Sri Lanka Journal of Agrarian Studies 3 (1), 1982, 34-52.

CHENA-PADDY INTERRELATIONSHIP AND DRY SOWING: THE EXPERIENCE IN AN IRRIGATION SCHEME IN SRI LANKA

BY

NELSON VITHANAGE

Agrarian Research and Training Institute

ABSTRACT

Two of the main problems which limit agricultural production in most of the major colonisation irrigation schemes in Sri Lanka seem to be the insufficient use of rainfall and wasteful use of stored water. Several reports point out that the main reasons for these problems are the priority given to chena cultivation and inadequate farm power for land preparation, and recommend land preparation with mechanical power within a short time, preferably a significant portion of it while dry or following the first monsoon rains and practice of dry sowing **(kekulan)** *with paddy. The results indicate that the annual net farm income is considerably higher if mud sowing is carried out as at present in December, when compared with dry sowing in September and the continuing of chena would not impede the development of paddy cultivation.*

INTRODUCTION

Appraisal reports of the Tank Irrigation Modernization Project (World Bank 1976), Kurunegala Rural Development Project (World Bank 1979), and Dewahuwa Rural Development Project (Japan International Co-opeation Agency 1970) point out that because of inadequate farm power for land preparation and the priority given to chena cultivation, the *Maha* [1] paddy sowing is extended into late January and insufficient use is made of rainfall. Also as a result little, if any, water is available in the tanks for the *Yala*[2] crop.

According to these appraisal reports a contributory reason for the extended *Maha* and *Yala* sowing periods is the practice of chena cultivation in nearby jungle areas. To make maximum use of the *Maha* rainfall and to enbale the crop to keep ahead of the regenerating weeds, planting of the chena lands takes place as soon as it begins to rain. Under present conditions, farmers consider chena cultivation as more dependable than their irrigated agriculture and they are reluctant to do anything that would interfere with its success. Only when the chena lands are secured is attention transferred to paddy lands where, in the meantime, much of the rainfall and often a significant amount of the irrigation water released from the storage for those who sowed earlier has been wasted. *Yala* plantings are delayed partly by the delays in starting the *Maha* crop and partly by the need to harvest and replant the chena lands, before starting the *Yala* crop on the irrigated lands.

1 Maha : great North - East monsoon season

2 Yala : little, South - West monsoon season

Appraisal reports of the Tank Irrigation Modernization Project and Kurunegala Rural Development Project envisage dry sowing (*kekulan*)from late September through October for harvesting in January through early February with the *Maha* crop. Early plantings of the *Maha* crop would permit taking advantage of the early monsoon rains so as to reduce the need for irrigation. *Yala* dry sowing would be from February to early March for harvesting in late May and June. The seedbed for the entire service area would be prepared with mechanical power within a shorter time than at present, preferably a significant portion of it while dry or following the first monsoon rains. This would decrease the demands on tank storage for pre-irrigation to soften the soil.

Using linear programming and representative farm techniques, this paper attempts to examine whether there are any possibilities of increasing farm income by starting *Maha* cultivation in September to make use of early *Maha* rains instead of mid December to early January, and to ascertain the impact of increase in water availability for *Yala* cultivation through better use of *Maha* rainfall and better management of water in the tank on farm income, employment and cultivation of subsidiary food crops in lowland during the *Yala* season.

This paper is based on the Mahavillachchiya irrigation colonisation scheme (MvCS), which is in the Tank Irrigation Modernization Project and the first tank in which modernisation has been completed. The data on the MvCS have been obtained from two field surveys conducted during the period October 1976 to June 1977 and in May 1980, using a stratified random sample.

Specification of the Analytical Linear Programming Model

A linear programming problem has an objective function to be maximised or minimised, alternative processes or activities none of which can enter at negative values and a set of constraints. Fundamental assumptions like linearity, the additivity of activities, the infinite divisibility of resources and products, finiteness in the number of alternative activities, fixed input-output coefficients and resource supply limit the usefulness of the technique to a certain extent. But, modifications to the basic linear programming model provide the means of overcoming many of these problems as amply demonstrated by various research workers (Giaver and Seagreaves 1960; McFarquhar 1961; McInerney 1965, etc.).

a. Objective function

The peasant in Sri Lanka has basically two closely inter-related common goals, namely, expanded family security and maximisation of farm income. There are various means for achieving these objectives such as increased land productivity, increased labour productivity and the establishment of congenial relations with other members of the community etc.

According to the field investigations in 1980, it is evident that 90 percent of surveyed farmers are interested primarily in maximising cash income after they have secured their subsistence level requirements with a high level of certainty. Six and four percent of farmers said that the main objective of farming is to maximise cash income only and to produce necessary food only, respectively. None of the farmers selected options such as to maximise land productivity, to maximise labour productivity or to maximise farm production. Farm production was found to be semi-subsistence in nature with approximately 40 to 50 percent of the farm produce being retained for domestic consumption.

Taking into account the above facts, maximisation of net farm income (gross income minus cash expenditure for production) is used as the objective function, subject to minimum paddy acreage being planted to ensure the attainment of farmers' subsistence level requirements with a high level of certainty and extended family security.

b. Resource and other constraints

Besides the categorisation of land into three groups, i.e. lowland, highland and chena, the availability of land during the two cropping seasons is included in the models. Within these land groups soil characteristics—fertility, past land use and land improvements—cannot be taken into account since data are not availabe to link such variations with corresponding input-output coefficients.

