DIVERSIFICATION INTO FRUIT PRODUCTION ON LOW-LAND RICE FARMS IN THAILAND : A MULTIPERIOD LINEAR PROGRAMMING ANALYSIS.[1]

by

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Introduction

Thailand has a total area of approximately 51 million hectares, about 46% of which is used for agriculture. A majority of the Thai population, 63.6% of a total of 54 million, are engaged in agricultural production (OAE., 1989a). Rice is by far the most important agricultural commodity although Thailand is now facing strong competition in world rice markets. The study by Ito *et al.*, (1989) shows that per capita rice consumption in most of the fourteen Asian countries under review is decreasing. Income elasticity of rice demand declined and in some cases became negative between 1961 and 1985. Domestic demand for rice in these countries which produce and consume about 90% of world's rice production, may therefore, decrease. Accordingly, the quantities of rice in Asia available for export may increase. As a consequence, a potential exists for excess supplies of rice in Asia, which will put an additional downward pressure on world rice prices.

In Thailand, a wide range of fruits are traditionally grown on a small scale by farmers. These have been of increasing interest to research and extension workers as potential alternative crops to rice and field crops. Hiranpradit (1989) shown that fresh fruits and processed products have a greater potential to increase export income than the main export crops, e.g. rice, field crops, para rubber. Mango is in the most promising group of fruit crops according to The Fifth and The Sixth National Agricultural Research Plan (OAE, 1989a), and it is the third fruit export earning products after longang and durian. Mango is tolerant to drought and temporary flooding, and can grow well throughout the country, except in the south where it does not grow successfully due to high humidity. However the Thai mango still faces problems of quality, competition, and market expansion. World mango production is about 14 million tons, but only 2.5% of this is from Thailand (OAE, 1989b). A study by Nochai (1988) indicated that potential foreign markets for Thai mango exist not only in Asia but in Europe, the Middle East and America, subject to the development and adoption of improved technologies which will overcome quality problems. These include attention to packaging, transportation, and standardization.

Investment in fruit trees, in this case mango, has several possible advantages over rice. Average net income is much higher, compared to rice which sometimes becomes negative if family labour is taken into account (FSRI & DOAE, 1986). These surveys also suggested that labour use is spread throughout the year in mango production, which favours small farmers who rely on their own family labour. Disadvantages include financing mango due to investment costs and no income from mango during the first two years. Once mango is established however, a diversified rice and mango farm may result in less income variation.

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As farmers are said to be risk averse (Young, 1979 ; Katikan, 1981), more secure production systems involving diversification, i.e. mango and rice, may be preferred by small-scale farmers. With all these positive and negative factors, the decision as to whether mango should be introduced is complex. Moreover, it may not be the same for all farmers, that is, the trade-off between mango and rice may vary, depending on the socio-economic aspects of each farm, i.e. farm size, credit, and family labour, being the three main resources which may relate to farmer welfare.

The case study area is Thambon Banlham, situated in Suphanburi province, in the central plain of Thailand. Agriculture in the region occupies 88% of the total land area, about 99% of which is rice paddy, accounting for about 90% of total farm income. (FSRI & DOAE, 1986). If farmers in this area could diversify some parts of their paddy into horticultural crops, such as mango, their income may be more stable and sustainable, than from growing rice alone. However, there has not been a thorough study to investigate whether mango is really an appropriate innovation for the farmers in the area, nor any study of optimal rice & mango areas for different farm sizes. Therefore, this study tests the hypothesis that mango is an appropriate technology for these farmers, and investigates how the optimum area of adoption is related to the farmers' socioeconomic situation.

The model

A multiperiod linear programming model is constructed (Phuphak, 1991) to analyze the transition, year by year, from a traditional rice system to a more diversified system incorporating mango production. The model covers a 25 year time horizon in order to evaluate the effect of introducing perennial fruit production on a whole farm, where account is taken of the farm family's access to credit, labour, and capital. Risk is represented in the objective function using a formulation of the MOTAD method. The model will determine optimum farm plans by maximizing cumulative cash surplus over a 25 year planning period subject to the constraints of available land area, capital, family labour and family living requirements (the purpose for having a 25 year planning period is to allow mango that may be grown in year 3 of the plan to have a life of 23 years which is the optimum life cycle of mango production according to a study by Rawonghet (1989)).

Linear programming makes farm planning with computers both feasible and practical (Crowley, 1985). Problems to which the LP method can be applied must have three basic components that can be expressed in numerical quantities:

(1) an objective, usually to maximize profit or minimize cost, in farm management;

(2) alternative activities or investments;

(3) resource and/or personal restrictions.

