Netherlands Journal of Agricultural Science 48 (2000) 105-114

An analysis of the economic values of novel cropping systems in N. E. Thailand and S. Sumatra

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Received 15 December 1999; accepted 5 March 2000

Abstract

The use of food-crop intercropping, hedgerow intercropping and secondary or cover cropping to increase incomes of resource-poor farmers in South East Asia was investigated. Since all systems improve conservation of nutrients and most give extra marketable produce, they were expected to increase farm profitability. On upland farms in Lampung, South Sumatra, both inter- and secondary crops were found to improve yields compared with cassava monocropping and thus the income derived from growing cassava or rice with maize. These increases were equivalent to between 70 and 440 US dollars per hectare. An economic analysis of the lowland rice-producing systems in North East Thailand suggested that with the exception of growing cowpea, the use of pre-rice cover crops was not profitable despite a substantial increase in rice yield, because the additional labour cost more than the additional income was worth. A benefit of leguminous crops, however, can be the extra marketable product. Groundnut in Indonesia and cowpea in Thailand gave an attractive extra US$ 400–1150 total income increase per hectare per year (i.e. extra yield of the main food crop plus extra marketable produce from the secondary crop) even after the additional costs were deducted. Hedgerow intercropping gave smaller profit margins of about US$ 90. Although both hedgerow intercropping and secondary cropping represent a considerable investment of labour by farmers, this investment may be more feasible than paying for fertilizer on credit. On balance the most attractive option tested was the use of a leguminous secondary crop, e.g. groundnut or multipurpose cowpea, within the food crop cycle.

Keywords: economics, income, labour, cropping systems, hedgerow intercropping, leguminous crops, cover crops, soil fertility, South East Asia

Introduction

Food-crop production on weathered, acid upland soils is one of the most marginal activities in South East Asian agriculture. Consequently farmers are poor, have little access to credit and can only afford fertilizer to improve yields with difficulty. The Biological Management of Soil Fertility (BMSF) project sought ways to recycle nutrients from crop residues as efficiently as possible and to introduce nitrogen into soil through the use of leguminous crops. A key aspect is thus the crop rotation and farming system. Hedgerow intercropping introduces nitrogen during a food-crop cycle, green manuring or cover cropping introduces N during a fallow cycle; in addition both systems scavenge nutrients that might otherwise be lost through leaching. Food-crop intercropping provides another kind of safety net: if one crop fails or misses nutrients another may survive or capture nutrients. Acceptance and adoption of novel practices requires more than simply demonstrating a yield increase. A practice must also be financially worthwhile to the farmer and because Becker *et al.* (1995) found little economic benefit of cover crops as pure green manures in a crop rotation and Rao *et al.* (1991) reported little economic benefit of growing food crops between hedgerows of leguminous trees, we decided to investigate the full value of our systems to farmers.

The benefits of BMSF in terms of nutrient recovery and sustainability have been reported on elsewhere (Hairiah *et al.*, 2000; Vityakon *et al.*, 2000, Toomsan *et al*, 2000; Whitmore *et al.*, 1998). Farmers, however, do not measure improvements in terms of, to them, abstract concepts such as nutrient supply or long-term preservation of soil organic matter. They are much more concerned with increases in food production, profit, prosperity, labour-reduction or time-saving. This article takes the results from the farming systems reported on by Hairiah *et al.* (2000) and Toomsan *et al.* (2000) and investigates the economic benefits of the novel cropping systems investigated.

Materials and Methods

The cropping systems were chosen to introduce N_2-fixing species into the cropping cycle either as a spatial intercrop between the rows of a food crop, as a sequential crop grown before or after the main food crop or both. Cover crops have the additional benefit that they can recover nutrients (including P) either released from crop residues or not used by the food crop. In general our expectation was that the increased efficiency of use of resources should lead to an increase in the profitability of the complete cropping cycle.