It is assumed that there is no difference in the level of efficiency of family and hired labour, and that hired labour can be used to supplement family labour at current wage rates, its use being constrained by the availability of working capital. It seems reasonable to assume that adequate wage labour is available to be hired by the settler farmers, as there are 200 squatters, who depend primarily on hiring out their labour for living, compared with 880 settler farmers in the MvCS. In computing the labour resources available, children between 12 and 15 years of age and women are considered as only 50 and 80 percent respectively as effective as men in chena and highland preparation. These weights are calculated on the basis of prevailing wage rates. Women are considered as effective as men in harvesting. Only women are engaged in paddy transplanting and only men are engaged in lowland preparation. The active population is considered to be all those between twelve and sixty five years of age. Labour periods based on seasonal peak requirements are defined and the labour availability and input coefficients computed accordingly rather than using monthly time periods. The specification of labour on a monthly basis implies that farm tasks can be performed at any time within the course of the month and it cannot be wholly accepted as satisfactory due to the other uncertainties operative in the production environment. The potential family labour force is computed on the basis of 250 working days per year, based on observations made during the field study. The total labour potential for each farm is considered as the product of total work days for the respective peak and the adult equivalents available for farming.

The need for working capital has become more important with the increased use of modern inputs in production. If there is adequate working capital, the fixed capital limitations such as the lack of draught power, whether tractors or buffaloes, can be overcome as these services can be hired. The capital available for production is assumed to be 70 percent of the cash income received by the farmers, based on observations made during the field study. This level is considered more useful than a measure of the ability of the farmer to borrow beyond his usual borrowing for paddy cultivation.

The availability of irrigation water is an important factor determining the success of farming in these schemes. The feasibility of cultivation in the *Yala* season generally depends on the water stored in the tanks during the *Maha* season. Irrigation water is introduced in the model as a constraint in order to investigate the size of the increased farm incomes and production obtainable when more water is made available. It is assumed that farmers will invariably cultivate all three acres[3] of lowland in *Maha*. The quality of irrigation water can be ignored as the source of water is common to all the farmers in the scheme.

Consumption requirements will enter the production model as a 'minimum bundle of goods' required per settler family during a cropping year. The only food constraint specified is a minimum paddy acreage put at one acre per household, which ensures the attainment of farmers' subsistence level requirements with a high level of certainty and extended family security.

To avert risk, most surveyed farmers cultivated not more than one acre of chillies. Paddy grown on chenas has also been limited to a maximum extent of one acre. The maximum area under chillies and paddy in chena did not exceed one acre per holding during *Maha* 1976/77. A maximum constraint of one acre under these crops has been included in the matrix.

No technological constraints in terms of rotational husbandry practice are incorporated as farmers practise a system of continuous cropping of paddy under conditions of improved water supply. In highland cultivation there is no systematic rotation and a pastoral fallow is not customary due to the lack of a systematic livestock industry in the locality.

c. Crop activities

Lowland paddy cultivation is sub-divided into a number of activities considering the duration of variety, kind of draught power and method of planting. The impact of these practices will be analysed by studying their impacts on the gross margin per unit activity and their impact on the input-output coefficients of the model. The culitvation of pulses and chillies is included as a probable activity in lowland during *Yala* season. Gingelly (sesame) cultivation is restricted to *Yala* while the crops which may be grown in the highland and chena areas in *Maha* are cowpea, green gram, upland rice, maize, finger millet and chillies (Annex 1). The period over which income is to be maximised is one cropping year.

Use of Representative Farms

If inadequate consideration is given to the variations in land, water and human resources, it will restrict the making of valid recommendations for farms which show a variation from the mean in resource endowments. The use of an average farm, therefore, aggregates non-homogeneous groups together and results in aggregation bias. Aggregative analysis assumes conditions of homogeneity within the groups of farms, resources and products. In such analysis consequently, the research worker continually weighs the convenience of aggregation at a higher level against the loss of relevant data. Details are significant when they represent differences in economic attributes.

3. Generally each settler is alienated three acres of lowland and two acres of highland

The average farm's caharacteristics may not exist in a single farm or it may represent only one group of the population. The analysis of income distribution and yield distribution of paddy shows a considerable variation among farmers in the MvCS (ARTI 1976; Vithanage 1982). Although there is an equivalent of 2.6 full-time adult equivalents per household, 32.6 percent of the farm households have less than two full-time adult equivalents in the MvCS. The paddy lands served by the left bank canal have a better water supply than those served by the right bank canal since the sluice at the head of the former is six feet lower than that of the latter. It is incorrect to include all these non-homogeneous factors together and to produce an average farm. The average input-output coefficients based on data from different farmers and fields, even if they are not completely infeasible, may not be used by any one farmer in practice. Farmers may infact alter their strategies or technical inputs under environmental conditions and there is no theoretical reason to believe that average inputs will give rise to average outputs. Use of a single average farm or modal farm in non-homogeneous conditions is likely to lead to substantial errors in predictions.

One way of avoiding aggregation bias would be to construct a farm model for each individual farm and to solve these models taking into account various interdependencies between farms such as the movement of intermediate goods of production and competition for common scarce resources. As mentioned ealier, there are 880 farms at MvCS and in practice it is not possible to programme all the individual farms.

To make more appropriate projections, several modal farms are used rather than one. This involves classifying the universe of farmers into a smaller number of homogeneous groups constructing a model for a representative farm for each group. In the first stage of categorisation the MvCS was divided into the two banks, so as to examine certain features of relevance to the availability of water. In the MvCS, land availability per household mainly depends on labour availability which determines the chena extent; labour has been chosen as the prime determinant of the farms representative of each bank. Two and three farms from the left bank and right bank, respectively, were chosen from different labour availability groups as representative farms for this study (see Tables 2 to 7).

Results

With the objective of achieving maximum economic efficiency, the analyses explore production and resource use possibility by modifying the 'state of arts' that is with improved water management and selective mechanisation, given the resource endowments of the farms.

