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Contents

Appropriate Intercropping Systems for Coconut Smallholders: An Application of Multi-period Linear Programming Technique in Coconut-Based Farming Systems

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ABSTRACT

Increasing the productivity of coconut-based farming systems is an important development issue. To achieve increased productivity, intercropping of coffee, pepper and cocoa with coconut was recommended. Farmers' adoption of such intercropping on a sustained basis has been very poor. The paper provides some intercropping plans developed using a multi-period linear programming model of the coconut-based farming systems. Farmers' objectives, namely profit maximising and survival, and resource constraints are included. The model maximises the present value of gross margins of intercropping activities for a 20-year period.

Both market interest and farmers' time preference rates are used as discount rates. Government subsidies for intercropping are included to highlight their implications on the model results.

The intercropping plans envisage that coffee, pepper or cocoa be planted in several stages simultaneously with annual and semi-perennial crops such as vegetables, betels, banana and pineapple. This method is markedly different from the recommended coconut intercropping methods. Utilizing the results, recommendations are made on intercropping subsidy policy and research strategies for coconut-based farming systems.

Introduction

Increasing the productivity of coconut small holdings is an important agricultural development issue in Sri Lanka (Ministry of Finance and Planning, 1981). The most notable strategy adopted to achieve this goal is the introduction of a financial subsidy scheme in 1977 for intercropping coconut with another crop such as coffee, pepper or cocoa. The subsidy schemes are implemented by the Department of Export Agriculture and

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the Coconut Cultivation Board. These institutions have emphasised, consistently for about two decades, the need to popularise and adopt intercropping recommendations. The top-down, researcher-to-farmer recommendation approach was used. Detailed investigations on the basis of first-hand field data showed that the recommendations were less appropriate to the coconut smallholders (Ranatunga et al., 1988; Herath, 1991).

It is now commonly accepted that agricultural technologies which are developed to suit **[a]** local agro-ecological conditions, and **[b]** farmers' socio-economic circumstances are better adopted at the farm level (Richards, 1986; Chambers et al., 1989; Doorman, 1991). This paper attempts to formulate such appropriate coconut intercropping systems considering the factors [a] and [b]. An economic analysis of this nature is a necessary, but not a sufficient criterion for identifying strictly appropriate coconut intercropping systems. An investment decision on perennial crop establishment must take social and political considerations into account. Therefore the extension messages regarding coconut intercropping should represent the best judgement of agricultural planners. This paper is an attempt to sharpen this judgement.

Analytical Method

The multi-period linear programming (MLP) framework is used as the analytical tool for the following main reasons: [a] the prescriptive nature of this economic analysis requires a normative analytical tool; [b] about 60% of the family income of coconut smallholders of this study is obtained from the farm (Herath, 1991). Any farm plan recommended should, therefore, generate a sufficient income for family living every year. Coffee, pepper and cocoa do not generate an income during the first five to eight years after planting. A static, one-period LP cannot explicitly take this period effect on income into account; [c] perennial nature of the crops (coconut and other intercrops) involved in the analysis.

Data and Classification of Farmers

Data for the study were obtained from a sample of 36 coconut smallholders (holdings of less than 8 hectares) from Gampaha and Kurunegala districts during the period from October 1988 to August 1989. Stratified cluster sampling method was used. On this field data, four homogeneous farm groups were identified using cluster analysis (Herath, 1991). Of these, two groups were selected for MLP analysis. These two groups have the highest socio-economic potential to adopt coconut intercropping: Group 3 farmers have coconut lands of above average size (more than 5 ha) and indicated a reluctance to undertake intensive farm activities (Herath, 1991); and Group 4 farmers have paddy as the main crop and are reluctant to increase the non-paddy farm activities. Table 1 shows some relevant characteristics of the two

groups.

MLP Model Structure

The MLP problem is presented in the following mathematical form:

$$\text{Maximise } PV = \sum_{j=1}^{n} \sum_{t=1}^{20} \frac{C_{jt} X_{jt}}{(1+r)^t}$$

$$\text{Such that } \sum_{j=1}^{n} a_{ijt} X_{jt} \leq b_{it}$$

$$X_{jt} \geq 0$$

where PV = present value

X_{jt} = the level of jth intercropping activity in the year t;

j = crop activity; then j = 1 to n.

t = the year in which a crop is cultivated.

C_{jt} = the expected gross margin of a unit of the jth activity in the year t (rupees per hectare).

r = Discount rate.

a_{ijt} = the quantity of the ith resource required to produce one unit of the jth activity in the year t.

b_{it} = the amount of the ith resource available in year t.

