R7212: Incorporating local and scientific knowledge in the adaptation of intercropping practice for smallholder rubber lands

A Final Technical Report on a Research Project Funded by the Department for International Development's Plant Science Research Programme

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Executive Summary

This report presents the results of a study to assess the potential for adoption of intensified banana/rubber intercropping on smallholdings in Sri Lanka. The study was located within two agro-climatic zones, the Wet and Intermediate zones, which encompass the widest possible range of socio-economic and climatic conditions under which rubber is grown in Sri Lanka. Rubber is grown extensively in the Wet zone and to a more limited extent in the drier regions of the Intermediate zone where livelihoods are largely rural based and chena cultivation still predominates.

On-farm trials confirmed the advantages of high density intercropping on growth of rubber and banana. Growth and foliar nutrient content of rubber in the high density banana/rubber intercrop indicated that the benefits of intercropping on rubber could not simply be explained by improved access to soil nutrients when fertiliser was applied to the component banana intercrop. Instead, gas exchange studies implicated a role for the beneficial effects of shade in the intercrops, alleviating high radiation stress thereby allowing leaves to maintain a positive CO_2 fixation for a greater duration of the day. In addition to the benefits of intercropping on early growth of rubber, our studies have also shown that intercropping results in long-term benefits in terms of earlier and higher latex yield returns.

Discounting analysis showed that whilst rubber and banana may not be as profitable as other crops such tea and pepper, the majority of smallholders preferred to cultivate them because of the low cost of establishment. Smallholders stated a clear preference for rubber due to its relatively low demand in terms of labour inputs (458 labour days ha^{-1} compared with 1184 total labour days ha^{-1} for tea). In addition, banana is very popular with smallholders because it is a highly flexible crop that has no particular seasonal demands for activities such as weeding, harvesting etc.

Full-time farmers, particularly the land poor in the Intermediate zone where infrastructure is less well developed than in the Wet zone, were identified as having the greatest potential

to benefit from high density rubber intercropping. The major constraint to uptake being access to effective extension information and advice.

Traditionally, the performance of smallholder rubber has been considered inferior to that produced by the estate sector and governments have attempted to raise productivity by promoting monoculture-based plantation practice. The outputs of this project show this approach to be severely misguided and in the case of smallholders, rubber-based intercropping systems can be developed that are not only compatible with, but also improve the productivity of traditional systems. High density intercropping of rubber offers a win win scenario; rubber can be successfully integrated with traditional cropping systems to provide many benefits to smallholders including earlier and greater latex yield, an additional income from the intercrop and better security of subsidy payments and property rights. Indirect benefits to soil fertility and stability will also accrue from the introduction of trees to traditional annual and perennial cropping systems.

Recommendations

This project successfully achieved all four outputs, culminating in the production of a new extension leaflet and identification of target farmers based on a detailed rural livelihoods analysis. Recommendations for follow-up work focus mainly on wider dissemination of the project outputs. Suitable sources of funding will be sought for:

- Development of pictorial extension material for smallholders in remote rural communities where access to extension services is limited.
- Publication of research outputs including internationally refereed journals, a book and website.
- Continued monitoring of uptake of rubber intercropping, particularly in the Intermediate Zone of Sri Lanka, and completion of data collection from long-term on-farm field trials.

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Background

Identification of Demand

Traditionally plantation crops, such as rubber, have occupied an important position in the economy of many Asian countries, not only as a major product for export but also through the provision of jobs, with natural rubber providing a major source of income to more than 20 million farmers world wide, the majority of whom are low income and land-poor. Approximately 90% of the world's natural rubber is produced in Asia with more than 80% of this is now produced on smallholdings, many of which are less than 2 acres. Rubber cannot be tapped during the first five or six years of growth and smallholder farmers are faced with an initial gap in their income after replanting, which can only partially be filled by the rubber subsidy. One means of alleviating this problem is to grow shorter duration annual and perennial crops, for cash or subsistence. This project built upon earlier agronomic (R5058) and socio-economic (R7002) studies, which showed the potential improvements that may be made to income and land-use efficiency through intercropping, particularly at higher densities. Adopting a participatory approach, the aim of the project was to assess the potential for adoption of high density intercropping on immature rubber lands, with the view of updating extension recommendations and practices based on smallholders needs and conditions.