At Khon Kaen (Thailand) sequential crops only were grown. A rice food crop was preceded by crops of *Sesbania*, cowpea, a mixture of *Sesbania* and multi-purpose cowpea, mungbean or groundnut, a bare fallow or bare fallow plus 30 or 60 kg N ha^{-1} fertilizer given to the rice (Table 1). Pre-rice crops were given 25 kg P and 30 kg K ha^{-1}. At Lampung (Indonesia, Table 2), cassava (CS1a) was compared with cassava intercropped with a mixture of rice and maize (CS1b), rice-maize mixtures grown between hedgerows of either *Flemingia congesta* (CS2b) or between rows of a mixture of alternate trees within each row of *Gliricidia sepium* and *Peltophorum* *dasyrrachis* (CS2a) followed by groundnut (both CS2 systems), rice-maize mixtures followed by groundnut (CS3a and b). All systems were followed by a cover crop not grown for food. Both rice-maize mixture and groundnut received 34 kg P ha^{-1} and 50 kg K ha^{-1}; in addition the rice-maize mixture received 60 kg N ha^{-1}. Cover crops were not fertilized. Full details are given by Toomsan *et al.* (2000) and by Hairiah *et al.* (2000).

Costs were divided into capital and labour. Whilst capital costs were relatively easy to determine based on the prices of local seed and fertilizer, labour was harder to quantify, and was estimated in terms of the time requirements for each activity and the daily labour rate in 1996. Labour rates and exchange rates with the US dollar were valid at the time the research was completed in the mid 1990's but since then political instability and currency speculation have confused the picture. Because our aim is to compare farming systems in two different countries in the economic conditions prevailing at the time of the experiments, we have chosen to express amounts of money in U.S. dollars at the 1996 exchange rate: 25.3 Baht or 2,500 Rp to 1 US dollar. At the time of writing 38.7 Baht and 6,900 Rp buy one US dollar. Labour costs and product prices are correct for 1996 too.

The economic analysis at Khon Kaen was relatively easy to perform because the crops were planted in sequence only. Rice was planted as the main crop in all instances and was preceded in the rotation by either nothing (fallow) or a cover crop. The cropping sequences in Table 1 are thus identified by the preceding crop treatment; the agronomy of the rice was identical in all treatments apart from the addition of 30 or 60 kg N ha^{-1} to two of the treatments. Labour required at Khon Kaen is given in Table 3

Intercropping in space as well as sequential cropping is a feature of the experiments at Lampung and this means that the calculations must be made in proportion to the area occupied by each crop. Comparisons are therefore less straightforward to make than at Khon Kaen. The cropping systems studied differed also in their main food crop, adding further to the complexity. A full description of the systems is given by Hairiah *et al.* (2000) but a summary including the relevant fractions of the land area occupied by each crop is given in Table 2. Labour at Lampung is shown in Table 4. Note that the additional labour required to prune hedgerows has not been included because Hairiah *et al.* (2000) have shown that the hedgerows shade out weeds, so reducing labour. We have assumed that the savings in weeding balance the additional effort of incorporation. Results are reported on a per hectare basis. Gauthier (2000) reports that smallholdings in Lampung are between 2 and 5 ha in size and farms around Khon Kaen are about 4 ha in size on average. The profits per hectare reported here are thus attainable on real farms in the region.

Results and discussion

Economic value of the cropping systems at Khon Kaen

At Khon Kaen *Sesbania* increased the yields of the rice food-crop by 0.8 t ha^{-1}, groundnut increased yields by 0.6 t ha^{-1} (Table 1 and Toomsan *et al.*, 2000); these increases were greater than achieved with fertilizer at a rate of 30 or 60 kg N ha^{-1} (0.4–0.6 t ha^{-1}). Mungbean increased the yield of rice by 0.1 t ha^{-1} only, The increases in rice yield due to groundnut and *Sesbania* were worth about an extra 2,500 or 3,500 Baht ha^{-1} to a farmer respectively. The *Sesbania*-cowpea mixture yielded 2.5 t ha^{-1} of marketable cowpea produce (fresh weight), whereas mungbean and groundnut yielded 0.7–0.8 t ha^{-1}. Mungbean and groundnut yielded products worth an additional 4,740 and 5,760 Baht ha^{-1} respectively (Table 1). In contrast the multi-purpose cowpea, which at the time was a pioneer crop, was worth almost 38,000 Baht ha^{-1} extra. The majority of the crop systems studied increased marketable yield (of both rice and pre-rice crop) in the range 3,000–8,000 Baht ha^{-1} (Table 1). The cowpea, however, led to a total increase in income of 41,000 Baht ha^{-1}. Costs of growing pre-rice crops were generally large too and the net balance in the groundnut system was negative at US$ –109 ha^{-1}. The cowpea was by far the most profitable system studied with a surplus of income over expenditure of about US$ 1150 ha^{-1}. About one fifth or one sixth of the expenditure on growing the secondary crops was on P fertilizer, which is needed to ensure nodulation and a vigorous growth of the legume as well as to compensate for the removal of P and so maintain long-term fertility of the soil. The need for fertilizer, however, may put these cropping systems out of reach of the poorest farmers.