The model is deterministic. It maximises the present value of gross margin (PVGM), i.e. revenue minus variable cost, for a 20-year period. The revenue is the product of annual yields and corresponding expected market prices. The latter is the average of a ten-year price series which is assumed to be a simple expectation in planning for the future. The 20-year period is a realistic planning horizon since it coincides with multiples of the length of economic life of the crops concerned (coffee, pepper and cocoa - 20 years, banana, betel and pineapple - 5 years and vegetable - annual). One period represents one year. The state bank interest rate for agricultural credit (15%) is used as the discount rate which is assumed to be the approximate opportunity cost of capital (Gittinger, 1982). The government subsidy for coffee, pepper and cocoa intercropping is included in the cash flow.

Three simple methods are used to take elements of income risk into account: [a] incorporating a minimum family expenditure level as a constraint in the model; [b] using time series average prices to compute the gross margin; and [c] using farmers' time preference rate (in addition to the prevailing market interest rate), which is a subjective risk indicator of farmers (Jayasuriya et al, 1981) in PVGM computation.

Table 1. Key Characteristics (relevant for the analysis) of Groups 1 and 2

Characteristics	Group 1	Group 2
% of the total sample	32%	44%
Land for intercropping (ha)	0.77	1.44
Family labour (Md): Period 1	36	26
Period 2	54	33
Period 3	66	34
Capital available (Rs/Year)	800	2,045
Time preference rate	27%	20%
Per capita family income (Rs/year)	2,152	6,090
Per capita off farm income (Rs/year)	456	3,289
Objectives:		
-income maximising	secondary	prime
-income security (survival)	prime	secondary

Activities of MLP Model

Five types are included: [1] annual (vegetable), semi-perennial (banana, betel and pineapple) and perennial (coffee, cocoa, pepper) crop production, [2] labour hiring, [3] capital borrowing, [4] cash transfer, and [5] household expenditure. Crop production activities represent the prevailing and recommended intercrops under coconut. Coconut farmers hire labour during certain months. Three labour hiring activities are thus included in each period of the model. The first hiring activity is for August, September and October; the second is for November, December, January and February; and the third is for March, April, May, June and July. The discounted value of the market wage rate is used as the objective function coefficient. In order to provide credit facilities, one cash-borrowing activity for each period is specified. The model allows the repayment of loan plus interest one year after borrowing. This is the prevailing credit situation in the study area. In practice loans are used both for household consumption and farm expenditure. However, this separation of use is not specified in the model. The objective function coefficient for credit is the discounted value of the prevailing market interest rate (15%) at the time of the survey. Cash transfer activities are necessary to steer cash transactions among the farming system and household activities. Accordingly, one cash transfer activity per period is

included in the model. A minimum amount of cash is provided each year through a household expenditure activity enabling a continuous food supply to the farm family.

Constraints in the Model

The constraints that play a central role in coconut-based farming systems include land available for intercropping, family and hired labour, farmers' capital availability, credit limit, and the minimum requirement of annual cash supply for family expenditure. The levels of these constraints are presented in Table 1, and are assumed to be constant over the planning period.

Labour is considered as a homogeneous resource. The efficiency differences of male, female, and child labour are unified into a standard unit (man-days): woman-day and child-day are equal to 0.75 and 0.5 man-day respectively. In each period (i.e. one year in the model) three labour constraints (one per each three-labour time period) are specified[1]. The level of the labour constraint is calculated by subtracting the family labour used in activities which are not included in the model from the total labour availability. Three hired labour constraints, one for each labour period, are used representing the periodic scarcity of hired labour. The group average of the annual cash surplus is used as the limit of the capital supply. The family living expenditure activity is linked to a corresponding minimum constraint which is Rs 3,000 and Rs. 1,700 per year for Groups 1 and 2 respectively. This is a way of including "survival objective" in LP (Hazell and Norton, 1986, p.72; D'Silva and Hassan, 1987). Appendix 1 presents the activities and their coefficients for these constraints.

The basic MLP model structure is further developed into the following different types (Table 2).

Initial runs of these three models showed that cropping patterns stabilize at the end of 6th to 8th-year period. This allows the formulation of a MLP-matrix for the above models (Table 2) of eight consecutive periods (1 to 8 years) and one other period representing the maturity phase of the crops. Appendix 2 presents the basic structure of the MLP which is common for coffee, pepper and cocoa models.

