COCOS (2003), 15 38 – 52
*Printed in Sri Lanka*

# ECONOMIC FEASIBILITY AND BIOLOGICAL PRODUCTIVITY OF COCONUT-BASED AGROFORESTRY MODELS IN SRI LANKA

**W. B. K. Peiris[a], M. T. N. Fernando[b], H. M. G. S. B. Hitinayake[c], K. B. Dassanayake[b], H. A. J. Gunathilake[b] and S. D. J. N. Subasinghe[b]**

[a] *HARDY Advanced Technical Institute, Inginiyagala Road, Ampara, Sri Lanka*
[b] *Coconut Research Institute, Lunuwila, Sri Lanka,*
[c] *Dept. of Crop Science, Faculty of Agriculture, University of Peradeniya, Peradeniya, Sri Lanka*

## ABSTRACT

This study evaluates the economic feasibility and biological productivity of coconut-based agroforestry models designed for coconut smallholders. Coconut Research Institute of Sri Lanka has developed and established twenty-six agroforestry models in farmers' fields. Of them, four models were selected for this study. They were: mixed farming for Wet Zone (model 1), mixed cropping for Wet Zone (model 2), mixed farming for Wet Intermediate Zone (model 3) and catch cropping in young replanted coconut for Wet Intermediate Zone (model 4), established at Gaspe, Hanchapola, Katuneriya and Thulawala, respectively. Input and output data for several years, for each model, were used in the evaluation. Annual Gross Margins (GM) payback period, Net Present Value (NPV) and Benefit-Cost Ratio (BCR) were employed for the economic analysis. Biological productivity of the models was determined employing Land Equivalent Ratio (LER) and Relative Yield Total (RYT).

NPVs of agroforestry models were higher than the monocrop, suggesting the higher net worth of the agroforestry models in the long run. Other economic indicators also showed that agroforestry models were more profitable than coconut monoculture. In all models, LER exceeded unity, indicating the yield advantage with agroforestry over coconut monocultures. However, RYT values indicated that there were negative interactions between component crops of certain models, which can be attributed to the competition that occurs between crops.

## INTRODUCTION

Coconut *(Cocos nucifera L),* which is known as "The tree of life", is the most extensively cultivated plantation crop in Sri Lanka, and plays a vital role as a multipurpose tree. During 1998, export earnings from all coconut products amounted to about Rs 6110 million[1] (Central Bank Annual Report, 1998). However, coconut monoculture utilizes biophysical resources sub-optimally. In a mature coconut plantation, nearly 75 per cent of productive land area remains unutilized, because coconut has to be planted at a wide spacing (7.9 m x 7.9 m) to permit canopy growth and root distribution at maturity. Also, a mature coconut plantation utilizes only 44 per cent of total available light (Nair and Balakrishnan, 1976). In economic terms, monoculture coconut brings low returns per unit land area.

Coconut-based agroforestry is one of the strategies to overcome the above problems by enhancing resource use and land productivity while raising return per unit land area. Liyanage and Dassanayake (1991) in their review of coconut-based agroforestry in Sri Lanka identified several systems such as intercropping, mixed cropping, coconut-based alley cropping, coconut-based mixed farming and cultivation of multipurpose trees in coconut lands. Availing itself of this large volume of findings and experience, the Coconut Research Institute of Sri Lanka (CRISL) developed many coconut-based agroforestry models for coconut growers to increase land productivity and farmers' income. Selected models were established in farmers' fields in different agro-ecological zones, to study their performance at the level of management prevalent in the farms rather than at experimental stations.

Evaluation of these models both in terms of agronomic and economic performance is an important pre requisite for making recommendations to farmers.

## Objectives of the study

The purpose of this study is to evaluate the economic feasibility and biological productivity of agroforestry models developed by the CRISL for smallholders in the Wet and Intermediate Wet Zones of Sri Lanka.

---

[1] 1 US$ = Rs 64.31 as on May 1998.