Of all the pre-rice green manure systems tested at Khon Kaen, only the *Sesbania*-multi-purpose cowpea system was satisfactorily profitable (Table 1). Groundnut as a pre-rice green manure failed to deliver a profit and was inferior to N fertilizer use (c.f. Lampung below). Pure green manure systems (i.e. *Sesbania* with no marketable produce) gave negative returns on investment despite the highest positive benefit in rice yields. Ali & Narisco (1994) also concluded that the short-term benefits of pure green manures in rice-based systems were negative in India and Nepal and only just positive in the Philippines. Green manures may become more economic in the long-term when the build up of soil fertility is included in the analysis. Legumes that also provide an economic yield not only generated more income, but were equally beneficial in sustaining resource productivity over time (Ali & Narisco 1994). The time spent on cultivating secondary crops is an uneven match against more attractive off-farm options that pay better than farm-labouring. Craig (1985) came to similar conclusions regarding the low returns from mungbean pre-rice crops. He identified the under-employment that precedes the rice season as an attractive window for inclusion of additional crops. However, secondary crops that did not increase rice yield and reduce fertilizer costs were not attractive even if they themselves were profitable as in the case of sweet corn. Alternatively, kenaf was another crop that fitted the farmer's low-input, low-risk stabilisation strategy. Our analysis suggests that a secondary crop as well as the main food crop is a viable option for farmers provided a good market exists for the extra produce.

Economic value of the cropping systems at Lampung

The economic value of the cropping systems CS1–3 at Lampung (Table 2 and Hairiah *et al.*, 2000) were evaluated using income and expenditure data from Table 5, the

Table 1. Cropping system, costs, profit and additional profit relative to the rice-fallow system of the various alternative cropping systems investigated at Khon Kaen, N.E. Thailand.

Crop grown between rice	Green Manure		Rice		Total income increase Baht ha^{-1}	Costs (Baht ha^{-1}) Capital		Labour		Total Costs Baht ha^{-1}	Balance Baht	Balance US$ ha^{-1}
	Economic yield kg ha^{-1}	Income Baht ha^{-1}	Yield increase kg ha^{-1}	Extra Income[4] Baht ha^{-1}		Seed	Fertilizer	Land Preparation & planting	Harvest & incorporation			
Sesbania	0	0	865	3,460	3,460	1,000	1,688	4,100	1,500	8,288	–4,828	**–191**
Sesbania+												
Cowpea	2,530(FW)	37,950[1]	815	3,260	41,210	2,500	1,688	5,100	2,700	11,988	29,222	**1155**
Mungbean[2]	790	4,740	103	412	5,152	400	1,688	5,100	2,800	9,988	–4,836	**–191**
Groundnut[3]	718	5,760	625	2,500	8,260	1,440	1,688	5,100	2,800	1,028	–2,768	**–109**
Fallow	0	0	0	0	0	0	0	0	0	0	0	**0**
Fallow+30[5]	0	0	561	2,244	2,244	0	714	100	0	814	1,430	**57**
Fallow+60[5]	0	0	418	1,672	1,672	0	1,428	100	0	1,528	144	**6**

[1] pioneer crop, 15 Baht kg^{-1} Fresh Weight (FW)
[2] 6 Baht kg^{-1}
[3] 8 Baht kg^{-1}
[4] rice 4 Baht kg^{-1}
[5] +30 and +60 kg N fertilizer respectively

Table 2. Cropping systems adopted at Lampung, Indonesia. Fractions of land covered by the intercropped species.