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[1] The criterion for distinguishing one labour time period from another is whether the effectiveness of farm operations and/or output would be affected if the labour input took place at one part of the time period rather than another. For example, the time-specific farm operations of coconut-based farming systems include harvesting of intercrops and coconut, and fertilizing of crops. The writer observed in the study area that the time of these activities vary within a period of about six to eight weeks. Within this period a particular farm operation is carried out without affecting the efficiency of the operation. The periods mentioned above are assumed as a homogeneous time periods for labour use.

Model Functioning

Banana, betel, pineapple, and vegetable are restricted to replace themselves on the area established, several times within the planning period. The MLP model allows to establish any crop in any year during the planning period. The crop then uses resources in that year and in subsequent years while the coefficient of the objective function has PVGM from that year through the last year of the production life. Both perennial and annual crops carry forward capital to the next year to be used in that year. The model is formulated in this manner so that vegetable, banana and betel are activated in the initial years to provide capital for the establishment of coffee, pepper and cocoa. Other capital components are fixed exogenously and are entered into the cash flow of each year.

Results and Discussion

Coffee Model 1

Table 3 presents the coffee intercropping plan for Group 1 when the survival objective is disregarded. Virtually all intercropping land is devoted to coffee and betel commencing in Year 1. The plan generates an annuity of Rs 5,774 (at 15% DR). In comparison with the present average income from coconut intercrops in Group 1, (i.e. Rs 3,864) the annuity is 49% higher. However the suitability of this plan depends on the annual cash flow pattern generated by the model.

The plan shown in Table 3 recommends to intercrop about 80% of the coconut land available for intercropping in one stage. This brings about a negative cash flow in the first seven years (Table 3) and hence does not meet the cash needs of the farmer in these years. This negative cash situation will limit the suitability of this type of models to the farmers of Group 1. The present intercropping recommendations too insist that farmers intercrop at least 0.5 ha in one stage. In this respect the model results are similar to the present recommendation for coffee intercropping. The pepper model 1 and the cocoa model 1 also give similar results.

Coffee Model 2

Tables 4 and 5 present the optimal plan of coffee model 2 (both profit max and "survival" objectives are included) for Group 1 and 2 respectively. The annuities of the crop plans are 36% and 97% higher than the present income from coconut intercrops of Groups 1 and 2 respectively. The considerable difference between the annuity and the present income of Group 2 is due to the large area of coffee and banana intercropping in the 1st year. This is possible as this group has a higher initial capital and lower constraint level of family expenditure. However, the annuities show that a substantial productivity increment can be achieved by adopting these intercrop plans.

Table 2. Different Types of the MLP Model

Crops	Type of Objectives	Name of the Model Type GROUP 1	GROUP 2
Coffee and others*	Only Profit Max Objective	Coffee-Model 1	Coffee-Model 1
	Both Profit Max & survival#	Coffee-Model 2	Coffee-Model 2
Pepper and others*	Only Profit Max Objective	Pepper-Model 1	Pepper-Model 1
	Both Profit Max & survival	Pepper-Model 2	Pepper-Model 2
Cocoa and others*	Only Profit Max Objective	Cocoa-Model 1	Cocoa-Model 1
	Both Profit Max & survival	Cocoa-Model 2	Cocoa-Model 2

* Others: banana, betel, pineapple and vegetable
\# Survival objective represents the maintenance of the minimum family income constraint (see Table 1 for minimum family income)

Table 3. Area Under Different Crops of Coffee Intercropping Plan of Coffee Model 1 : Group 1

Year	Coffee [ha]	Betel [vines]	Pineapple [ha]	Total Area [ha]	Labour Used [Md]
1	0.61	694	0.01	0.63	117
2	0.61	694	0.10	0.72	145
3	0.61	904	0.15	0.77	175
4	0.61	1188	0.15	0.77	217
5	0.61	1188	0.15	0.77	239
6	0.63	1188	0.15	0.77	148
7	0.71	1188	-	0.77	146
8	0.71	1130	-	0.77	252
20th	0.71	-	-	0.71	
% Land Use			90%		
PVGM = Rs 37,613; Annuity = Rs 6756					

In both Groups, the entire land available is intercropped with coffee in several stages. The necessary funds for coffee establishment in the 1st year are supplied by the government subsidy, the income generated from betel and banana, both of which are planted in the 1st year, and using the maximum amount of loan allowed in the first three years. In the case of Group 1, betel is extensively planted in an extent which is permitted by the labour supply. Due to

Table 4. Area Under Different Crops of Coffee Intercropping Plan of Coffee Model 2 : Group 1

