the Upland Development Programme in Southern Mindanao by Kenneth R S Proud, Upland Farming Systems/Soil and Water Conservation Consultant. 16 October 2004

[5] RePPProT (1988). *Reconnaissance survey of the land resources of Sumatra*. Report of the Regional Physical Planning Programme for Transmigration. (Land Resources Department (ODNRI) of the British Government's Overseas Development Administration (ODA) in association with the Republic of Indonesia's Ministry of Transmigration, Directorate General of Settlement Preparation).

[6] A World Bank report (c. 1989), with reference to the Philippines

- Corn and cassava grown almost continuously on steep slopes are responsible for much of the soil loss (see ref. [6] above). Farmers' in the UDP area estimate soil depth reductions of 50 cm over the last twenty years. This amounts to 2.5 cm/yr, which is similar to the World Bank's estimate of 16 years ago.

- The height of the canopy is important. Water drops falling from seven metres attain 90% of their terminal velocity, while small raindrops coalesce on the leaves to form larger drops that are more erosive. Raindrops, striking bare soil under coconut trees, detach soil particles from the main soil mass leaving them susceptible to transport downhill by gravity and running water.

- Sheet-erosion is a combination of the detachment of surface soil particles by raindrop impact and their transport by overland flow of run-off. The lengths and gradients of the slopes in the uplands enables run-off to reach velocities sufficient to cause scouring of the soil surface that detaches more soil particles, often exposing the tree roots (see Photo 4). The amount of soil removed from a hillside increases dramatically when sheet erosion becomes channelled into rills.

Photo 3. Build up of eroded soil above base of tree and loss of soil below from cultivation. Note severed roots at base of tree

Photo 4. Coconut tree roots exposed by sheet erosion

- Cover crops such as *Pueraria*, *Calopogonium* and *Centrosema* are planted to protect the soil from the impact of raindrops falling from the crowns of tall industrial tree crops. However, they cannot prevent run-off from occurring, so sheet erosion and rilling is common under cover crops on long slopes. Cover crops also compete with the main crop for the available moisture when water is scarce, lowering crop yields. Shade produced by the established tree crop can cause the cover crop to die out. This prevents a satisfactory ground cover from developing, increasing the erosion risk.

- Under-storey weeds, crops and pasture compete with the coconut palms for nutrients and water. Some of the most effective ground covers against erosion on sloping land are short, turf-forming, stoloniferous grasses, such as carabao grass (*Paspalum conjugatum*). Carabao grass is shade-tolerant as its horizontally-aligned leaves are able to intercept more downward light than erect leaves. Horizontal leaves protect the soil from the impact of raindrops, and the turf helps reduce rill erosion by slowing down run-off velocity and improving infiltration of water into the soil.

3. Water requirements for coconuts

Because coconut palms produce nuts throughout the year, an adequate supply of water in the root zone is crucial for the absorption of nutrients by roots. Moisture stress leads to stunted growth and decreased yield.

- Five- to six-year old coconut palms require 2.2 mm to 5.0 mm of moisture per day during dry periods (average is 3.3 mm/day). Older trees require more.

- Coconuts depend mainly on stored soil moisture to meet their water requirements during dry seasons of 17 to 21 weeks. Exposure of palms to field stress for 16 to 24 days lower vegetative dry matter production and reduce nut production.

- Coconuts meet their evapo-transpiration (E_T) demands from moisture stored in the top 70 cm of the soil profile. The 90–130 cm layer and lower layers make little contribution unless drought conditions prevail. The truncated soils of 30-50 cm depth observed under coconuts plantations (and on annually cultivated land) in the UDP area mean that the trees can only survive on shallow or very coarse soils if the rock below is sufficiently fractured or fissured to allow their roots to penetrate deeply enough reach moisture.

- Drip irrigation would be the most suitable system of irrigation for coconut on sloping land, but widespread destruction of forests and failure to protect streams and springs makes this impractical for most of sloping lands[7]. Three to four drippers are needed per coconut palm to provide a daily requirement of 40 to 50 litres per day *in the root zone*. (The same amount of water sprayed on the soil surface would mainly benefit weeds and grasses as 50 litres is equivalent to applying a depth of 2.0 mm of water in a circle within 2.3 m from the base of the tree, i.e. an area of just 25 m^2).