The linear programming with MOTAD risk form may be written as:-

$$\text{maximize} \quad C'X - \phi K L' (d^+ + d^-),$$

$$\text{subject to} \quad AX \leq B,$$

$$DX + I(d^+ + d^-) \geq 0,$$

$$X, d^+, d^- \geq 0$$

where X, A, B and C represent activity levels, activity coefficients, resource availabilities, and gross margin expectations respectively. D is the deviation matrix of gross margin observed and the gross margin expectation in a particular year, I is an S*S identity matrix. The vector, d^+, represents the positive absolute deviations, and d^-, represents the negative absolute deviation. If the sum of $d^+ + d^-$ is positive, I will be zero. Thus, only if the sum of the net revenue deviations for any year is negative, I will be forced to an equivalent positive value (greater than or equal to sign) and then summed over S years by L, a row vector of ones, to give a measure of summed total negative deviation over all years. This sum is transformed into an estimate of the standard deviation by multiplication by the constant K[5], and ø is the risk aversion coefficient.

The structure of the studied model

Figure 1 shows an outline of the block diagonal structure of the model. Rice and mango activities and associated constraints are repeated for each year in the diagonal blocks. The objective function of this multiperiod linear programming model is the maximization of cumulative cash surplus at the end of the planning horizon. Letter A (see Figure 1) represents coefficients of mango areas to be linked from previous year to the next (common constraint). Letter B represents transfer activities, for instance the transfer of cash surplus from one year to another. A 15 year repayment of long-term loan for mango establishment appears in the Z area in Figure 2. Risk constraints are represented to allow the selection between area of rice and mango production to be affected by the variability of gross margin and risk preference of the farmers. The mean absolute deviation (±MAD) of each enterprise appear underneath the enterprise (see Figure 1). -K is a constant value, and -ø is the risk aversion coefficient.

Multiperiod linear programming permits the programming of activities and constraints for t years (where t is a finite number). Outputs of any one year in the program become inputs for the following year. Thus, activities in each of the t years are interrelated. In the optimum plan, the plan for each year represents the most profitable plan in terms of the t-year optimum. In each year, the cost of family living (household expenditure) is considered to compete with the farm business. A family expenditure constraint in the RHS is necessary in view of the fact that not all capital forthcoming as income from a year's farm production will be available for further production, as some must be used for family living. In this way, family living expenses are represented as taking precedence over farm production in the allocation of available resources.