Year	Coffee [ha]	Betel [vines]	Banana [ha]	Vege. [pits]	Total Area [ha]	Gross* margin [Rs]	Labour Used [MDs]	Loan Used [Rs]
1	0.09	950	0.18	49	0.29	3000	132	2000
2	0.34	950	0.18	-	0.53	3009	164	1200
3	0.55	1123	0.18	-	0.74	3479	188	1200
4	0.55	1426	0.18	-	0.75	2704	214	308
5	0.55	1426	0.18	-	0.75	3025	250	-
6	0.70	1426	-	-	0.72	2121	148	-
7	0.70	303	-	-	0.72	4713	141	-
8	0.70	1443	-	-	0.73	7021	252	-
20thr	0.70	-	-	-	0.70	12500	141	-
% Land Use					90%			

PVGM = Rs 34,075; Annuity = Rs 5,249

* Gross margin is presented after deducting the loan plus the interest re-payment which is due in the respective year. This applies to every model.

Table 5. Area Under Different Crops of Coffee Intercropping Plan of Coffee Model 2 : Group 2

Year	Coffee [ha]	Betel [vines]	Banana [ha]	Vege. [pits]	Total Area [ha]	Gross margin [Rs]	Labour Used [MDs]	Loan Used [Rs]
1	0.50	614	0.55	48	1.06	1717	120	2000
2	0.77	614	0.55	-	1.33	1713	144	1675
3	0.77	614	0.55	-	1.33	1743	145	970
4	0.77	614	0.55	-	1.33	1721	163	926
5	0.77	-	0.55	-	1.33	1721	170	-
6	1.33	-	-	-	1.33	2000	132	-
7	1.33	-	-	-	1.33	6991	119	-
8	1.33	1260	-	-	1.35	7757	199	-
20th	1.33	-	-	-	1.33	10524	119	-
% Land Use					92%			

PVGM = Rs 42,029; Annuity = Rs 6,475

the shortage of family labour, a smaller area of betel is intercropped in Group 2. This solution is notably different from the coffee model 1 solution. The stage by stage coffee establishment in coffee model 2 solution is a result of the inclusion of the "survival objective" in planning. This method of coffee establishment is more appealing to the farmers. The farm plans stabilize after the 8th year in both groups.

Pineapple did not enter the optimal solutions because of its very high establishment cost. In the study area too, pineapple is not a popular crop among smallholders. Vegetables are not selected except in the first year, because it requires large quantities of labour upon a low PVGM per hectare.

The cash flow of the solutions (Figure 1) shows that there is adequate cash to meet the family expenditure

every year[2]. This positive gross margin in each year is provided by cultivating betel and banana in the initial years and borrowing cash. The amount of cash borrowing is gradually reduced and solutions become self-sustaining at the end of the 5th year for both groups. This type of cropping pattern is, therefore, more suitable for cash deficit farmers.

Pepper Model 2

Tables 6 and 7 present the results of pepper model 2. Unlike coffee, pepper was established in smaller areas over a longer period of time in the solutions. This is an expected result as the cost of establishment of an intercropped hectare of pepper is higher than that of coffee. The crop plans came to a static level at the end of the 8th year and the 7th year for Groups 1 and 2 respectively showing a stage by stage intercropping. The annuities of the crop plans are 68% and 138% higher than the income from intercrops in the prevailing systems of Group 1 and 2 respectively. The interpretation of other results of the model is similar to that of coffee model 2. The cash flow of the model is presented in Figure 2.

Cocoa Model 2

The solution of the cocoa model 2 for Group 1 indicates that cocoa is not competitive enough in economic terms when compared with banana, betel, pineapple and vegetables to be included in the optimal plan. This result partly explains why none of the farmers in Group 1 has intercropped cocoa with coconut. The economic competitiveness of cocoa has to be increased by making technical improvements (e.g. high yielding varieties) in order to introduce cocoa into these farming systems.

Cocoa intercropping models developed for Group 2, indicate that cocoa intercropping can only be started in the 6th year of the cropping plan after securing a sufficient annual income to meet the cocoa establishing cost (Table 8). The annual income, until about the 12th year, is generated by cultivating banana, betel, pineapple and borrowing cash loans. It takes about ten years for the plan to become self- sustaining.
The analysis demonstrated that the different models generated notably different intercropping plans. To a larger extent the conditions included in the models represent the real world

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[2] The amount of family expenditure over and above the amount stated in the model for Group 1 and 2 per annum is met by the income obtained from off-farm jobs and from coconut. Ideally the monthly cash flow of the solution has to be studied to show the appropriateness of the crop plans in terms of cash flow variations. However, the inclusion of the monthly cash flows in a multi-period model increases the size of the model to an unmanageable level. Hence the pattern of annual cash flow is used to comment on the appropriateness of the solution.