4. Effects of drought and moisture stress on coconuts

- The frequent occurrence of drought in high rainfall areas, due to erratic distribution of rainfall, long dry spells and poor moisture retention in the sandy soils, can result in poor nut yields.

- Coconut palms exhibit the following adverse effects when exposed to very severe moisture stress:
  - Dry, broken, and drooping leaves (see Photo 5);
  - Poor spathe[8] development, and
  - Nearly empty spikes due to heavy shedding of buttons and immature nut fall.

- The effects of prolonged drought on rainfed palms can persist for up to 2.5 years. Severe drought at initiation of the inflorescence may kill the growing point, causing the inflorescence to abort, affecting production of nuts up to 28 to 30 months later.

- Moisture stress can result in a loss of over 60% of the potential crop due to poor setting of nuts and/or immature nutfall. The lower numbers of nuts harvested combined with a reduced amount of copra produced per nut, seriously reduces the

[7] Major advantages of drip irrigation include: it saves water, enhances plant growth and yield, saves energy and labour, is most suited for soils having low water holding capacity and undulating terrain, reduces weed growth and improves efficiency of fertilizers.

[8] Spathe - A leaflike bract that encloses or subtends a flower cluster or spadix

total crop per hectare, affecting farm incomes. Although the amount of copra per nut is reduced during the drought period it increases sooner than the number of nuts.

- In March of 2005, the mayor of Manay in Davao Oriental reported that the size of nuts being harvested was considerably smaller than usual. According to the mayor of Mati, an 11-month drought in 1990 killed 250,000 coconut trees in the municipality, and there has been little rain in the municipality since August 2004. Coconut trees on sloping land in Brgy Dawan are now dying (Photo 6), because there has been no effective rainfall since December 2004,

Photo 5. Young coconut trees showing severe moisture stress Brg Dawan Mati. 7 Apr 2005

Photo 6. Dead and dying coconut trees Brgy Dawan Mati 7 Apr 2005

D. RECOMMENDATIONS

Implement:

- *short-term strategies* to improve the availability of moisture in coconut plantations on shallow soils; and
- *long-term strategies* to conserve the remaining soil and improve the plantations productivity and income-generating potential

1. Short-term strategies

Adopt the following *Drought management* practices in the coconut plantations to minimize the risk of moisture stress:

a) *Increase the supply of moisture to the root zone by burying fresh or dried coconut husk in trenches around the palm to intercept and absorb run-off.*

b) *Conserve stored soil moisture by applying mulch around the trees to reduce evaporation of moisture from the soil*.

c) *Reduce the demand for soil moisture by cutting down the leaf area available for transpiration.*

2. Long-term strategies

a) *Adopt multi-storey cropping to protect the soil from erosion and increase the relative humidity in the under-storey*

The basis of multi-storey cropping is to recreate the multi-level canopy of the original rain forest by planting a mix of fruit and cash crop trees[9], eventually restoring the process of recycling of organic matter occurring in natural forests[10]. The layered canopy formed by trees of different heights dissipates the energy of raindrops. The leaf fall from the trees will gradually cover the soil with a thick layer of protective mulch (Photo 7) that provides nutrients for tree growth, while improving infiltration of rainfall and run-off and retaining soil moisture.

Various multi-storeyed coconut cropping systems that give higher income per hectare than a monoculture of coconuts, include:

- Coconut plantations underplanted with ipil ipil to support vanilla plants and provide forage for livestock (e.g. Indonesia),

- Other suitable intercrops for coconuts on sloping lands include cacao, coffee, citrus, cloves, banana and papaya (e.g. Malaysia and Papua New Guinea).

Multi-storey cropping is possible, regardless of the age of the palms, if the spacing between trees is 7.6 m or more. Most of the coconut plantations in the UDP are planted at 9m spacing. Mature plantations, i.e. over 25 years' old, allow sufficient light to enter the under-storey making conditions suitable for underplanting.

Photo 7. Build up of leaf litter from multi-storey cropping

b) Replace the existing over-mature palms with high-yielding, drought-resistant coconut varieties planted in an East-West direction to facilitate intercropping.

[9] *STOP2: Multi-storey cropping*. A handout produced for the UDP by KRS Proud, Upland Farming Consultant.
[10] *STOP 3: Mulching and Zero-Tillage*. A handout produced for the UDP by KRS Proud, Upland Farming Consultant.