Irrational or economically inefficient production can be defined as it relates to profit maximisation if resources can be used differently from the present in any manner whatsoever to either (i) give a greater product from the same collection of resources or (ii) give the same product with a smaller outlay of fixed and variable resources (Heady 1952). Therefore as far as the present problem is concerned the difference between the optimum income obtained by reorganising the cultivation calendar and product combinations to maximise farm incomes, given present resource endowments and the income obtained at present by famers, should indicate the level of allocative efficiency.

A linear programming run was carried out assuming farmers will prepare lowland for dry sowing during September and another run, assuming the lowland preparation for mud sowing will be done in December and January as at present. It is not practicable to have a combined programme of dry sowing in September and mud sowing in December due to the unwillingness of farmers to dry sow and the administrative infeasibility of dividing water for one area for dry sowing and for another area for mud sowing within the same scheme. Dry sowing in September leads to a saving of 7.6 inches per acre on net irrigation requirements (Table 1) with 44 percent on-farm and 70 percent transmission efficiencies. This will increase the water available in the tank for *Yala* from 4.4 acre feet per farm to 11.0 acre feet. The optimal farm incomes generated by linear programming under these two conditions for the five representative farms will be compared.

The results indicate that farm incomes are not improved by dry sowing in September in any farm group with the given level of resources and state of technology (See Tables 2 to 7, Annexes 1 and 2). It is evident that the net farm income (after subtracting costs of material inputs and hired labour from gross income), is considerably higher under present conditions. In fact, 17 to 23 percent higher income is possible for all representative farms, if mud sowing is carried out in December with 4.4 acre feet per farm of water available in the tank for *Yala*, when compared with dry sowing in September. In any case, this type of situation might not have been expected as the cultivated lowland area in *Yala* would be increased with greater availability of *Yala* water with dry sowing, (from 4.4 to 11.0 acre feet per farm). In fact, other than the fourth representative farm, which would cultivate 2.2 acres of lowland, all other farms would cultivate all three acres of lowland in *Yala* with dry sowing in September (Table 2). But out of all paddy activities, only the broadcast paddy activity and tractor ploughing can be adopted in lowland under dry sowing, and the yield of broadcast paddy is 13 percent lower than that transplanted, and tractor ploughing would reduce the gross margin of the A4, A8, AA4 and AA8 activities still further (see Annexes 1 and 2 for a description of abbreviations). The representative farms with the lowest amount of labour available would cultivate a smaller area of lowland in *Maha* and all representative farms would cultivate reduced areas of chena and highland in *Yala* season with dry sowing in September. This is primarily due to the competition for labour as chena and highland have to be cultivated with first *Maha* rains. In contrast to the appraisal report assumptions, farmers would concentrate more on lowland than chena. This implies that continuing of chena cultivation would not impede the development of paddy cultivation.

The Tank Irrigation Modernization Project appraisal report assumes that net farm income as well as labour requirements for agriculture would increase with dry sowing in September. It is evident according to Tables 2 and 3 that due to the exhaustion of family labour, more hired labour has been used in the December plan as against that with September dry sowing. This type of result should be expected as although the cultivated area of lowland in *Yala* would be increased with dry sowing, the cultivated area of highland and chena would be reduced, and buffalo ploughed and transplanted paddy required about 19 man days per acre more than with tractor ploughed and broadcast paddy.

Looking at the activities in the optimal plans, the results are quite consistent with the farming systems followed at present. A paddy dominant farming system with a few other crop enterprises emerging in the optimal plans, under the *ceteris paribus* assumptions. According to the December plans farmers would cultivate all three acres of lowland, an extent of 0.7 acres of highland and 2 to 3 acres of chena per farm in a *Maha* season. These figures are compatible with 1976/77 *Maha* season (ARTI 1979). The results indicate that although labour can be supplied by the farm family itself, labour has to be hired particularly on the representative farms with only low amounts of labour available. The need to accomplish farm operations on time and consequently the need for hired labour exists. It should be pointed out that the farmers would prefer high yielding long duration paddy varieties and land preparation with buffaloes rather than tractors as at present (A1, A2, AA1, and AA2 activities shown in Tables 3 to 6). Tables 2 to 6 show the marginal value products of constraints. From Tables 2 to 6 it can be seen that almost all the lowland and chena acreages have been utilised in *Maha*. This has resulted in higher marginal value products of lowland and chena in *Maha* with December plans when compared with September plans. A similar interpretation can be given to the family labour and availability of water in *Yala*.

Of importance for farm planning are the excluded activities, i. e. activities which did not enter the programmes. The plans show how much the gross margin of each enterprise should rise before it could enter the programme. If this rise is added to the existing gross margin, a 'shadow gross margin' or marginal opportunity cost can be obtained. This marginal opportunity cost, therefore, shows the level which the existing gross margins would have to attain before the excluded activities come into the programme. These marginal opportunity costs for three different plans are given in Table 8. Apart from showing possible areas of expansion on farms, the changes in gross margin, needed to bring alternative solutions, are an indication of the stability of the present solution. Barnard and Nix (1973) state that where large changes in net revenues are needed to induce new plans, there can be greater confidence that even if the values were uncertain in the first place the solution will nevertheless be the same as that obtaining if the true values had been known and incorporated. For instance, other than for chena chillies and maize, the changes needed in the present plans are high and so one might assume stability in the solution (Table 8).