Table 6. Area Under Different Crops of Pepper Intercropping Plan of Pepper Model 2 : Group 1

Year	Pepper [ha]	Betel [vines]	Banana [ha]	Vege. [pits]	Total Area [ha]	Gross Margin [Rs]	Labour Used [Mds]	Loan Used [Rs]
1	0.01	922	-	140	0.30	3055	99	2000
2	0.14	922	0.16	-	0.58	3005	124	1868
3	0.27	922	0.16	-	0.71	3021	141	2000
4	0.29	1588	0.16	-	0.74	3001	151	2000
5	0.29	666	0.16	-	0.74	5015	158	-
6	0.57	666	0.16	-	0.75	1754	214	844
7	0.75	666	-	-	0.77	2357	146	1727
8	0.75	666	-	-	0.77	3008	251	-
20th	0.75				0.75	12500	251	-
% Land Use					97%			

PVGM = Rs 42,324; Annuity = 6,498

Table 7. Area Under Different Crops of Pepper Intercropping Plan of Pepper Model 2 : Group 2

Year	Pepper [ha]	Betel [vines]	Banana [ha]	Vege. [pits]	Total Area [ha]	Gross Margin [Rs]	Labour Used [Mds]	Loan Used [Rs]
1	0.13	487	0.66	55	0.80	3427	99	2000
2	0.22	487	0.31	-	1.20	1950	124	1868
3	0.29	487	0.97	-	1.27	4760	133	2000
4	0.32	487	0.97	-	1.30	5022	145	2000
5	0.33	-	0.97	-	1.31	3960	158	-
6	0.97	-	0.97	-	1.29	4395	214	844
7	1.17	-	0.31	-	1.17	1040	146	1727
8	1.17	-	-	-	1.17	1308	251	-
20th	1.17	-	-	-	1.17	27852	251	-
% Land Use					81%			

PVGM = Rs 50,741; Annuity = Rs 7,790

Table 8. Area Under Different Crops of Cocoa Intercropping Plan of Cocoa Model 2 : Group 2

Year	Cocoa [ha]	Betel [vines]	Pineapple [ha]	Total Area [ha]	Labour Used [Mds]	Loan Used [Rs]
1	-	500	-	1.05	66	2000
2	-	500	-	1.24	105	125
3	-	500	0.12	1.36	132	2000
4	-	612	0.16	1.40	141	-
5	-	112	0.16	1.40	159	-
6	1.04	112	0.25	1.34	149	-
7	1.04	112	0.25	1.15	72	-
8	1.04	1639	0.54	1.15	204	-
20th	1.04	-	-	1.04	204	-
% Land Use					72%	

PVGM = Rs 29,840; Annuity = 4,597

conditions (resource availability, farmers' objectives, and crops under consideration) in regard to coconut intercropping recommendations. The overall implication therefore is that one blanket coconut intercropping plan as

the DEA's and the CCB's present recommendations will be less appropriate for a population of farmers whose circumstances are different. It is emphasised therefore that different coconut intercropping plans considering different circumstances have to be developed and recommended for effective adoption.

Sensitivity of the Solutions to the Farmers' Time Preference Rate

The proposition which underlies this sensitivity analysis is that farmers who discount the future income more heavily (high time preference rate) would tend to prefer the cultivation of annual and semi-perennial crops to perennial crops. The coffee and pepper model 2 was re-run using the average time preference rate (TPR) of Group 1 (27%) and Group 2 (20%). The key differences between the solutions with these TPR and 15% discount rate are presented in Appendices 3 and 4 for the coffee model 2 and the pepper model 2 respectively.

For Group 1, the solutions do not select coffee or pepper as showing high sensitivity to the TPR of 27%. This implies that if the PVGM of coffee and pepper is discounted at 27%, these two crops are not competitive enough with other crops so as to come into the intercropping plan. As the TPR of individual farmers is, however, different from the group average, it is useful to ascertain the discount rate above which coffee and pepper become non-selective to the intercropping plans generated from these models. After a series of model runs, it was found that these particular discount rates are approximately 23% for coffee and 24% for pepper.

The implication of this finding is that if a farmer is found to be subjectively discounting the future return from coffee and pepper at a discount rate higher than 24%, he would tend to prefer annual and semi-perennial crops to coffee and pepper. The TPR of about 60% of the farmers in Group 1 and 90% in Group 2 is, however, lower than 23% (Herath, 1991). This implies that coffee and pepper solutions are appropriate for a majority of the farmers in both groups as far as the TPR is concerned.