E. ACTIONS NEEDED

1. Short-term drought management strategies

a) Increasing the supply of moisture to the root zone

- To maximize the infiltration and storage of run-off water dig trenches 0.5 m wide and deep, either in linear trenches taken 3 m away from the trunk between rows of palms; or in circular trenches dug round the palm 2 m from the trunk. The beneficial effects can last for 5-7 years.

- Place the coconut husks in layers with concave surface facing upwards and cover them with soil. (*Whether this method from India will work on truncated soils less than 50 cm depth needs testing on the learning sites*).

- Ploughing to a depth of 20 cm, before the onset of the rains, increases moisture penetration to as deep as 60 to 90 cm. (*To avoid accelerating erosion, this strategy should only be used on slopes below 12%*).

b) Conserving moisture by minimizing evaporation from the soil surface

- Mulch the area round the coconut trees with green or dry leaves or cut grasses to reduce the soil temperature. This prevents upward capillary movement of moisture to the soil surface, suppresses competition from weeds and adds organic matter to the soil. Infiltration of water is also increased. (The advantages of mulching will need to be balanced against the risk of fire).

c) Reducing demand for soil moisture by lowering transpiration rates

- Reduce the transpiration rates of the coconut palms by cutting off the lowermost 3-5 green leaves and use them as a mulch to cover the soil around the base of the tree. The stumps of the cut leaves left on the tree should be at least 120 cm long to help prevent inward movement of Red palm weevil grubs *(Rhyncophorus ferrugineus)* through the cut ends.

- Reduce the demands for soil moisture by regularly cutting down the weeds and shrubs and applying them as mulch around the trees. Clean weeding and spraying with herbicide can result in yield increases from 10–47 nuts per palm per year, but should be restricted to slopes of 0-12%, to prevent erosion.

2. Long-term strategies to control land degradation and conserve soil

a) Diversify production through *Multi-storey cropping* in mature plantations

With established coconut plantations start the sequence of multi-storey cropping by planting with bananas, citrus, coffee and ginger to get short-term and medium-term income. Phased cropping gives a continuous supply of food, fruits and fibre, and spreads labour requirements throughout the year.

The alleys between rows of coconut trees, if planted in an East-West direction, have less shade so solar radiation can be maximized by crops planted in the alleys. Different types of tree crops are planted in sequence. For example:

Stage	Crops to be planted	Comments
1	Banana, citrus, ginger	Rows oriented E-W.
2	Coconut, mango or durian, lansones	Rows oriented E-W between 1st stage trees
3	Coffee, cacao, jackfruit, medicinal plants	Plant in the shade produced by 2nd stage trees

- Identify the planting sites for the fruit trees in the alley between rows of coconut trees, to form a quincunx layout with four coconut trees.

- Each planting site should be well-mulched to diameter of 3 metres, using locally cut shrubs and grasses – taking care they are free of seeds.

- When sufficient rain has fallen at the start of the rainy season plant the *seeds* of fruit trees in the alley *between* the rows of coconut trees. Mangoes, which prefer more light, should be planted in open spaces or between rows of coconut trees that are aligned in an East-West direction. (The tap root of the seedling developing from the planted seed should be able to penetrate any fissures or cracks in the rock strata underlying the shallow soil to obtain deeply stored moisture and nutrients. The fibrous root systems of nursery-produced seedling planted in shallow soil will be more susceptible to drought).

- Field-graft scions from certified fruit trees when the seedlings are 6-12 months old.

- Plant bananas, coffee, cacao, and other shade-tolerant species in a random manner between the coconuts and fruit trees.

- If ginger is planted, the planting areas should be covered with cocnut fronds, and soil replaced in the holes after harvesting.

By diversifying production into other fruit trees, the upland farmer can offset income losses should any one crop fail, produce low yields, or the price drops on the market. Incomes of P 100,000/ha/yr are feasible with the right mix of coconuts, mangoes, bananas, lanzones, and durian, with pineapple, and a patch for growing vegetables such as egg plant and okra.

b) Plant higher-yielding, drought-resistant varieties of coconut trees

Municipalities with a pronounced dry season, that are likely to be most affected by El Niño, might consider encouraging a gradual replacement of existing trees with new high yielding coconuts. For example, in India, Yellow Dwarf coconut varieties are the most promising for regions subjected to a water deficit, because of their deeper rooting abilities.