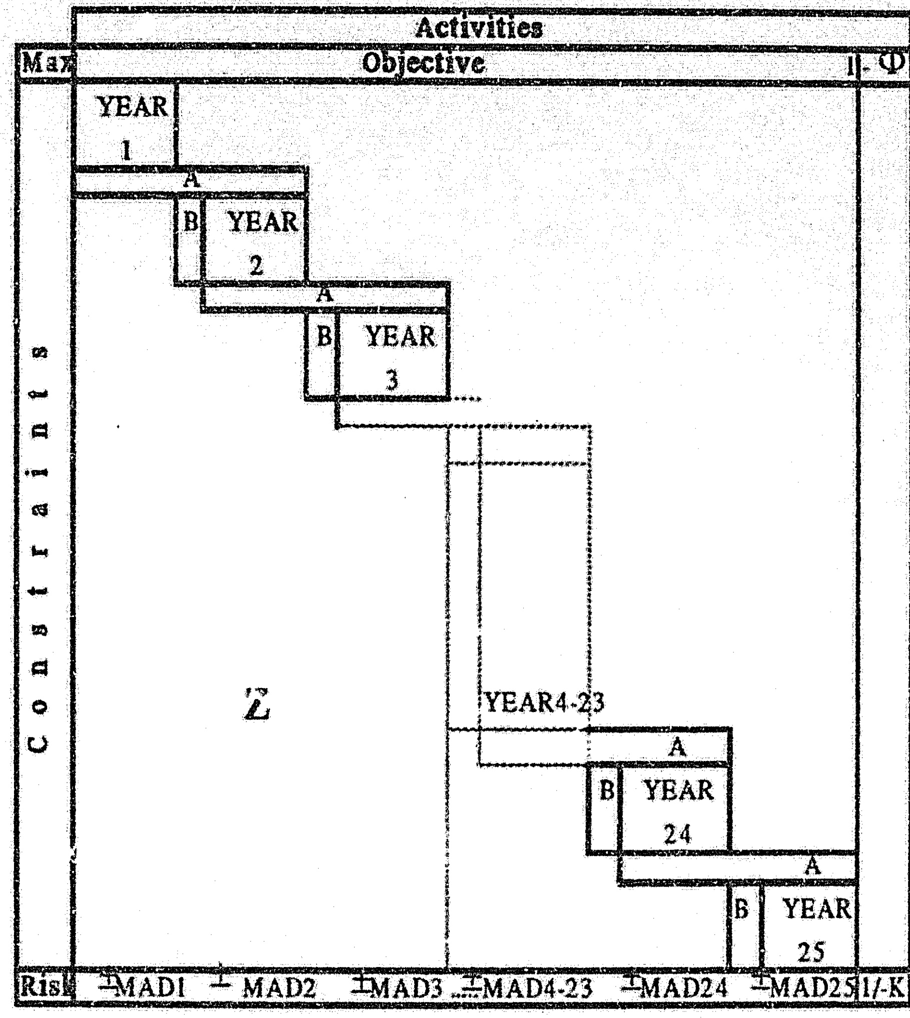
The data

Thambon Banlham was chosen by The Farming System Research Institute (FSRI) in co-operation with The Office of Agricultural Economics (OAE) as the main key site to study the feasibility of introducing crop diversification into paddy areas between 1982-1988. A total of 182 farms were sampled and divided into 7 groups according to farm area in order to look closely at farmers' traditional rice systems and the socio-economic characteristics that may influence the adoption of innovations (FSRI & DOAE, 1984). Data on the physical and socio-economic characteristics of the present study area are based on the FSRI & DOAE study. The costs, yields, prices, and labour used in rice production were obtained from a

[5] K equal $2/S(\sqrt{(2*\Pi/(2(S-1))})$; (for S = 8, K = 0.3349).
The factors outside the square root sign convert total negative deviation to mean absolute deviation, and the square root converts the mean absolute deviation to the estimated value of the standard deviation (see, Brink and McCarl, 1978).

study by FSRI & DOAE (1986), from 1982-1985. Costs and prices were inflated to 1988 by the consumer price index of the central plain & eastern region. The data on mango production were based on a study by Rawonghet (1989).

Figure 1 The structure of the model.



Note Letter A and Z represents a set of tied rows (common constrains), B = tran ferred activities, Φ risk aversion coefficient, K = a constant value, and MAD = the mean absolute deviation of rice and mango investments.

The model runs and assumptions

Farm size is the first factor on which this study has focused. The comparison was made using a "small farm" (10 rai[6]), a "medium farm" (25 rai), and a large farm (40 rai) for the standard run. All other parameters were set at the standard level for the analysis (average values closest to the real situation), i.e. 160 mandays/year of off-farm work, mango price at 20 baht/kg, family expenditure at 1,800 baht/month, land leased available for rice production at 10 rai/season, credit from the BAAC (The Bank of Agriculture and Agriculture-Cooperative) at 15,000 baht/rai, family labour available for on farm work at 68 mandays/month, and neighbour loan available to 10,000 baht/year. Therefore, the standard models were run, using the assumptions above for small, medium and large farms.

Sensitivity analysis was conducted on mango price, credit from the BAAC, family expenditure, income from off-farm work, and the farmer's risk attitude. The model runs were based on the assumptions of the standard models described last paragraph. Mango prices used were 20, 15 and 10 baht/kilogram; credit from the BAAC was 15,000, 10,000, 8,000, and 5,000 baht[7]/rai of land owned; family expenditure was 1,800, 1,500, and 1,000 baht/month; income from off-farm sale of labour was 10,000 (250 mandays), 6,000 (160 mandays), and 3,000 (80 mandays) per year. The models consider six levels of risk aversion coefficient i.e. 0.0 (risk neutrality), 0.03, 0.50, 1.0, 1.50 and 2.00. The 0.03 is chosen based on Sirijinda's study (Sirijinda, 1988).

Results and discussion.

The relationships among different factors associated with rice and mango production, farm size, income from labour sale and the nature of farmers' attitude to risk, led to different optimum solutions. The larger the farm the greater the area of mango adopted. Graph 1. shows that mango area was, 5.4 and 9.6 rai for medium and large farms respectively but that the solution is infeasible for the small farm. The small farm model is infeasible because, with the assumption that short-term debt is not carried over to the next year, there is insufficient cash flow to meet the required level of household expenditure. The issue of infeasibility of the small farm is dealt with in further section.

A comparison of the growth in cumulative cash surplus between a rice farm and an integrated mango & rice production farm is shown in Graph 2A,B. If a medium sized farm can have 5.4 rai of his paddy diversified into mango production, the farmer would earn an end cumulative cash surplus (cash accumulated at year 25) about 3 times greater than the purely rice farming system (Graph 2A). The end cumulative cash surplus, is found to be 3 times greater (Graph 2B) with 9.6 rai mango production for the large farm. The end cumulative cash surplus was almost double across the different farm sizes, being 997,591 baht for a medium farm and 1,756,985 baht for a large farm.