Label	Description	Hedgerow crop		Main Crop		Secondary crop	
		Tree	Fraction	Crop	Fraction	Crop	Fraction
CS1a	Cassava mono-crop followed by *Mucuna*	None	–	Cassava	1.0	*Mucuna*	1.0
CS1b	Cassava intercropped with maize and rice; followed by cowpea	None-	–	Cassava : Rice : Maize	0.5:0.4:0.1	Cowpea	1.0
CS2a	Intercropped maize and rice in a permanent hedgerow; followed by groundnut	*Gliricidia* and *Peltophorum*	0.18	Rice : Maize	0.66 : 0.16	Groundnut	0.82
CS2b	Intercropped maize and rice in a permanent hedgerow; followed by groundnut	*Flemingia*	0.18	Rice : Maize	0.66 : 0.16	Groundnut	0.82
CS3a	Intercropped maize and rice followed by groundnut followed by *Mucuna*	None	–	Rice : Maize	0.8 : 0.2	Groundnut, *Mucuna*	1.0 1.0
CS3b	Intercropped maize and rice followed by groundnut followed by *Mucuna*	None	–	Rice : Maize	0.8 : 0.2	Groundnut Cowpea	1.0 1.0

Table 3. Labour (days ha^{-1}) requirements for pre-rice crops at Khon Kaen, N.E. Thailand. (All labour is costed at 100 Baht d^{-1}).

	Fertilizer (N or PK) application	Additional land Preparation	Planting + Weeding	Harvest	Residue Incorpo-ration	Total Additional days
Sesbania	3	4	34	12	3	56
Sesbania+						
MP-Cowpea	3	4	44	24	3	78
Mungbean	3	4	44	25	3	79
Groundnut	3	4	44	25	3	79
Fallow	0	0	0	0	0	0
Fallow+30N	1	0	0	0	0	1
Fallow+60N	1	0	0	0	0	1

cropping fractions in Table 2 and the labour requirements in Table 4. The benefits of each novel cropping system were compared with cassava monocropping as a base-line and expressed in US$ (Table 6) for comparison with the results from Khon Kaen (Table 1).

Although hedgerow intercropping increased food-crop yields from the food-crop plots (Hairiah *et al.*, 2000) and increased income from Rp 500,000 to about Rp 900,000 ha^{-1} (Table 6), net profitability was not increased as much (Rp 250,000–300,000 ha^{-1}) because of the land area (Table 3) occupied by the hedgerows and because of the cost of the extra labour. The low value of the maize and high production costs relative to yield held down profitability of the cassava and rice-maize mixtures (CS1b, Tables 2 and 6). The respectable yield and price (Rp 1,000 kg^{-1}) commanded by the groundnut helped make the rotational crop systems (CS3a and b, Tables 4 and 6) the most profitable system at Lampung (US$ 440 ha^{-1}, Table 6) despite the greater than average costs (Rp 727,000 ha^{-1}).

Costs per hectare of growing maize were large compared with the income to be derived (Table 5). In contrast cassava, rice and groundnut all show a healthy profit over expenditure by a factor of between two and three. Incomes in Table 5 are based upon reasonable expectations of yield at Lampung. Cassava mono-cropping is prof-

Table 4. Labour (days per hectare) requirement for the crops grown at Lampung

Crop	Labour days			
	Land preparation	Planting and weeding	Harvest	Total labour incorporation
Cassava	5	15	7[1]	27
Rice	30	50	20	100
Maize	5	30	10	45
Groundnut	5	35	25	65

[1] Harvest of Cassava is costed in Table 3 as labour per kg. Day tally here is the time needed to harvest 20 t ha^{-1} assuming labour rates are 5000 Rp per kg and labour costs 2500 Rp per day.

Table 5. Income and expenditure for each food crop grown at Lampung expressed on a per hectare basis assuming labour costs were 2,500 Rp per day in 1996.

Crop	Gain		Capital costs		Labour costs		Total Costs kRp
	Target Yield t ha^{-1}	Income kRp[1]	Seed kRp	Fertilizer + insecticide kRp	Establishment and preparation kRp	Maintenance and harvest kRp	
Cassava	20	1,420	–[2]	175	137.5	112.5	425
Rice	2.5	1,400	44	199	175	75	493
Maize	4	440	52.5	149	62.5	50	314
Groundnut	0.8	800	80	35	175	88	378

[1] Thousand of Rupiah
[2] Costs are negligible as crop regenerates spontaneously from woody cuttings.

itable provided yields are at the 20 t ha^{-1} level. Hairiah *et al.* (2000) found that cassava yields declined from 40 to 5 t ha^{-1} (fresh weight) during 10 years. A farmer would be better off earning off-farm at the labour rates used in this study and using this income to buy cassava once yields fall below 6 t ha^{-1}. Without off-farm employment, however, subsistence farmers must continue to grow their own food, perhaps at rates well below 6 t ha^{-1}.