In the above analysis, farms are assumed to be profit maximising enterprises. In reality they include farm business and household activities in combination. For incorporating the behavioural aspect of the settlement farms consumption constraints were also considered. A minimum paddy acreage (1 acre) in *Maha* with a minimum level of living constraint based on the field investigations was specified. It was, however, found that it was not necessary to re-run the model without the minimum paddy acreage as only two representative farms with a low amount of labour available would cultivate the minimum paddy acreage with dry sowing in September. This indicates that the objective of profit maximisation does not in most cases conflict with the consumption needs of the settlement farmers and that the optimal solutions are congruent with farmers' needs.

A primary objective of the modernization is to increase water availability for *Yala* cultivation through better use of *Maha* rainfall and better management of water in the tank. It was, therefore, necessary to re-run the model only changing the water available in the tank per farm during *Yala* with the relevant ex-sluice water duty per acre. Optimal plans with mud sowing in December and with 4.4, 7.0, 9.4, and 23.1 acre feet per farm water available in the tank for *Yala* cultivation are given in Tables

3 to 6. It is observed that all representative farms would cultivate all three lowland acres when the *Yala* water availability is increased to 23.1 acre feet per farm. Dramatic changes in net farm incomes, production possibilities and resource use can also be observed. The increase in net farm income of representative farms with a low amount of labour available is 6.5 percent and of representative farms with medium and high amounts of labour available is about 15 to 20 percent. But it is observed that farmers would prefer to cultivate paddy in lowland when there is more water available. Farmers would cultivate subsidiary food crops on all cultivable lowland area (1.6 acres) when there is only 4.4 acre feet per farm water availability. Other than the representative farms with a low amount of labour available in the left bank all other farms would cultivate 0.4 acres of subsidiary food crops and 2.6 acres of paddy in lowland when there is 23.1 acre feet per farm water availability. These results are quite consistent with the present situation at MvCS. Tail end farmers at MvCS, who face water shortages cultivated subsidiary food crops in lowland in 1980 *Yala* when all other farmers cultivated paddy. Farmers at MvCS were reluctant to cultivate subsidiary food crops in 1978 and 1979 *Yala*, and they cultivated paddy on about 93 percent of lowland in these seasons. It was evident again that farmers would concentrate more on lowland rather than chena or highland when there is adequate water to cultivate lowland. Farmers would cultivate smaller areas of chena and highland in *Yala* with 23.1 acre feet per farm water availability when compared with 4.4 acre feet per farm.

However, the analyses indicate that the net farm income does not increase substantially when there is more than 9.4 acre feet per farm water availability under present resource endowments and assumptions (Tables 5, 6 and 7). The increase in net farm income is only about 0 to 1.2 percent for representative farms with a low amount of labour available and is about 3 to 7 percent for other representative farms. When there is 9.4 acre feet per farm water availability, representative farms with low amount of labour would cultivate all three lowland acres and others would cultivate about two acres of lowland. As discussed earlier there is a shift from subsidiary food crops to paddy in lowland and a smaller area of highland is cultivated when water availability in *Yala* is increased from 9.4 to 23.1 acre feet per farm.

CONCLUSIONS

The primary concern of the project is to conform to the rainfall pattern in timing of primary tillage and planting. Although dry sowing in September will increase the availability of water in the Mahavillachchiya tank from 4.4 acre feet per farm to 11.0 acre feet, the annual net farm income is considerably higher if mud sowing is carried out as at present in December, when compared with dry sowing in September. Dry sowing could only make a negative contribution toward easing unemployment and under-employment in settlement schemes. It therefore, seems unlikely that dry sowing could be forced on farmers in the major irrigation schemes.

In contrast to common assumptions, farmers would concentrate more on lowland than chena cultivation when there is adequate water to cultivate lowland. This implies that the continuing of chena cultivation would not impede the development of paddy cultivation.

Although the government insists on subsidiary food crops cultivation in lowland during the *Yala* season, farmers would prefer to cultivate paddy in lowland when there is more water available. There is a shift from subsidiary food crops to paddy in lowland, and a smaller area of highland is cultivated when water availability in *Yala* is increased. On the other hand, the net farm income does not increase substantially when there is more than 9.4 acre feet per farm (3.1 acre feet per acre) water availability in *Yala* under present resource edowments and assumptions. This implies that emphasis should be given to the supply of an optimum amount of water rather than to the provision of water to all cultivable lowlands.

REFERENCES

BARNARD, C. S. (1963). Farm models, management objectives and the bounded planning environment. *Journal of Agricultural Economics* **15**, 525–549.

BARNARD, C. S. and NIX, J. S. (1979). *Farm: planning and control*, 2nd ed. Cambridge: Cambridge University Press.

CARTER, H. O. (1963). Representative farms guides for decision making? *Journal of Farm Economics* **45**, 1448–1468.

CLAYTON, E. S. (1963). *Economic planning in peasant agriculture*. London: Department of Agricultural Economics, Wye College, University of London.

COLLINSON, M. P. (1972). *Farm management in peasant agriculture: a handbook for rural development planning in Africa*. London: Praeger.

FARRINGTON, J. (1976). A note on planned versus actual farmer performance under uncertainty in underdeveloped agriculture. *Journal of Agricultural Economics* **27**, 257–259.

GIAVER, H. and SEAGREAVES, J. (1960). Linear programming and economics of size. *Journal of Farm Economics* **42**, 103–117.

HEADY, E. O. (1952). *Economics of agricultural production and resource use*. New Jersy: Prentice Hall.

JAPAN INTERNATIONAL COOPERATION AGENCY (1970). *Sri Lanka-Japan Rural Development Project*. Tokyo: JICA.

JOY, J. L. (1967). An economic homologue of Barth's presentation of economic spheres in Darfur. In *Themes in economic anthropology*, edited by R. Firth. London: Tavistock Publications.