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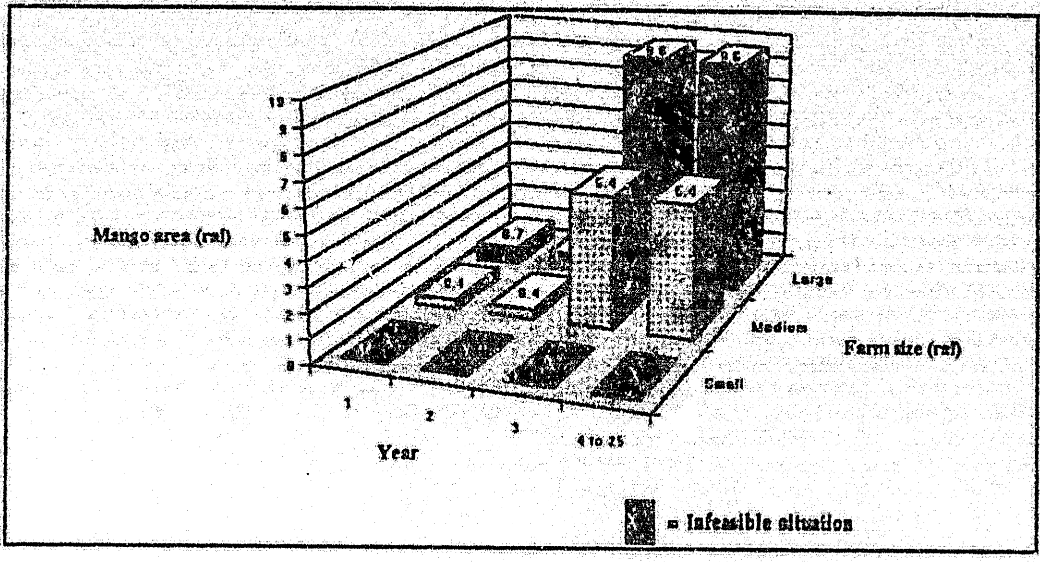
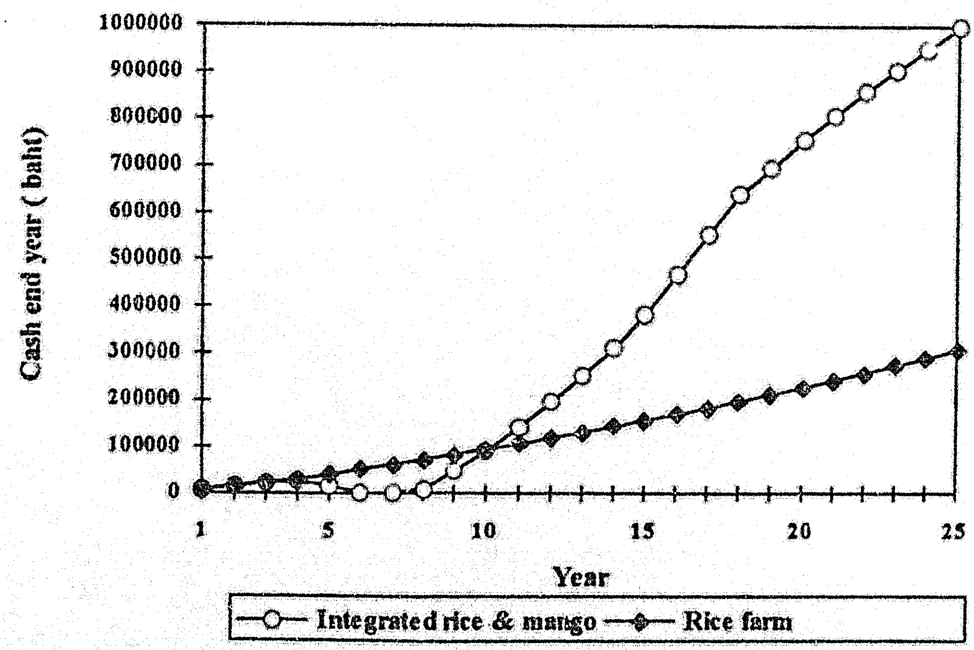
[6] 1 Hectare = 6.25 rai