**Table 1: Coconut–based agroforestry models established by CRISL in farmers' fields**

| Serial no | Agro-ecological region | District | Soil type | Location | Type of model | Components |
|---|---|---|---|---|---|---|
| 1 | WIZ | Puttalam | LG | Kahatawila | Intercropping | Banana, ginger |
| 2 | WIZ | Puttalam | LG | Thulawala | Mixed crop | Pepper, lime,Ginger |
| 3 | WZ | Gampaha | LG | Walpita | Mixed crop | Pepper, banana, ginger |
| 4 | WZ | Gampaha | LG | Hanchapola | Mixed crop | Pepper, coffee, ginger |
| 5 | WZ | Gampaha | LG | Gaspe | Mixed farm | Pasture, NFT's, local x jersey |
| 6 | WZ | Gampaha | LG | Banduragoda | Intercropping | Banana, ginger |
| 7 | WZ | Gampaha | LG | Mirigama | Mixed farm | Brachiaria ruziziensis,NFT, gliricidia, pepper, coffee, Sindhi x Jersey |
| 8 | WIZ | Puttalam | SL | Ihalakatuneriya | Mixed farming | Coffee,Guini B, B. milliformis, pueraria,Gliricidia, Sindhi x Jersey |
| 9 | WIZ | Puttalam | LG | Thulawala | Intercropping | Pineapple, ginger, banana |
| 10 | WIZ | Puttalam | LG | Kahatawila | Mixed crop | banana, pepper, ginger, coffee |
| 11 | WZ | Gampaha | LG | Divulapitiya | Mixed crop | banana, pepper, yams, coffee |
| 12 | WZ | Gampaha | LG | Mirigama | Mixed crop | pepper, coffee |
| 13 | WI,IL1 | Puttalam | LG | Pothuwatawana | Mixed crop | pepper, coffee, banana, ginger |
| 14 | WL3 | Gampaha | LG | Divulapitiya | Mixed crop | pepper, coffee |
| 15 | WL3 | Gampaha | LG | Walpita | Intercropping | banana |
| 16 | WL3 | Gampaha | LG | Walpita | Intercropping | pineapple |
| 17 | WL3 | Gampaha | LG | Udulla | Mixed crop | ginger, pepper, coffee, yam |
| 18 | WL3 | Puttalam | LG | Katuneriya | Mixed crop | pineapple, ginger, cashew |
| 19 | IL1 | Puttalam | LG | Kahatawila | Mixed crop | pepper, coffee |
| 20 | IL1 | Puttalam | LG | Rathmalagara | Mixed farming | NFT's, pasture, goat |
| 21 | IL1 | Kurunegala | LG | Deegalla | Mixed crop | cashew, lime, NFT's |
| 22 | IL1 | Gampaha | LG | Divulapitiya | Mixed crop | lime, mango |
| 23 | WL3 | Gampaha | LG | Madurupitiya | Mixed farm | pepper, pasture, cattle |
| 26 | IL3 | Puttalam | SL | Katuneriya | Mixed farm | pepper, pasture |

Key : LG-Lateritic Gravel, SL-Sandy Loam, NFT's-Nitrogen fixing trees.

## MATERIALS AND METHODS

The Agronomy Division of CRISL established 26 coconut-based agroforestry models in small-scale farmers' fields in different agro-ecological regions to investigate the agronomic performance, economic feasibility and the conformity of these models with the existing resource base of the farmers. The details of the established models are given in Table 1. At each site, a control plot monoculture coconuts was maintained for comparison with the model.

Of the 26 models, 4 models (see Table 2) were selected for detailed study considering the time and other resource limitations.

**Table 2: Description of the selected models**

| Attribute | Model 1 | Model 2 | Model 3 | Model 4 |
|---|---|---|---|---|
| Location | Gaspe, Banduragoda | Hanchapola, Divulapitiya | Ihala Katuneriya | Thulawala |
| Model | Mixed farm | Mixed crop | Mixed farm | Catch cropping (replanting) |
| Farmer | P A Hemachandra | K Amaradasa | Michael Fernando | T Madurapperuma |
| Agroecological zone | Wet Zone (WZ) | WZ | Wet Intermediate Zone (WIZ), (IL1) | WIZ (IL1) |
| Soil type | Lateritic gravel | Lateritic gravel | Sandy loam | Lateritic gravel |
| *Coconut plantation* | | | | |
| Planting system | 8 x 8m | 8 x 8 m | 8 x 8 m | 10 x 6.5 m. Avenue |
| Age | 30 Years | 40 Years | 40 Years | 1 Year |
| Average yield | 47nuts/palm/year | 57 nuts/palm/year | 72 nuts/palm/year | – |
| Other crops/livestock | | | | |
| 1. Season of establishment | May/June,1992 | Oct/Nov, 1987 | Yala 1989 | Maha 91/92 |
| 2. Extent of the model | 1 acre | 0.05 ac | 2 ac | 0.5 ac (40 palms) |
| 3. Crops/pasture | pasture, NFT's | pepper 130 vines Coffee 60 plants Ginger 40 plants Banana 40 suckers | Coffee 262 plants Guinea B & Brachiaria milliformis, Pueraria & Gliricidia | Pineapple- 2600 plants, Banana- 48 suckers, Ginger- 50 kg, |
| 4. Animals | Local x Jersey | None | Sindhi x Jersey crossbred heifers -2 | None |