Sensitivity to the Removal of Government Subsidy

The key differences of the solutions obtained from the models without subsidy and the previous solutions are presented in appendices 5 and 6. Noteworthy differences are that: [a] coffee and pepper come into the intercropping plans in relatively later years when the subsidy is excluded in the model in comparison with the solutions with subsidies. This gives a lower PVGM for the non-subsidy solutions. Vegetable, betel and banana are selected at increased levels (relative to the subsidy models) during the first three years to supply cash. Pineapple is also selected in pepper non-subsidy model; [b] the non-subsidy solutions obtain a lesser amount of cash loans than subsidy solutions because the latter

select coffee and pepper in the earlier years needing more cash to maintain a positive cash flow.

The implication is that the contribution of the subsidy to the cash flow of intercropping plans can be brought about by cultivating annuals and semi-perennial in the first one or two years and then start the cultivation of coffee and pepper stage by stage. The model results demonstrated that this pattern of intercropping does not generate a negative gross margin. This needs a well planned intercropping schedule phased over a period of three to six years. The crops including coffee and pepper can be scheduled to be planted in different stages (see Table 3 to 8 for different stages of crop planting).

Conclusions and Recommendations

The intercropping plans generated from the MLP models are different from the present recommendations importantly by: [a] the model plans include annual and semi-perennial crops in addition to coffee, pepper and cocoa; [b] coffee, pepper and cocoa are planted in several stages rather than in a single stage as presently recommended. Since these intercropping plans are developed within farmers' resource restrictions and objectives, the plans can be seen as more appealing to the coconut farmers of the type included in this study. Similar intercropping plans adopted by a few farmers in the sample were observed during the survey. However, the provision of planting material, the financial assistance and extension advice are given only to those who have adopted the recommended coconut intercropping pattern. This may have prevented many coconut smallholders adopting the models generated in this study.

The model does not include all the income and yield risks that these crop may generate. The model results are therefore considered as generated in a risk-free situation. However, the farmers consider these risks as important determinants on the adoption of the farm plan. Hence it is possible that farmers view the modeled type intercropping pattern as high-risk models and show a reluctance for adoption. The inclusion of a measure for risk in this type of farm planning is important for obtaining further improved results.

In developing the type of intercropping plans mentioned in this study, several institutional factors have to be given proper consideration. They include [a] close supervision, through extension officers, of the adoption of the recommended intercropping schedule; this is necessary as intercrops are planted in different stages according to the plans; [b] since these intercropping plans include various types of crops, collaborative effort among the Department of Agriculture, the DEA and the CCB in conducting agronomy research and disseminating extension messages have to be encouraged; [c] the farming system approach can be effectively used in organising agronomy research as well as recommendations of

the intercropping schedule as these schedules address many factors i.e. labour use, cash needs, land allocation in different crops etc. of the system; and [d] prior to recommendation, socio-economic factors of farmers, particularly some idea of their subjective evaluation of the cash flow of intercropping plansare useful to be incorporated in deciding which type of intercropping schedule to be recommended.

The intercropping plans developed in this paper can be used as guidelines to formulate the recommendations and the policies in connection with the transfer of this technology to the farmers.

Appendix 1: Crop Activities, and their Input Coefficients per Hectare of Intercropping: (# plants/ha: coffee=750; pepper=1250; cocoa=500; banana=700; betel=1000 (0.01 ha); and pineapple=11250; Vegetable=100 pits (.01 ha.)

Crops	Yr:1	Yr:2	Yr:3	Yr:4	Yr:5	Yr:6	Yr:7-10	Yr:11-20
COFFEE:.....								
Gross Income	0	0	0	0	4600	8050	16100	23000
Labour-Period 1*	52	22	32	37	37	36	36	36
Period 2	30			13	13	53	53	53
Period 3	15	30	40	45	45	45	45	45
Capital	2935	625	1025	2000	3125	3125	3125	3125
PEPPER:.....								
Gross Income	0	0	0	0	2100	12000	16800	45000
Labour-Period 1	100	43	55	75	75	85	85	85
Period 2	97				37	37	37	37
Period 3	25	15	20	35	35	40	40	40
Capital	4410	3815	5375	5375	5375	5375	5375	5375
COCOA:.....								
Gross Income	0	0	0	0	0	2820	7050	16920
Labour-Period 1	65	18	27	35	35	40	40	40
Period 2	25					18	18	18
Period 3	10	8	15	20	20	20	20	20
Capital	2160	625	1025	1925	2525	2525	2525	2525
BANANA:.....								
Gross Income	2075	3735	4150	5810	5810			
Labour-Period 1	33	15	20	20	20			
Period 2	3	5	5	8	8			
Period 3	5	8	10	12	12			
Capital	2125	1425	1425	1425	1425			
BETEL:.....								
Gross Income	800	4500	4500	4500	4500			
Labour-Period 1	19	33	33	33	33			
Period 2	15	42	42	42	42			
Period 3	16	61	61	61	61			
Capital	890	270	270	270	270			
PINEAPPLE:.....								
Gross Income	0	28053	27951	44588	25185			
Labour-Period 1	100	53	53	38	38			
Period 2	30	5	5	8	8			
Period 3	47	112	112	59	59			
Capital	33125	6625	6625	6625	6625			
VEGETABLE:.....								
Gross Income	512							
Labour-Period 1	14							
Period 2	10							
Period 3	35							
Capital	100							