PLAXICO, J. S. and TWEETON, L. G. (1963). Representative farms for policy and projection research. *Journal of Farm Economics* **45**, 1458–1468.

MCFARQUHAR, A. M. M. (1961). Rational decision making and risk in farm planning: an aplication of quadratic programming in British arable farming. *Journal of Agricultural Economics* **14**, 552–563.

MCINERNEY, J. P. (1969). Linear programming and game theory models: some extensions. *Journal of Agricultural Economics* **20**, 269–279.

SHEEHY, S. I. and MCALEXANDER, R. H. (1965). Selection of representative benchmark farms for supply estimations. *Journal of Farm Economics* **47**, 681–695.

UPTON, M. and CASEY, H. (1974). Risk and some pitfalls in the use of average of in-farm planning. *Journal of Agricultural Economics* **25**, 147–152.

VITHANAGE, N. (1982). *Analytical techniques in agricultural development planning: a critical appraisal of a project for the modernization of an irrigation scheme in Sri Lanka*. Unpublished Ph.D. Thesis, University of Leeds.

WORLD BANK (1976). *Sri Lanka, Appraisal of the Tank Irrigation Modernization Project*. Washington: World Bank. 101 p.

WORLD BANK (1979). *Sri Lanka, Appraisal of the Kurunegala Rural Development Project*. Washington: World Bank. 124 p.

Table 1—CROP WATER DEMAND PER ACRE FOR PADDY

	September dry sowing						*December mud sowing*					
	Sept.	Oct.	Nov.	Dec.	Jan.	Total	Dec.	Jan.	Feb.	Mar.	Apr.	Total
Evapo–transpiration (in.)	6.7	5.2	4.1	4.3	4.5		4.3	4.5	5.5	6.7	6.5	
Crop factor		1.00	1.15	1.20	0.9			1.00	1.15	1.20	0.9	
Consumptive use (in.) ...		5.2	4.7	5.2	4.1	19.2		4.5	6.3	8.0	5.9	24.7
Land- preparation (in.)	4.0	2.0				6.0	4.0	2.0				6.0
Total water requirements (in.) ...	4.0	7.2	4.7	5.2	4.1	25.2	4.0	6.5	6.3	8.0	5.9	30.7
Effective rainfall [a] (in.) ...	0.5	3.5	3.4	3.0	0.8	11.2	3.0	0.8	0.6	1.7	2.5	8.6
Net irrigation requirements (in.) ...	3.5	3.7	1.3	2.2	3.3	14.0	1.0	5.7	5.7	6.3	3.4	22.1
Field water requirements [b] (in.) ...						31.8						50.2
Ex-sluice water duty [c] (in.) ...						45.5						71.8

Note: *a. A* 75% rainfall exceedance expectancy; *b.* with 44% on-farm efficiency; *c.* with 70% transmission efficiency.

Source: *World Bank Appraisal Report* (1976).

Table 2—OPTIMUM PLAN WITH DRY SOWING IN SEPTEMBER

	Left Bank		Right Bank		
	Low Labour (1) *Amount*	*High Labour* (2) *Amount*	*Low Labour* (3) *Amount*	*Medium Labour* (4) *Amount*	*High Labour* (5) *Amount*
Net farm income (Rs.) ...	7152	8896	6487	8468	8775
Activities Basis A 4 ...	1.0	3.0	1.0	3.0	3.0
H 2 ...	1.1				
C 2 ...	1.9	3.0	1.8		0.1
C 3 ...	0.1				
C 4 ...			0.2		
C 5 ...				3.0	3.9
AA 4 ...		0.3		1.0	0.3
AB 2 ...	2.1	1.7	2.0	0.2	1.7
AB 3 ...	0.9	1.0	1.0	1.0	1.0
CC 1 ...	2.0	2.3	0.4	0.1	
HL 2M ...		44.6			
HL 4M ...	6.9	45.5	4.8	31.5	48.6
HL 6M ...	75.5	92.0	63.8	7.6	40.3
HL 8 ...	29.0	36.8	20.2		12.5
E ...	1556	1924	951	2135	1278

Note: a. Low, medium and high labour, means that representative farms have been chosen after stratifying farm household according to farm labour availability; b. Col. 1–amount used in acres by crops, man days, for hired labour, borrowing in rupees for credit; c. description of abbreviations; see annex 1.

	(1)	(2)	(3)	(4)	(5)
Resources: ML ...	0	410	0	412	446
MH ...	0	0	0	0	0
MC ...	120	33	53	41	207
YL ...	322	204	211	0	226
YH ...	0	0	0	0	0
YC ...	48	0	0	0	0
FL2M ...	4.4	10.0	7.4	7.8	4.9
FL 3 ...	0	0	0	0	0
FL4 ...	10.0	10.0	10.0	10.0	10.0
FL6M ...	10.0	10.0	10.0	10.0	10.0
FL7 ...	8.6	0.6	5.8	0	0
FL8 ...	10.0	10.0	10.0	6.4	10.0
YW ...	0	31.58	0	65.88	16.32

Note: a. Col. 1–marginal value product of resources in rupees; b. description of abbreviations, see annex 2.