| Attribute | Model 1 | Model 2 | Model 3 | Model 4 |
|---|---|---|---|---|
| Location | Gaspe, Banduragoda | Hanchapola, Divulapitiya | Ihala Katuneriya | Thulawala |
| Model | Mixed farm | Mixed crop | Mixed farm | Catch cropping (replanting) |
| Farmer | P A Hemachandra | K Amaradasa | Michael Fernando | T Madurapperuma |
| Agroecological zone | Wet Zone (WZ) | WZ | Wet Intermediate Zone (WIZ), (IL1) | WIZ (IL1) |
| Soil type | Lateritic gravel | Lateritic gravel | Sandy loam | Lateritic gravel |
| *Coconut plantation* | | | | |
| Planting system | 8 x 8m | 8 x 8 m | 8 x 8 m | 10 x 6.5 m. Avenue |
| Age | 30 Years | 40 Years | 40 Years | 1 Year |
| Average yield | 47nuts/palm/year | 57 nuts/palm/year | 72 nuts/palm/year | – |
| Other crops/livestock | | | | |
| 1. Season of establishment | May/June,1992 | Oct/Nov, 1987 | Yala 1989 | Maha 91/92 |
| 2. Extent of the model | 1 acre | 0.05 ac | 2 ac | 0.5 ac (40 palms) |
| 3. Crops/pasture | pasture, NFT's | pepper 130 vines Coffee 60 plants Ginger 40 plants Banana 40 suckers | Coffee 262 plants Guinea B & Brachiaria milliformis, Pueraria & Gliricidia | Pineapple- 2600 plants, Banana- 48 suckers, Ginger- 50 kg, |
| 4. Animals | Local x Jersey | None | Sindhi x Jersey crossbred heifers -2 | None |

## Data Collection

### A. Economic data

Monthly input and output data of each model and the control, were collected from the time of establishment.

### B. Biological productivity data

Per hectare yields of component species when grown in mixtures and as a monocrop were recorded to calculate the Land Equivalent Ratio (LER). Per plant yields of the component crops in the mixtures and in the monocultures[2] were also recorded to calculate the Relative Yield Total (RYT) values.

## Analytical Procedure

### A. Economic feasibility of agroforestry models

Economic feasibility of selected agroforestry models in relation to coconut monocrop was examined employing different economic indicators described below.

#### *a. Annual gross margin (GM) and pay-back*

Annual gross margins (GM) shows the annual net cash flow of agroforestry models and monocrop. It is the net return to the farmer for his investment.
GM is computed by deducting total variable cost from annual gross income.

GM= Annual gross income - Total variable cost

Pay-back period of each model indicates the time needed to cover the total investment by gross margins. Cumulative gross margins were plotted against years of investment to determine the pay-back period.

#### *b. Net present value (NPV)*

The component crops or livestock of agroforestry models do not always generate the benefits immediately after the investment. Perennial crops particularly need nearly ten years to generate significant benefits. NPV is used in such situations to compare net worth of monocrop and agroforestry model for the production period.

[2] The latter data was collected from secondary sources.

It brings the future cash flows to the present value. NPV is computed by subtracting the sum of the discounted cost from the sum of discounted benefits.

$$NPV = \sum_{t=1}^{n} Bt/(1+r)^t - \sum_{t=1}^{n} Ct/(1+r)^t \qquad (1)$$

Where
Bt = Value of benefits in the "t" th year
Ct = Value of costs in the "t" th year
t = Time period/year
r = Discount rate
In calculating NPV, discount rates of 10%, 15% and 25% were used.