*Labour Periods (man-days): Period 1= August, September, October
Period 2= November, December, January, February
Period 3= March, April, May, June, July.

Gross income and capital are in Rs.
Source: Author's survey data and Economics Research Unit, Department of Export Agriculture.

Period		PERIOD ONE				PERIOD TWO - 9					RESOURCE CONSTRAINTS		
No:Columns		5	3	1	1	5	3	1	1	1	B COLUMN		
Variables		crop	labour hire	cash loan	family Expe.	crop	labour hire	cash loan	cash trans	family Expe.	B Column Sign	Units of the Row	No:of Rows per Resource
Units		ha	Md	Rs	Rs	ha	Md	Rs	Rs	Rs			
Ob.Fun.Sign		[+]	[-]	[-]	nil	[+]	[-]	[-]	nil	nil			
Objective: Max PV[GM]		PV GM	wage rate	interest	nil	PV GM	wage rate	inte-rest	nil	nil			
PERIOD ONE	Land	[+]									≤	ha	1
	Fam. Lab.	[+]	[-]								≤	Md	3
	Hir.Lab.Li		[+]								≤	Md	3
	Cash Row	[+/-]	[+]	[-]	[+]				[+]		≤	Rs	1
	Fam.Expe.				[+]						=	Rs	1
	Loan Limit			[+]							≤	Rs	1
PERIOD 2 1 9	Land	[+]				[+]					≤	ha	1
	Fam. Lab.					[+]	[-]				≤	Md	3
	Hir.Lab.Li						[+]				≤	Md	3
	Cash Row			[+]		[+/-]	[+]	[-]	[-]	[+]	≤	Rs	1
	Fam.Expe.									[+]	=	Rs	1
	Loan Limit							[+]			≤	Rs	1

Note:Ob.Fun=objective function; NO:=number of; Fam.=family; Lab.=labour; Hir.=hired; Li.=limit; Expe.=expenditure; PV=present value; GM=gross margin;Rs=rupees;ha=hectare;Md=man-days

Appendix 3: Activities in the Optimum Plans Under Different Discount Rates: for Intercropping Coffee

Year	Activity	Units	Crop Plans Group 1 Models 15% DR	Crop Plans Group 1 Models 27% DR	Crop Plans Group 2 Models 15% DR	Crop Plans Group 2 Models 27% DR
1	Coffee	ha	0.09	-	0.50	0.12
	Banana	ha	0.18	0.30	0.55	0.98
	Betel	vine	948	1016	614	593
	Vegetable	pits	49	48	48	-
	Loan	Rs	2000	2000	2000	2000
2	Coffee	ha	0.25	0.15	0.27	0.21
	Banana	ha	-	0.32	-	0.01
	Loan	Rs	1200	759	1675	273
3	Coffee	ha	0.21	-	-	-
	Betel	vine	173	-	-	-
	Pineapple	ha	-	0.04	-	0.05
	Loan	Rs	1200	-	970	-
4	Betel	vine	303	413	-	-
	Pineapple	ha	-	0.09	-	-
	Loan	Rs	308	-	926	-
5	Betel	vine	-	209	-	-
6	Coffee	ha	0.15	0.32	0.56	995
	Banana	ha	-	0.12	-	-
	Loan	Rs	107	-	-	-
8	Betel	vines	1140	1145	1260	1260
	Pineapple	ha	-	0.08	-	-

NB: Only the activities which are selected in each year are presented. 27% DR and 20% DR are average time preference rate of Group 1 and 2 respectively. 15% DR is the average discount rate used.