Although hedgerow intercropping systems (Table 4, CS2a and b) were clear winners in terms of sustainability and returns of N to soil (Hairiah *et al.*, 2000), the loss of cropped land area appears to be a serious limitation to their profitable application in the humid tropics. The profit derived from cropping rice-maize mixtures between hedgerows (Rp 274,000 – 313,000 ha^{-1} compared with Rp 250,000 ha^{-1} intercropped with cassava Table 6) was barely enough to compensate for the loss of land area. Hedgerow intercropping might have most benefit where land is not an issue and additional work in pruning the hedgerows is not in conflict with other labour demands. Hedgerow trees may reduce labour by shading out weeds during the dry season; fruit

Table 6. Profit, expenditure and economic benefits of the cropping systems (see Table 2) at Lampung. Net income expressed in US$ relative to Cassava monocropping.

	Total value of crops kRp[1] ha^{-1}[2]	Total costs kRp ha^{-1}	Net profit Rp ha^{-1}	Balance[2], income increase US$ ha^{-1}
CS1a	497	425	72	
CS1b	646	387	250	72
CS2a	901	588	313	97
CS2b	862	588	274	81
CS3a	1,902	727	1,174	441
CS3b	1,861	727	1,133	425

[1] Thousands of Rupiah
[2] Referred to cassava monocropping as baseline.

trees that provide income might increase the profitability of hedgerow intercropping. Hedgerows may delineate borders or prevent slippage of fertile soil on slopes. These benefits were not tested in the current series of experiments, however.

Analysis and comparison of the systems

Despite the advantages in growing extra marketable yield, leguminous green manures in which most of the extra N_2 fixed was exported in produce did badly in this analysis. Mungbean at Khon Kaen, for example, fixes about half the amount of N fixed by groundnut (Toomsan *et al.*, 2000) and leaves little extra N behind. Consequently the residual benefit to the rice crop was small and the overall economic benefit of the mungbean was more negative than any other pre-rice crop including *Sesbania*, which does not yield marketable produce. Vityakon & Keerati-Kasikorn (1987) and Craig (1985) also concluded that labour demand is a crucial factor in determining the degree to which growing a minor field crop before rice will be practised. Crops can also be grown after rice but the low probability of rainfall allows this practice only in soils with a high residual moisture.

One conclusion emerging from the research at Khon Kaen is that crop mixtures can be tailored to the system requirements. The *Sesbania*/multi-purpose cowpea mixture gave a very healthy return on investment, combining both a valuable product with a large residual effect on the food crop. Interestingly a part of the benefit of mixtures may derive from the mixed N-release from the crop residues. Vityakon *et al.* (2000) have discussed this in terms of synchronising the release of nutrients from the residues with the time when the food crop has most need of it.

In economic terms, systems including sequential leguminous crops proved to be the most profitable of all systems studied. All the farming systems considered here are costly in some sense, but the costs of the additional cropping are chiefly labour, reducing a farmer's need for credit in order to pay for capital-intensive options such as fertilizer. The greatest yields, however, inevitably required maintenance applications of fertilizer e.g. P, K and micronutrients.

Labour demands are tricky to estimate and this is reflected in some of the disparities in the days of work a task takes between the two sites (Tables 3 and 4). The differences should be regarded as a measure of the error to be attached to our estimates of costs and thus net profit. Labour costs are different too; a day's labour has been costed at US$ 1 in Indonesia but US$ 4 in Thailand. Such a difference affects the analysis and conclusions greatly and partly explains why the groundnut system is profitable in Indonesia but not in Thailand. Prices were more uniform: groundnut in 1996 could sell for 40 cents in Indonesia and 32 cents in Thailand.

The cowpea is multi-purpose in the sense that if the growing season is too short to provide grain yield, the pods can also the sold as a vegetable. This flexibility is a valuable characteristic for farmers in the region. A recent development is the sale of fresh-pod groundnuts as a vegetable. The gross return of such a crop is about 516–1275 US$ ha^{-1} and a net return of 59–696 US$ ha^{-1} has been reported (Ittipongs, 1999; at 1996 exchange rates).

Realistically the price of the multi-purpose crops is unlikely to be sustained in

Thailand. The benefit of groundnut in the rotation was better at Lampung than at Khon Kaen and may be a good indicator of the potential value to farmers of secondary leguminous crops.

Acknowledgement

We are grateful to the European Union for financial support under the Scientific and Technical Developments programme third phase grant number TS3*CT94–0261

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