Table 3—OPTIMUM PLAN WITH DECEMBER LOWLAND PREPARATION AND 4.4 ACRE FEET PER FARM WATER AVAILABLE IN THE TANK FOR *YALA* CULTIVATION

	Left Bank		*Right Bank*		
	Low Labour (1) *Amount*	*High Labour* (2) *Amount*	*Low Labour* (3) *Amount*	*Medium Labour* (4) *Amount*	*High Labour* (5) *Amount*
Net farm income (Rs.) ...	8621	10433	7952	10017	10266
Activities-basic A1	3.0	2.3	3.0	3.0	2.3
A2		0.7			0.7
H2			1.7		1.9
H3	0.6				
C1	1.0				
C2		2.0			
C3	1.0	1.0	1.0	1.0	1.0
C4			1.0		2.0
C5				2.0	1.0
AB2 ...	1.6	1.6	1.6	1.6	1.6
HH1 ...	0.4		2.0	2.0	2.0
CC1 ...	2.0	3.0	2.0	3.0	4.0
HL1 ...		3.8		3.9	
HL2M ...	22.9	13.2	25.9	13.7	14.2
HL2F ...	14.5		13.5	14.5	
HL3 ...				3.0	
HL4 ...	24.2	24.1	24.2	25.2	28.2
HL5M ...	13.2	28.0	38.0	59.0	85.0
HL6M ...			12.0		
HL7 ...		10.0	12.0	21.0	
E	1740	302	1867	1564	614
Note: See note on activities in basis in Table 2					
Resources: ML	183	660	229	697	582
MH	0	0	0	0	0
MC	89	73	74	11.4	86
YL	0	0	0	0	0
YH ...	0	0	20	15.0	30
YC	156	52	39.4	14.4	52
FLI ...	8.2	10	9.4	10.0	6.1
FL2M ...	10.0	10	10.0	10.0	10.0
FL2F ...	8.0	7.0	8.0	8.0	5.3
FL3 ...	0	0	0	10.0	0
FL4 ...	10.0	10.0	10.0	10.0	10.0
FL5 ...	10.0	10.0	10.0	10.0	10.0
FL6M ...	0	0	10.0	0	0
FL6F ...	0	0	0	0	0
FL7 ...	5.9	10.0	10.0	10.0	0
FL8 ...	0	0	0	0	0
YW ...	264	285	126	200	285

Note: See note on resources in Table 2.

Table 4—OPTIMUM PLAN WITH DECEMBER LOWLAND PREPARATION AND 7.0 ACRE FEET PER FARM WATER AVAILABLE IN THE TANK FOR *YALA* CULTIVATION

		Left Bank		*Right Bank*		
		Low Labour (1) *Amount*	*High Labour* (2) *Amount*	(*Low Labour* (3) *Amount*	*Medium Labour* (4) *Amount*	*High Labour* (5 *Amount*
Net farm income (Rs.)	...	9044	10925	8163	10500	10683
Activities–Basis: A1 ...	...	3.0	2.3	3.0	3.0	2.3
A2 ...	...		0.7			0.7
H2 ...	...			1.7		1.9
H3 ...	...	0.6				
...	...	1.0				
C1 ...	...		2.0			
C2 ...	...	1.0	1.0	1.0	1.0	1.0
C 3 ...	...			1.0		3.0
C5 ...	...				2.0	
AA1	...		0.2		0.5	0.3
AB2	...	2.6	2.0	2.6	1.4	1.9
HH1	...			2.0	2.0	
CC1	...	2.0	3.0	2.0	2.2	4.0
HL1 ...	...		3.8			
HL2M	...	22.9	13.2	25.9	13.7	14.2
HL2F	...	14.5	0	13.5	14.5	
HL3 ...	...		0		3.0	
HL4 ...	...	24.2	24.1	24.2	25.2	28.1
HL5 ...	...	8.0	28.0	38.0	43.4	51.0
HL6M	...	19.4	9.3	38.0		7.4
HL7 ...	...	5.7	10.0	12.0	13.2	
HL8 ...	...	5.7		11.7		
E ...	...	2552	747	2705	1763	806
Note: See note on activities in basis in Table 2						
Resources: ML ...	...	183	660	229	697	582
MH ...	...	0	0	0	0	0
MC ...	...	89	73	74	21	86
YL	...	0	0	0	0	0
YH	...	0	0	20	1	0
YC ...	...	174	22	39	0	22
FL1	...	8.2	10.0	9.4	5.7	6.1
FL2M	...	10.0	10.0	10.0	10.0	10.0
FL2F	...	8.0	7.0	8.0	8.0	5.3
FL3	...	0	0	0	10.0	0
FL4 ...	...	10.0	10.0	10.0	10.0	10.0
FL5 ...	...	10.0	10.0	10.0	10.0	10.0
FL6M	...	10.0	10.0	10.0	4.8	10.0
FL6F	...	0	0	0	0	0
FL7 ...	...	0	10.0	10.0	10.0	
FL8 ...	...	10.0	6.9	10.0	0	9.5
YW	...	119	126	78	174	103

Note: See note on resources in Table 2

Table 5--OPTIMUM PLAN WITH DECEMBER LOWLAND PREPARATION AND 9.4 ACRE FEET PER FARM WATER AVAILABLE IN THE TANK FOR *YALA* CULTIVATION