[7] $US 1 ≈ 25 Baht

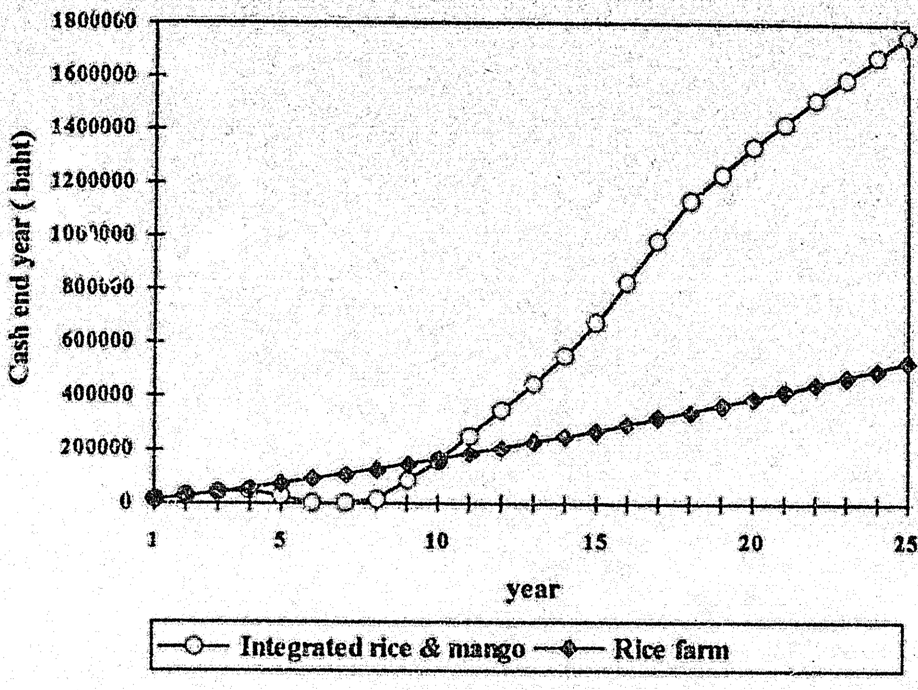
Graph 1. Optimum mango production area by farm size



Graph 2. A The comparison of growth between rice & mango and rice farms (Medium farm).



Graph 2. B The comparison of growth between rice & mango and rice farms (Large farm).



Cumulative cash surplus increased gradually from year 1 to year 4 in both rice and an integrated mango & rice farm when long-term loan repayments for mango production were still in a holiday[7] period (3 year). After year 4, the cumulative cash surplus of the rice farm kept increasing whereas in the integrated mango & rice farm, the cumulative cash surplus began to fall because long-term loan repayments for mango production started while income from mango remains negligible. After year 8 cumulative cash surplus increases sharply as income from mango production grows by year 10, the cumulative cash surplus is equal to that of the rice farm and thereafter it grows very rapidly, increasing to well above that for the rice farm.

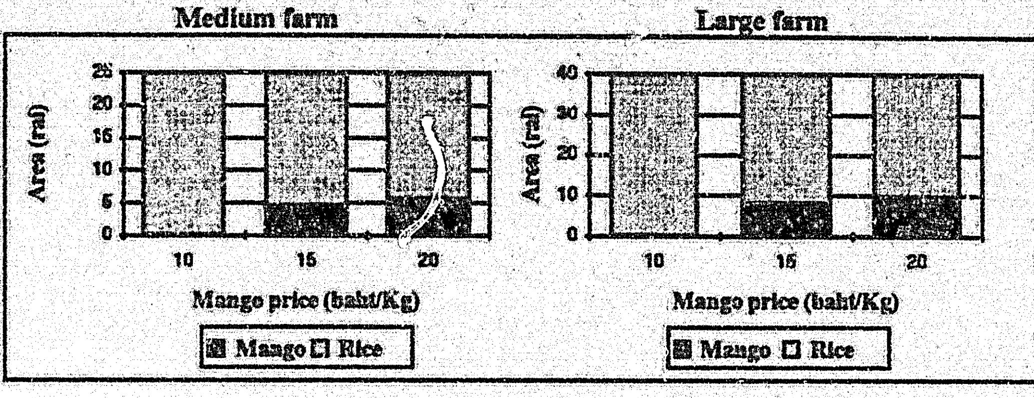
Sensitivity analysis of the standard model results

Mango prices

The optimum mango area is very sensitive to the mango price, and the mango area decreases if the price of mango falls. The area of mango decreased from 5.4 rai to 4.4 rai on the medium farm (Graph 3). For the large farm, 8 rai of mango production was selected at a mango price of 15 baht/kilogram compared with 9.6 rai at a mango price of 20 baht/kilogram. No mango area entered the optimum solution when the mango price was reduced 50% to 10 baht/kilogram indicating that farmers would be better off having purely rice farms.

[7] holiday repayment period used in this case means a period in which the bank requires no repayment during mango establishment after planting.