*(c) Benefit-cost ratio (BCR)*
BCR analysis explains the returns that can be earned from the investment compared to the cost involved. If the BCR is more than one, that model is economical. If it is less than one, the model is not economically worthwhile. BCR for each model was computed as below.

$$BCR = \frac{\text{Sum of discounted benefits}}{\text{Sum of discounted costs}}$$

$$BCR = \frac{\sum_{t=1}^{n} \frac{Bt}{(1+r)^t}}{\sum_{t=1}^{n} \frac{Ct}{(1+r)^t}} \qquad (2)$$

All notations are similar as in equation (1).

BCR was calculated using 10%, 15% and 25% discount rates.

## B. *Biological productivity*

Biological productivity was analyzed employing Land Equivalent Ratio (LER) and Relative Yield Total (RYT).

### a. *Land equivalent ratio (LER)*

LER explains yield advantage from agroforestry as compared with monocultures.

$LER = \Sigma (Y_i^m / Y_i^a)$ ______________ (3)

Where

$Y_i^a$ = Per hectare yield of $i^{th}$ component species when grown in mixtures

$Y_i^m$ = Per hectare yield of $i^{th}$ component species when grown in monoculture

*b.* ***Relative yield total (RYT)***

$RYT = \_\ \Sigma \{(P_i^a/P_i^m) + (P_j^a/P_j^m)\}$ ______________ (4)

Where

$P_i^a$, $P_i^m$ = Per plant yield of species "i" in agroforestry and in monoculture respectively

$P_j^a$, $P_j^m$ = Per plant yield of species "j" in agroforestry and in monoculture respectively

## RESULTS AND DISCUSSION

### A. Economic feasibility

#### *a. Annual gross margins (GM)*

The annual GMs of the coconut monoculture and agroforestry systems are presented in Table 3.

**Table 3: Annual GMs of coconut monoculture and agroforestry systems**

| Years | Model 1 (Rs/ac) | | Model 2 (Rs/0.5 ac) | | Model 3 (Rs/2ac) | | Model 4 (Rs/0.5ac) | |
|---|---|---|---|---|---|---|---|---|
| | Mono crop | Mixed farm | Mono crop | Mixed crop | Mono crop | Mixed farm | Monocrop | Catch cropping |
| 1 | -4756 | -14396 | 513 | -1541 | 20820 | 729 | -3741 | -24308 |
| 2 | 8616 | 25634 | 1621 | 40 | 12295 | -18 | -1686 | 36623 |
| 3 | 8704 | 19792 | 3803 | 7080 | 24125 | 6879 | -1542 | 31497 |
| 4 | 5023 | 19615 | 6942 | 5233 | 17988 | 53537 | -2118 | 24087 |
| 5 | 10046 | 89987 | 4949 | 5835 | 37901 | 49791 | - | - |
| 6 | - | - | 2084 | 2553 | 23587 | 46296 | - | - |
| 7 | - | - | 3627 | 5415 | 15733 | 41436 | - | - |
| 8 | - | - | 5543 | 11903 | - | - | - | - |
| 9 | - | - | 10262 | 17788 | - | - | - | - |

Note: 1 US$ = Rs 64.32 as on May 1998.

In model 1, both monocrop and mixed farming systems had negative GMs in the first year. The mixed farming system had a negative value three times higher. The negative gross margin of the monocrop system in the first year was due to the expenses involved in preparation of husk pits. Higher negative GM of the mixed farming system was due to the initial cost involved in establishment of pasture, purchasing of animals and preparation of husk pits. From the second year onwards, gross margins of the mixed farming system increased considerably over the monocrop system. In the fourth year, return of mixed farming was nearly four times greater than the monocrop, and in the fifth year, it was nine times more. This significant increase of GM was due to the net return contributed by dairy farming and increased coconut yield due to complementary effects of mixed farming.

In model 2, first, second and fourth year of the mixed cropping system GMs were very low because of the long payback period of pepper, a perennial intercrop. Pepper was introduced into the model during the first year but it did not give a satisfactory yield until the eighth year. Coffee was introduced into the model in the fourth year and it failed to generate a significant yield within the cropping period. Establishment cost of coffee in the fourth year caused a low GM in that year compared to monocropping. In order to overcome the long pay-back period of coffee, ginger was introduced into the model during the fifth year. Although it generated a considerable GM, it was not continued thereafter. The GM values of agroforestry systems consistently exceeded monocropping from fifth year onwards. During the second year, banana was introduced into the system, and costs of inputs reduced the GM of the second year. The GM of the monocrop model was half that of mixed cropping model during the eighth and ninth years due to the increased yields of pepper and coffee. The complementary effect on coconuts of the mixed cropping system was not significant.