Appendix 4: Activities in the Optimum Plans Under Different Discount Rates: for Intercropping Pepper

Year	Activity	Units	Crop Plans Group 1 Models 15% DR	Crop Plans Group 1 Models 27% DR	Crop Plans Group 2 Models 15% DR	Crop Plans Group 2 Models 27% DR
1	Pepper	ha	0.01	-	0.13	0.02
	Banana	ha	0.27	0.30	0.66	0.98
	Betel	vine	922	1042	487	400
	Vegetable	pits	140	44	-	-
	Loan	Rs	2000	2000	2000	2000
2	Pepper	ha	0.13	-	0.09	0.11
	Banana	ha	0.16	-	0.31	-
	Loan	Rs	2000	292	1868	651
3	Pepper	ha	0.13	-	0.07	0.11
	Banana	ha	-	0.23	-	-
	Pineapple	ha	-	-	-	0.01
	Loan	Rs	1200	-	2000	-
4	Pepper	ha	0.02	-	0.03	0.04
	Pineapple	ha	-	-	-	0.11
	Loan	Rs	-	-	2000	1658
5	Pepper	ha	-	-	0.01	-
	Pineapple	ha	-	0.22	-	-
	Loan	Rs	-	1200	-	-
6	Pepper	ha	0.28	-	0.64	0.64
	Betel	vine	-	456	-	-
	Pineapple	ha	-	0.06	-	-
	Vegetable	pits	-	38	-	-
	Loan	Rs	-	-	844	-
7	Pepper	ha	0.18	-	0.20	0.25
	Pineapple	ha	-	0.09	-	-
	Loan	Rs	1122	-	1727	-
8	Betel	vines	-	724	-	-
	Pineapple	ha	-	-	-	-

NB: Only the activities which are selected in each year are presented. 27% DR and 20% DR are average time preference rate of Group 1 and 2 respectively. 15% DR is the average discount rate used.

Appendix 5: Activities in the Optimum Plans With and Without the Government Subsidy: for Intercropping Coffee

Year	Activity	Units	Crop Plans Group 1 Models With Subsidy	Crop Plans Group 1 Models Without Subsidy	Crop Plans Group 2 Models With Subsidy	Crop Plans Group 2 Models Without Subsidy
Present Value		Rs	34075	33153	42029	38850
1	Coffee	ha	0.09	-	0.50	
	Banana	ha	0.18	0.31	0.55	1.04
	Betel	vine	948	998	614	473
	Vegetable	pits	49	138	48	-
	Loan	Rs	2000	2000	2000	2000
2	Coffee	ha	0.25	0.15	0.27	0.26
	Banana	ha	-	0.04	-	-
	Loan	Rs	1200	1192	1675	1285
3	Coffee	ha	0.21	0.22	-	0.03
	Betel	vine	173	-	-	-
	Pineapple	ha	-	-	-	0.06
	Loan	Rs	1200	1200	970	2000
4	Betel	vine	303	632	-	-
	Loan	Rs	308	-	926	-
6	Coffee	ha	0.15	0.32	0.56	1.04
	Loan	Rs	107	289	-	-
8	Betel	vines	1140	1140	1260	1200

NB: Only the activities which are selected in each year are presented.

Appendix 6: Activities in the Optimum Plans With and Without the Government Subsidy: for Intercropping Pepper

Year	Activity	Units	Crop Plans Group 1 Models		Crop Plans Group 2 Models	
			With Subsidy	Without Subsidy	With Subsidy	Without Subsidy
Present Value		Rs	42324	39664	50741	47985
1	Pepper	ha	0.01	-	0.13	-
	Banana	ha	0.27	0.32	0.66	1.06
	Betel	vine	922	1090	487	543
	Vegetable	pits	140	134	-	57
	Loan	Rs	2000	2000	2000	2000
2	Pepper	ha	0.13	0.06	0.09	-
	Banana	ha	0.16	0.25	0.31	0.02
	Loan	Rs	2000	1162	1868	2000
3	Pepper	ha	0.13	0.05	0.07	0.04
	Pineapple	ha	-	0.04	-	0.04
	Loan	Rs	1200	1200	2000	-
4	Pepper	ha	0.02	-	0.03	-
	Pineapple	ha	-	0.03	-	0.19
	Loan	Rs	-	-	2000	2000
5	Pepper	ha	-	-	0.01	-
6	Pepper	ha	0.28	0.33	0.64	0.69
	Loan	Rs	-	-	844	-
7	Pepper	ha	0.18	0.24	0.20	0.45
	Loan	Rs	1122	-	1727	-

NB: Only the activities which are selected in each year are presented.

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