Graph 3. The expected optimum area of mango production in each farm at different mango prices



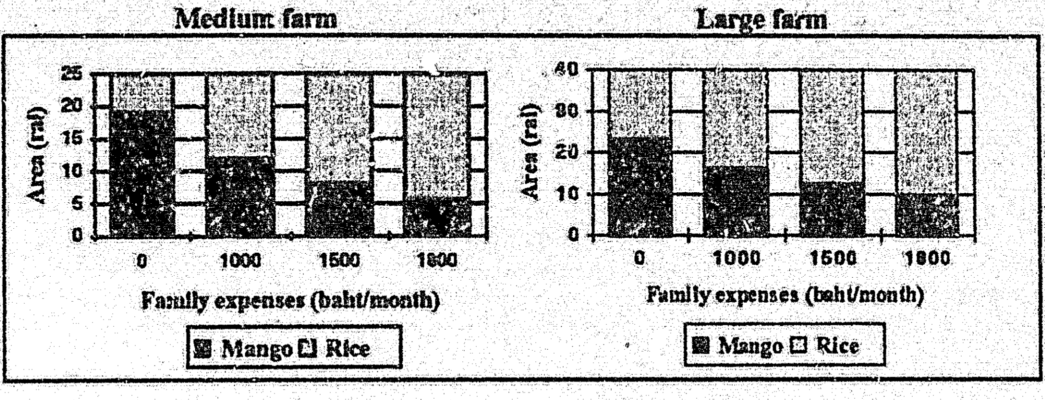
Credit

The amount of long-term loan available was not a constraint to mango production for either farm size when the land mortgage value was set at 15,000 baht/rai. Sensitivity to this factor was tested at 10,000, 8,000, and 5,000 baht/rai and surprisingly it was found that the amount of loan available did not bind the selection even at 5,000 baht/rai. The model gave an identical solution for both the medium and large farms. Where long term borrowing capacity exceeded 15,000 baht/rai, the area of mango production did not change since the maximum amount of loan available was not used up and the optimum solution showed that the shadow price of this constraint was zero.

Family expenditure

Family expenditure has a strong effect on the optimum solution. Sensitivity analysis of this constraint indicated that when farm size, land leased and mango price are kept constant, the optimum area of mango production is negatively related to family expenditure (Graph 4.). If family expenditure was set at zero the model selected 18.9 and 23.1 rai mango area for the medium and the large farms respectively. When family expenditure was constrained to 1,000 baht/month the area of mango decreased to 11.8 rai for the medium farm, and 16 rai for the large farm. The model selected 5.4 rai of mango for the medium farms and 9.6 rai for the large farms when family expenditure was 1,800 baht/month. The reason for the effect of family expenditure is that it is cash flow in years 5 to 8 that is limiting mango area. An implication of this finding is that through decreasing family expenditure or improving the cash flow position at this time, it is profitable to finance the planting of more mangoes. This, in turn will lead to greater returns in the long term. This may or may not be attractive to farmers. The ability of households to survive on food generated on the farm means that decreasing family expenditure may be feasible. If data on how consumption is a function of income were available, further analysis could be conducted incorporating such a consumption function to give a more realistic treatment of family expenditure.

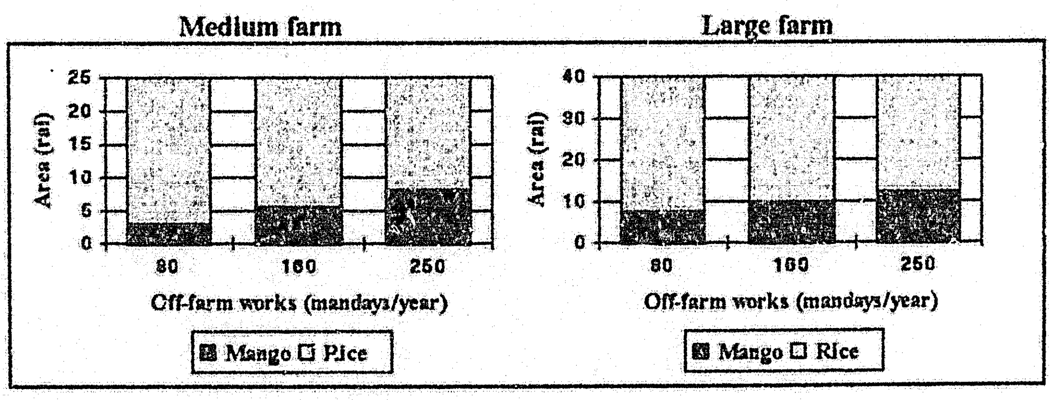
Graph 4. The optimum area of mango production at different levels of family expenditure.