Returns to the farmer were high in coconut monoculture up to third year in model 3. Mixed farming system showed a significant increase in GM from fourth year onwards. The main reason for this is that cattle were introduced into the model in the third year thus increasing the total income of the model after the third year. The negative GM of second year of the mixed farming system was due to the labour cost for harvesting and removing excessively grown Peuraria. In fact, this cost would not have been incurred in the model, cows had been introduced into the model in the second year. The aim of the model was to introduce cows after one year of establishing pasture, but this farmer failed to do so. This is a practical problem farmers' encounter in practicing agroforestry systems. Introduction of component crops and animals resulted in a low GM in the first three years of mixed farming over monocropping. Coffee started to generate an income from the fourth year onwards.

Although replanting is agronomically superior to underplanting as a mean of replacing senile plantations, farmers prefer underplanting due to economic reasons. Agroforestry model 4 is designed for a replanted coconut land. In the monoculture system, negative GMs were recorded each year as there was no produce. This is a major constraint to the adoption of replanting over-aged coconut plantations. But in the catch cropping model, except in the first year, GMs were positive and very high. So, the adoption of catch cropping can mitigate the deferment of income due to replanting. Only annuals and semi-perennials can be grown with coconut seedlings in the first five years. Therefore, annual cash crops like ginger, helps to provide a higher income during the unproductive immature phase of the plantation. During the first year, GM of catch crops model was negative as the establishment cost of pineapple, ginger and banana were included, but by the end of the second year there was a positive balance, which increased annually thereafter.

### b. *Pay-back period*

In model 1, payback period of the dairy unit was as low as a little over one year, which was due to the improved GM from the second year (Figure 1). Pay-back period of the mixed cropping model 2 was little more than two years (Figure 2), which is a fairly long pay-back period. This is because coffee and pepper did not generate a positive return during the initial growth stages. This may reduce the attractiveness of the model to resource-poor smallholder farmers who often cannot wait long for returns. There is no pay-back period for model 3, as the model covered the initial cost within the first year itself because the GM from coconut was high.

The pay-back period of the catch cropping system (model 4) was less than two years (Figure 3). It is evident that catch cropping a replanted coconut land is more beneficial than a coconut monoculture and possibly underplanting, judging by the income from coconut monoculture in models 1 and 2.