		Left Bank		*Right Bank*		
		Low Labour (1) *Amount*	*High Labour* (2) *Amount*	*Low Labour* (3) *Amount*	*Medium labour* (4) *Amount*	*High Labour* (5) *Amount*
Net Farm income (Rs.)		9175	11444	8306	11200	11143
Activities–Basis	A1	3.0	2.3	3.0	3.0	2.3
	A2		0.7			0.7
	H2			1.7		1.9
	H3	0.6				
	C1	1.0				
	C2		2.0		1.6	
	C3	1.0	1.0	1.0	1.0	1.0
	C4			1.0		3.0
	C5				0.4	
	AA1 ...		1.4	0.5	1.8	1.6
	AA2					
	AB2 ...	3.0	0.8	2.5		0.4
	HH1			2.0	2.0	2.0
	CC1 ...	2.0	3.0	2.0	3.0	4.0
	HL1		3.8			
	HL2M ...	22.9	13.2	25.9	13.0	14.2
	HL2F ...	14.5		13.5	14.5	
	HL3				9.4	
	HL4	24.2	24.1	24.2	25.2	28.1
	HL5		28.0	38.0	59.0	85.0
	HL6M ...	8.0		45.8		
	HL7		10.0	12.0	21.0	
	HL8	11.0	4.0	8.2	2.1	3.7
	E ...	2917	769	3163	2280	924
Note: See note on activities in basis in Table 2						
Resources:	ML ...	183	660	229	697	582
	MH ...	0	0	0	0	0
	MC ...	89	73	74	21	86
	YL ...	322	0	92	0	0
	YH ...	0	0	20	15	11.7
	YC ...	174	38	39.4	14.4	33.7
	FL1 ...	8.2	10.0	9.4	2.7	6.1
	FL2M ...	10.0	10.0	10.0	10.0	10.0
	FL2F ...	8.0	7.0	8.0	8.0	5.3
	FL3 ...	0	0	0	10.0	0
	FL4 ...	10.0	10.0	10.0	10.0	10.0
	FL5 ...	10.0	10.0	10.0	10.0	10.0
	FL6M ...	10.0	4.5	10.0	0	6.1
	FL6F ...	0	0	0	0	0
	FL7 ...	0	10.0	10.0	10.0	0
	FL8 ...	10.0	10.0	10.0	0	10.0
	YW ...	0	173	44	203	148

Note: See note on resources in Table 2

Table 6—OPTIMUM PLAN WITH DECEMBER LOWLAND PREPARATION AND 23.1 ACRE FEET PER FARM WATER AVAILABLE IN THE TANK FOR *YALA* CULTIVATION

		Left Bank		*Right Bank*		
		Low Labour (1) *Amount*	*High Labour* (2) *Amount*	*Low Labour* (3) *Amount*	*Medium Labour* (4) *Amount*	*High Labour* (5) *Amount*
Net Farm Income (Rs.)	...	9175	12218	8465	11983	11787
Activities-Basis	A1 ...	3.0	2.3	3.0	3.0	2.3
	A2 ...		0.7			0.7
	H2 ...			1.7		1.9
	H3 ...	0.6				
	C1 ...	1.0				
	C2 ...		2.0		1.6	
	C3 ...	1.0	1.0	1.0	1.0	1.0
	C4 ...		1.0			3.0
	C5 ...			0.4		
	AA1 ...		2.3	2.6	2.8	2.28
	AA2 ...		0.3		0.2	0.35
	AB2 ...	3.0	0.4	0.4		.37
	HH1 ...			2.0		
	CC1 ...	2.0	3.0	2.0	2.1	4.0
	HL1 ...		3.8			
	HL2M ...	22.9	13.2	25.9	12.9	14.2
	HL2F ...	14.5		13.5	14.5	
	HL3 ...				9.4	
	HL4 ...	24.2	24.1	24.2	25.2	28.1
	HL5 ...	8.0	28.0	38.0	11.0	51.0
	HLM ...	30.0	19.2	32.9	7.8	21.8
	HL6F ...			9.3	11.1	
	HL7 ...		10.0	12.0		
	HL8 ...	11.0	22.5	23.3	20.4	26.2
	E ...	2917	1372	3585	2863	1382
Notes: See note on activities in basis in Table 2						
Resources:	ML	183	660	229	697	582
	MH	0	0	0	0	0
	MC	89	73	74	27	86
	YL ...	322	115	202	0	122
	YH ...	0	0	20	0	0
	YC	174	22	39	0	22
	FL1	8.2	10.0	9.4	2.7	6.1
	FL2M ...	8	10.0	10.0	10.0	10.0
	FL2F ...	8.0	7.0	8.0	8.0	5.3
	FL3 ...	0	0	0	10.0	
	FL4	10.0	10.0	10.0	10.0	10.0
	FL5	10.0	10.0	10.0	10.0	10.0
	FL6M ...	10.0	10.0	10.0	10.0	10.0
	FL6F ...	0	7.0	8.0	8.0	5.3
	FL7 ...	0	10.0	10.0	8.4	0
	FL8	10.0	10.0	10.0	10.0	10.0
	YW ...	0	64.9	3.16	82.98	54.74

Table 7—SUMMARY TABLE OF DRY SOWING IN SEPTEMBER AND MUD SOWING IN DECEMBER PLANS

	Left Bank [a]									*Right Babk* [a]					
	Low Labour (1) 1*st* *Representative Farm*			*High Labour* (2) 2*nd* *Representative Farm*			*Low Labour* (3) 3*rd* *Representative Farm*			*Medium Labour* (4) 4*th* *Representative Farm*			*High Labour* (5) 5*th* *Representative Farm*		
	September dry sowing	*December plans with 4.4.*[d] *ac. ft.*	*December plans with 23.1*[d] *ac. ft.*	*September dry sowing*	*December plans with 4.4 ac. ft.*	*December plans with 23.1 ac, ft.*	*September dry sowing*	*December plans with 4.4 ac. ft.*	*December plans with 23.1 ac. ft.*	*September dry sowing*	*December plans with 4.4 ac. ft.*	*December plans with 23.1 ac. ft.*	*September dry sowing*	*December plans with 4.4 ac. ft.*	*December plans with 23.1 ac. ft.*
Net farm income (Rs.)	7152	8621	9175	8896	10433	12218	6487	7952	8465	8468	10017	11983	8775	10266	11787
A. *Maha* cultivated area (ac.)–															
(a) Lowland	1.0	3.0	3.0	3.0	3.0	3.0	1.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
(b) Highland	1.1	0.6	0.6	0.0	0.0	0.0	0.0	1.7	1.7		0.0	0.0	0.0	1.9	1.9
(c) Chena	2.0	2.0	2.0	3.0	3.0	3.0	2.0	2.0	2.0	3.0	3.0	3.0	4.0	4.0	4.0
B. *Yala* cultivated area (ac.)–															
(a) Lowland	3.0	1.6	3.0	3.0	1.6	3.0	3.0	1.6	3.0	2.2	1.6	3.0	3.0	1.6	3.0
(i) Paddy	0.0	0.0	0.0	0.3	0.0	2.6	0.0	0.0	2.6	1.0	0.0	3.0	0.3	0.0	2.6
(ii) Other crops	3.0	1.6	3.0	2.7	1.6	0.4	3.0	1.6	0.4	1.2	1.6	0.0	2.7	1.6	0.4
(b) Highland	0.0	0.4	0.0	0.0	0.0	0.0	0.0	2.0	2.0	0.0	2.0	0.0	0.0	2.0	0.0
(c) Chena	2.0	2.0	2.0	2.3	3.0	3.0	0.4	2.0	2.0	0.1	3.0	2.1	0.0	4.0	4.0
Borrowings (Rs.)	1556	1740	2917	1924	302	1372	951	1867	3585	2135	1564	2863	1278	614	1382