Income from off-farm work

The optimum area of mangoes increases significantly with the opportunity for off-farm work in both medium and large farms. The optimum mango area of 2.8 rai in the case of 80 mandays income from off farm work, increased to 5.4 rai and 7.9 rai when income from off-farm work increased to 160 and 250 mandays respectively, for the medium sized farm (Graph 5.). For the large farm mango areas increased from 7.2 rai when income from off-farm work was 80 mandays/year, to 9.6 and 11.9 rai if this income increased to 160 and 250 mandays/year respectively

Graph 5. The expected optimum areas of mango production in each farm at different levels of off-farm works.



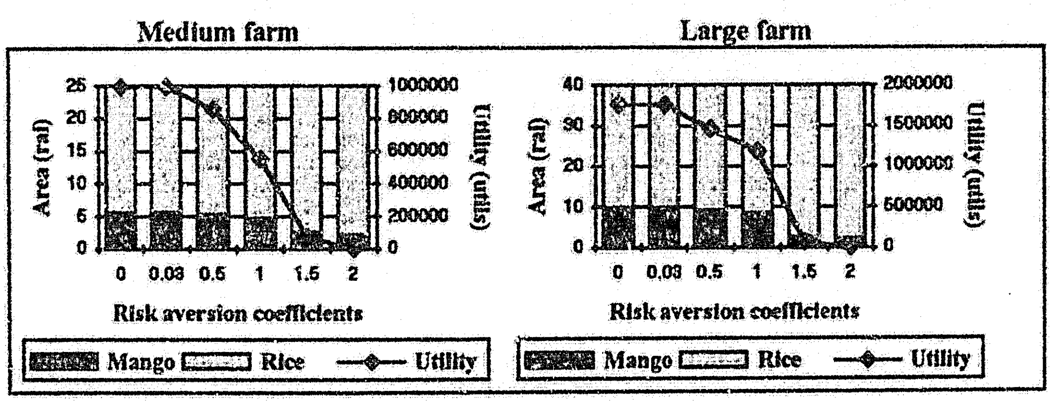
As with reduced household expenditure, increases in off-farm income led to more mango production by providing additional finance in the critical periods (years 5 to 8). This reduces the level of long-term borrowing, since income from this source can substitute for long-term borrowing. Thus higher income from off-farm work led to a lower long-term borrowing requirement per rai of mangoes.

Income from off-farm work is an important part of household incomes because it can help to overcome a working capital constraint, including family expenses or even finance the adoption of innovations. An implication of these results is that the opportunity for off-farm work is an important determinant of the area of mango it is profitable to grow, especially for the medium sized farm. Assumptions on income from off-farm work that were used in the model were based on survey data of income from off-farm work of the farmers in the area in 1982/83. The lowest possibility from the survey to earn income from this source (80 mandays), the average (160 mandays) and the highest (250 mandays) per year were used. However, information on income from this source, although the best available, is not considered highly reliable.

Farm sizes and farmer's attitude to risk

The results showed that at the same degree of risk aversion, the area of mango production is higher for the larger farm (Graph 6.). However, as risk aversion increases the optimum area of mangoes converges for the two farm sizes. This indicates that larger farms, at the same levels of risk attitude, could adopt larger areas of mango production, and leading to greater utility. At risk neutrality (ø = 0.0), mango area for the medium farm is 5.4 rai and 9.6 rai for the large farm with utility levels of 997,591 and 1,763,861 utils for the medium and large farms respectively. The mango area decreases as risk aversion increases in both farm cases, and at a risk aversion coefficient of 2.00, the mango area becomes 2 rai when the utility became zero for both farms. The area of mango production decreases when the risk aversion coefficient increases (farmer being more averse to risk) and so does the area of rice production.

Graph 6. Expected mango production areas and expected utility (at year 25) in different farm sizes, relating to farmer's attitude toward risk.