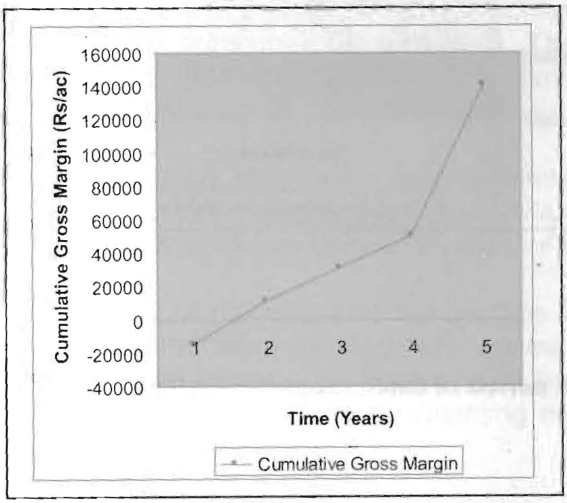


**Figure 1 : Pay-back period of agroforestry system – model 1**

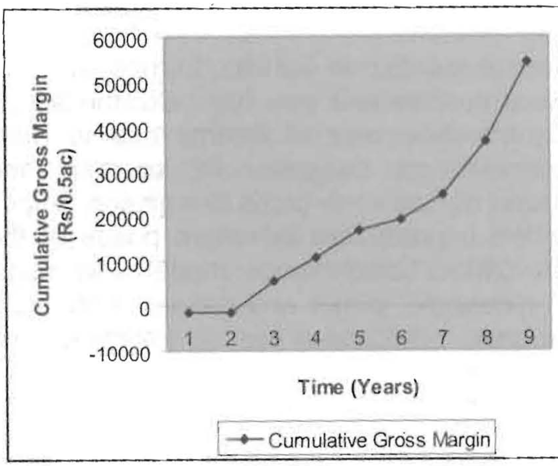


**Figure 2 : Pay-back period of mixed farming system - model 2**

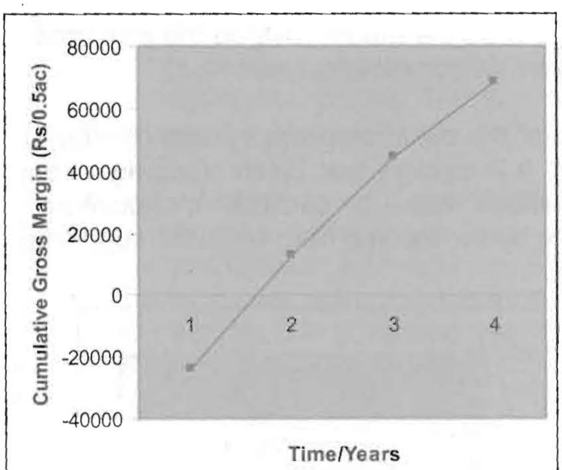


**Figure 3 : Pay-back period of catch cropping system - model 4**

*c. NPV*

All four agroforestry models generated substantially higher returns at all the discount rates than the comparable monoculture (Table 4).

Table 4: **NPV of agroforestry and coconut monocrop systems at different discount rates**

| | | Discount rate | | |
|---|---|---|---|---|
| | | 10% | 15% | 25% |
| Model1 (Rs/ac/5 years) | Mixed farming system | 101491 | 87231 | 65698 |
| | Monocrop system | 20905 | 18364 | 14394 |
| Model 2 (Rs/0.5 ac/9 years) | Mixed cropping system | 31312 | 24525 | 15828 |
| | Monocrop system | 21525 | 17578 | 12440 |
| Model 3 (Rs/2ac/7 years) | Mixed farming system | 132764 | 110515 | 78955 |
| | Monocrop system | 107061 | 93799 | 74530 |
| Model 4 (Rs/2ac/4 years) | Catch cropping system | 132764 | 110515 | 78955 |

The NPV of agroforestry model 1 was about 4-5 times greater than that of the monocrop at different discount rates, indicating that investment in mixed farming is more beneficial than the adoption of monocropping. This agroforestry model could be recommended for coconut smallholders as the model generates benefits within a short period of time.

The NPVs of the agroforestry model 2 were 1.2 to 1.5 times higher than monocropping at different discount rates. The relatively low increase in NPV of the agroforestry system is especially due to the long payback period of pepper and coffee, which need four years to generate a sizeable benefit. Component crops were introduced into the model in different years, and the establishment cost was high within the first five years. This model needs at least another three to five years' data for a rigorous analysis because coffee needs a long time to generate its maximum yield. This mixed cropping model cannot be recommended for small-scale farmers who expect immediate benefits.

In agroforestry system model-3, NPVs were only marginally higher than with monocropping. This model has the potential to generate large benefits, but coffee had not generated its maximum yield within the trial period.

It is clear from the NPVs of model-4 that catch crops in replanted fields generated significant returns while the monocrop does not generate any income during the immature phase. This model could be recommended to the farmers who hesitate to adopt coconut replanting due to zero income until the plantation comes into bearing.

t all the

*d. BCR*

The BCRs of all agroforestry models and the coconut monocultures exceeded unity, and were therefore financially worthwhile (Table 5).

**Table 5: BCRs of agroforestry and coconut monocrop systems at different discount rates**

| | | Discount rates | | |
|---|---|---|---|---|
| | | 10% | 15% | 25% |
| Model - 1 | Mixed farming system | 1.95 | 1.88 | 1.76 |
| | Monocropping system | 2.18 | 2.09 | 1.93 |
| Model - 2 | Mixed cropping system | 1.92 | 1.87 | 1.74 |
| | Monocropping system | 3.01 | 2.98 | 2.94 |
| Model - 3 | Mixed farming system | 1.95 | 1.90 | 1.78 |
| | Monocropping system | 3.21 | 3.21 | 3.20 |
| Model - 4 | Catch cropping system | 2.35 | 2.24 | 2.04 |

It is noteworthy that the BCR for monocropping was higher than for the agroforestry models, except for the monoculture comparison for model 4, as there are no benefits during the immature period. Coconut is well known as a "lazy man's crop" for its less-intensive utilization of inputs, especially labor, which is the main reason for the higher BCR of monocropping.