The largest quantity of roots of six-year-old dwarf coconut trees occur in the 20-60 cm horizon and 90% of total roots and 85% of fine roots within a radius of 1.5 m around the stem. This is advantageous if mulching materials are scarce. It remains to be seen whether the new varieties of coconut can be established in soils on less than 50 cm deep. If so, then planting densities that allow various intercropping systems to be developed need to be identified and adopted. Work

in Sri Lanka recommends planting coconuts in avenues or hedges, with wider rows oriented east to west (e.g., 10 × 5 m, 12 × 5 m, 15 × 5 m)[11] to make more light available for the intercrops.

Similarly, in Indonesia planting young coconuts at 5 × 12 m in an E-W direction, gives a tree population of 160 palms/ha and wide inter-row areas with sufficient sunlight for growing other crops[12].

F. CONCLUSIONS

- Agricultural practices on the long slopes and fragile soils of the uplands in Southern Mindanao are contributing to serious land degradation under many coconut plantations. As a result, the present truncated soils, with depths of only 30-50 cm, are no longer able to store sufficient moisture to tide the coconut trees over extended periods of drought without suffering severe, yield-reducing stress. In some areas, coconut trees are already under great moisture stress and dying off. If the estimated rates of soil loss of 360 t/ha/yr (equal to a reduction in soil depth of about 3.0 cm per year) are allowed to continue, a mass die off of coconut plantations is likely within the next 10-15 years.

- Reducing transpiration rates through simple strategies, such as removing the lower green leaves of the palms and mulching, may enable some trees to survive until sufficient rain falls. These strategies, however, cannot maintain the productivity of severely moisture stressed palms. Trials are needed to see if drought-resistant dwarf varieties of coconut palms can grow productively on the truncated soils in the uplands, and replanting programmes planned accordingly.

- The levels and causes of environmental degradation in the uplands need publicising in neighbouring municipalities and provinces. LGUs and upland farmers outside the UDP Project area need exposing to, and trained in applying, the short- term strategies to conserve scarce soil moisture, so their coconut trees can survive longer during extended dry periods.

- Slope treatment-oriented practices (STOP); and diversified farming systems such as multi-storey cropping, which safeguard the soil, *the* most critical upland resource for farmers, must be demonstrated outside the Project area. A three-pronged approach, along the following lines, is required:

    1. Carry out an awareness campaign in neighbouring municipalities or provinces to draw the attention of LGUs, farmers and politicians to the irreversibly damaging effects of growing annual crops on sloping lands, and of the erosion occurring under monocultures of coconut trees. It should also highlight the increase in incomes and benefits to be gained from switching from annual crops, such as corn and cassava, to bananas and fruit trees.

    2. Set up model farms to showcase STOP technologies (land unit farming, multi-storey cropping, etc). The following procedure is suggested:

[11] Liyanage, M. de S. and Dassanayake, K.B. (1993). Experiences in coconut based farming systems in Sri Lanka. In: Advances in Coconut Research and Development (eds. Nair, M.K., et al.). Proc. of Intern. Sympos., Kasaragod 26–29 Nov. 1991, 357–367. Indian Soc. for Plantation Crops.

[12] Darwis, S.N. (1988). Status of intercropping on coconut lands in Indonesia. Proc. Workshop on Intercropping and Intergrazing in Coconut Areas, 7–11 September, 1988, Colombo, Sri Lanka.

- Groups of farmers should be asked to select one or two of their neighbours as the model sites.
- The farms should have terrain typical of the area, and the farmers should understand that only the persons chosen will have their farm developed with UDP inputs.
- The selected farms should be readily accessible and be close to and visible from roads or footpaths leading to the sitios or barangays.
- UDP and LGU staff should visit the showcase farms to train the neighbouring farmers and LGU extension staff in appropriate upland agricultural practices, including introducing dwarf coconut varieties.
- The farms will be a source of planting materials for soil and water conservation measures (e.g. Napier and Vetiver grass, leguminous hedgerow species etc.) and well as scions for field grafting of directly seeded fruit trees.

3. Train LGU staff in UDP's agricultural extension approach.