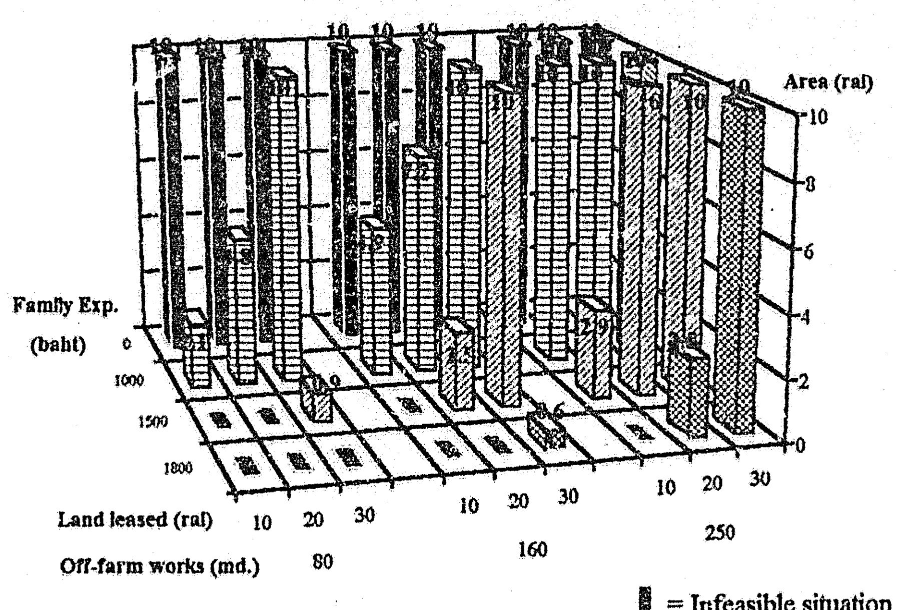


Multiple sensitivity analysis for the small farm

Under the assumptions of this model, the medium and large farms can profitably adopt mango production. In the case of the standard assumptions for the small farm the model was found to be infeasible; not only was it infeasible to introduce mango but it was found to be infeasible even as a purely rice farm. The reason for this is simply that the margin for rice production is so low that even an 1,800 baht/month family expenditure could not be covered, thus violating the constraint that no negative cash balances can be passed from one year to the next. Farm income comes from two main sources, (i) the returns to rice or integrated mango & rice production, (ii) sale of labour off-farm. The result could be infeasible if there is a shortage of revenue to meet family expenses, costs of production and loan repayments such as when mango is being established or income generated from mango production is still negligible between year 1 to year 9. Therefore, off-farm income and rice production plays an important part in those years of mango establishment.

The following results investigate the circumstances under which the small farm model is feasible and under which mango would be profitably grown. Graph 7, summarizes those circumstances showing that an increase in farm size, land leased or a decrease in family expenditure is associated with an increase in mango area. The small farms may be able to adopt mango if family expenditure per month can be decreased from 1,800 baht/month to 1,500 baht or less. Alternatively the income from off-farm work would have to increase from about 160 mandays/year (6,000 baht), which was the average off-farm income of all farms in the study area to about 10,000 baht/year (250 mandays). In both these cases, it would be profitable for the small farm to adopt 2.5 rai of mango.

Graph 7. The interaction of factors that affects mango area and feasibility of small farm model



Conclusion

Mango adoption is not best for all farmers: it is clearly profitable for large farms, probably profitable for medium farms and, under some circumstances, appears profitable for small farms. The appropriate mango area varies and depends on the farmer's socioeconomic situation. Under the assumptions of the model, on the medium farm (25 rai) 5.4 rai of mango is optimal, and also leads to about a 3 times higher end (cumulative) cash surplus than rice alone. The large farm (40 rai) can adopt 9.6 rai of mango which could lead to about a 3 times higher end cumulative cash surplus than the rice-rice system.

The difficulty of adopting mango, especially for the small farmer, relates to cash flow and financial constraints. In the case of a small farmer, he could grow 2.5 rai of mangoes if it was possible to spend less than 1,800 baht a month, or to earn more off-farm income to bring in at least an extra 10,000 baht/year in the early years of the plan. If the government wants to encourage growing mango it can do so by helping to address the cash flow situation of farmers during year 5 to year 9 cash flow problem. This could be better achieved by (i) the reduction or subsidizing of the loan interest rate (ii) extending the holiday periods of the long-term loan repayment beyond 3 years and/or (iii) extending the period of the long-term loan repayment to more than 15 years to ease a shortfall of cash in years 5 to 9 of the plan.

The linear programming model used in this study has proved to be a powerful tool in analyzing appropriate innovations for an individual group of farmers, and to identify those whom extension should target, and whom not. It has also shown that if the Government wants farmers to adopt mango, then the present financial impediments have implications for the kind of finance that would encourage the maximum area of mango. This sophisticated approach has also contributed by showing that the extra information it has included does make a difference to the answers. Details of the farm such as cash flow over many years, household expenditure, farm size, opportunity to work off-farm etc. have been shown to affect the ʻ ʼer. Also it has been important to compute an optimum area of mango under these diffe .. rcumstances.
This approach could be applied to other studies in similar situation, such as economic and/or policy analysis of potential innovations requiring major changes to the farming system. Such situations arise with the introduction of new perennial crops into annual cropping systems, for example, cashew, rubber, coconut and a wide range of tree crops or even of livestock and fish farming.

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