In summary, the BCR analysis proved that all models are financially worthwhile in terms of return to investment except for the immature phase of monocrop model where coconut is replanted.

## B. Results of biological productivity analysis

The Land Equivalent Ratio (LER) and Relative Yield Total (RYT) of different agroforestry systems are presented in Table 6.

**Table 6: Land Equivalent Ratio (LER) and Relative Yield Total (RYT) of different agroforestry systems**

| Model | LER | RYT |
|---|---|---|
| 1 | 3.220 | * |
| 2 | 2.473 | 1.62 |
| 3 | 2.306 | * |
| 4 | 4.825 | 0.76 |

* Per plant yield of pasture (dry matter yield) was not recorded in the trials.

*a. LER*

LER can be used to measure the land use efficiency when many crops are grown together in the same land. The LER of all the agroforestry models are higher than one, implying that the yield advantage or biological productivity is higher in agroforestry systems than in monocrop coconuts.

*b. RYT*

RYT values were calculated only for the two crop models due to lack of per plant dry matter yield of pastures in the mixed farming models. RYT value was greater than one in model 2. This means that there were beneficial inter-specific interactions or supplementary interactions. Although the farmer of model 2 indicated that inter row spacing of pepper was too low (i.e. density of pepper was too high), the RYT value does not prove it. This may be due to the positive effects of nitrogen fixing legumes such as gliricidia. RYT removes the effect of population density on the yield. In model 2, LER and RYT were both greater than one, indicating that there was no competition between the component crops. In model 4, RYT is less than one, which means that there were some negative interactions between the component crops. It may be due to over crowding of plants. Therefore, increasing the inputs of resources such as fertilizer and moisture, or reducing the densities of the crops could be useful to minimize the competition of crops.

## CONCLUSIONS AND RECOMMENDATIONS

Coconut-based agroforestry is one of the strategies to overcome the sub optimal utilization of bio-physical resources by coconut monocultures and thereby raise farm income. This study evaluates the economic feasibility and biological productivity of two coconut-based agroforestry models and two crop-livestock integrated coconut-based agroforestry models, employing such indicators as GMs, NPV, pay-back period, BCR, LER and RYT.

1. In comparison with coconut monoculture:

   - NPVs of all the agroforestry models were higher indicating better economic viability.
   - BCRs of all the agroforestry models were lower because of much greater use of inputs.
   - Agroforestry models 1 and 4 were more profitable, even in the short run.
   - All the agroforestry systems require additional resources.
   - Biological productivity or yield advantages of the agroforestry models were greater.

2. Positive interspecific interactions were evident in model 2. This may be due to supplementary effects of components in the agroforestry model.

3. Negative interspecific interactions were evident in model 4. This may be due to competition among component crops because of high plant population.

The components to be included in agroforestry models should be carefully decided taking farmers' objectives and resource availability into consideration. Crops providing early returns such as ginger, banana and pineapple, and dairy units should be included into agroforestry models for farmer categories seeking quick returns and can afford to intensive use of purchased inputs and labor. In contrast, for farmers who cannot afford for intensive use of purchased inputs and labor, can wait for returns, component crops to be included into agroforestry models should be perennials such as pepper, coffee etc.

## REFERENCES

*Central Bank Annual Report* (1998). Central Bank of Sri Lanka. Colombo.

Liyanage, M.de.S. and Dassanayake, K.B. (1991). Experience in coconut-based farming systems in Sri Lanka. In: *Advances in coconut research and development*, (Eds.) M. K. Nair, H. H. Khan, P. Gopalsunderam and E. V. V. Bhaskara Rao. New Delhi Oxford and IBH publishing company, 357 – 367.

Nair, P.K.R. and Balakrishnan, T.K. (1976). Pattern of light utilization by canopies in a coconut/cocoa crop combination. *Indian Journal of Agricultural Science*, 46, 453-462.

## ACKNOWLEDGEMENT

We are grateful to Dr. (Mrs) C. Jayasekera, Director of the CRISL, for approval to publish this paper. Authors also wish to acknowledge the early hard work of Messrs. K D D Appuhamy, E M Gunerathnebanda and Ryle Silva on establishing the on-farm agroforestry models. Co-operation of Mrs. Nilmini Jayalath and Mr M. J. I. Costa, CRISL, is gratefully acknowledged. Useful comments of anonymous referees are gratefully acknowledged.