Note: a. for situation of representative farms, see Table 7.5 and section 7.3.

b. 4.4 and 23.1 ac. ft. per farm are water available in the tank for *Yala* cultivation

Table 8—SHADOW GROSS MARGINS [a] OF THE EXCLUDED ACTIVITIES

Activities	*Left Bank Low Labour (1)*			*High Labour (2)*			*Low Labour (3)*			*Right Bank Medium Labour (4)*			*High Labour (5)*		
	Sep-plan with dry sowing (Rs.)	*December plans with 4.4 [b] ac. ft. (Rs.)*	*December plans with 23.1 [c] ac. ft. (Rs.)*	*Sep-plan with dry sowing (Rs.)*	*December plans with 4.4 ac. ft. (Rs.)*	*December plans with 23.1 ac. ft. (Rs.)*	*Sep-plan with dry sowing (Rs.)*	*December plans with 4.4 ac. ft. (Rs.)*	*December plans with 23.1 ac. ft. (Rs.)*	*Sep-plan with dry sowing (Rs.)*	*December plans with 4.4 ac. ft. (Rs.)*	*December plans with 23.1 ac. ft. (Rs.)*	*Sep-plan with dry sowing (Rs.)*	*December plans with 4.4 ac. ft. (Rs.)*	*December plans with 23.1 ac. ft. (Rs.)*
A2	21	33	33				21	22	22	73	74	74			
A3	271	279	279	271	279	279	257	279	279		100	100	231	279	279
A6	236	247	247	132	149	149	146	198	198	320	338	338	62	28	28
H2	64	8	8	116	52	52	95			122	106	19	90		
H3	224			230	58	58	261	23	23	226	186	59	201	2	2
C2	76	12	12	71			155	41	41	133	107		118	39	
C4		4	4	8	16	16	27			151	90	85			
C5	22	7	7		9	9	28	1	1				2		13
AA1	284	1039	39	39	637		279	346			52		442	692	
AA2	296	1176	172	38	725		301	461	22	74	228	74	684	763	
AA6	422	1318	386	144	794	116	446	620	196	295	446	297	536	811	101
AB1	183	183	183	195	195	195	136	136	136	210	10	144	216	195	195
AB2										200		10			
HH1	84			77	107							6			0
CC2	394	438	385	432	543	636	303	547	547	397	440	494	386	239	342

Note: a. Amount of change necessary in the gross margin of excluded activities for them to merit inclusion in the solution.

b. and c. with 4.4 and 23.1 ac.ft. per farm water available in the tank for *Yala* cultivation.

Annex 1

Description of Abbreviations used for Resources and Other Constraints in the Linear Programming Model Tableau

	December Plans	September Plans
ML and YL	Maha and Yala lowland area respectively	Maha and Yala lowland area respectively
MH and YH	Maha and Yala highland area respectively	Maha and Yala highland area respectively
MC and YC	Maha and Yala chena area respectively	Maha and Yala chena area respectively
FL1 and HL1	Family and hired labour for chena and highland preparation (Maha)	
FL2 M and HL 2 M	Family and hired male labour for lowland preparation (Maha)	Family and hired male labour for land preparation (Maha)
FL2 F and HL2F	Family and hired female labour for paddy transplanting (Maha)	Family and hired female labour for paddy transplanting (Maha)
FL3 and HL3	Family and hired labour for chena and highland harvesting (Maha)	Family and hired labour for chena and highland weed control (Maha)
FL4 and HL4	Family and hired labour for paddy harvesting (Maha)	Family and hired labour for harvesting (Maha)
FL5 and HL5	Family and hired labour for chena and highland preparation (Yala)	
FL6 M and HL6M	Family and hired male labour for lowland preparation (Yala)	Family and hired female labour for land preparation (Yala)
FL6 F and HL6F	Family and hired female labour for paddy transplanting (Yala)	Family and hired female labour for paddy transplanting (Yala)
FL7 and HL7	Family and hired labour for chena and highland harvesting (Yala)	Family and hired labour for chena and highland weed control (Yala)
FL8 and HL8	Family and hired labour for lowland harvesting (Yala)	Family and hired labour for harvesting (Yala)
Min.	minimum paddy cultivation area	minimum paddy cultivation area
Max.	maximum chillie and chena paddy area	maximum chillie and chena paddy area
Cap.	own working capital	own working capital
Cr.	credit available	credit available
YW	water available in the tank per farm during Yala	water available in the tank per farm during Yala