Rubber Intercropping and Rural Livelihoods

Rubber provides an extremely important source of income for the poor in Sri Lanka as it can prevent those who are hovering on the poverty line (as locally defined by the Samurdhi programme) from falling below it (Janowski, 1997). Even households whose income placed them below the poverty line were found to grow some rubber on their homestead plots (Janowski, 1997).

Consequently, any means of increasing the efficiency of land use during the immature phase of rubber, would appear to have relevance even to those who are considered to be very poor by village standards i.e. those with less than one acre of land. Some families, however, have such small plots that they are classed for all intents and purposes as being landless. This particularly disadvantaged group may also benefit from intercropping as they are able to contract other people's rubber land for intercropping or satisfy the increased demand for labour on intercropped land. During an earlier survey (R7002), three individuals were interviewed who had started out with no land and had managed to do well enough through contracting immature rubber land for intercropping with banana, to lift themselves out of poverty (Janowski, 1997). Thus, it is feasible that the land-poor, and even the landless, may benefit from intercropping with rubber.

A key constraint to the uptake and development of improved cropping practice on immature rubber lands is the poor quality of information available to, and being disseminated by, the extension service (Rodrigo, 1997; Gray, 1997; Janowski, 1997). Guidelines for intercropping are issued by the Rubber Development Officers who, because they are also responsible for administering the rubber subsidy, have substantial control over farming practice on immature rubber lands. Until recently, however, intercropping was not encouraged on rubber lands as it was thought that the presence of another crop could detrimentally affect the growth of rubber through competition. An earlier project (R5058) has found that this is not the case (see below).

Appropriate crops for intercropping will depend on what farmers are willing to grow and what complements, rather than competes with, rubber. Crops that are generally considered for intercropping are banana, aubergine, pineapple, passion fruit and vegetables. These crops differ widely in their production needs with, for example, estimated costs of production ca. five-fold higher for pineapple than banana (Gray, 1997). Aubergine is another capital intensive crop, requiring reasonably flat land, the setting up of expensive irrigation systems and because it is short in stature and therefore susceptible to shading by rubber it can only be grown for the first two years. It is unlikely, therefore, that crops such as aubergine will be suitable for adoption by resource-poor farmers and indeed where aubergine intercropping was found, it was done under contract by relatively affluent entrepreneurs (Gray, 1997). In an earlier survey (R5058), Rodrigo (1997) found that ca. 80% of smallholders who were intercropping with rubber had chosen banana as the companion crop and did so for two reasons. The first was because of financial sustainability resulting from the lower capital costs, ready market and high profitability. The second was that banana required relatively little attention and therefore labour requirements were low.

Present recommendations for planting density of intercropped banana, in which a single row of banana is sown between each row of rubber, is based on the performance of banana when grown as a monoculture and is designed to impose minimum risks of latex yield losses through competitive effects on rubber (Rodrigo et al. 1997). However, an on-station experiment (R5058) showed that planting density of banana could be increased three-fold over the present recommendations without any detrimental affect on growth of either component crop; in fact growth of rubber was actually improved in the intercrop (Rodrigo et al. 1997). Similar increases in component crop productivity were observed in a more extensively managed intercrop experiment in which banana received little additional fertiliser after planting (Rodrigo, 1997), suggesting that the advantages of increasing planting density may be maintained even under low input conditions. These results highlight not only the potential of intercropping for improving land use efficiency on immature rubber lands, but also the improvements that may be made to the information available to the extension service.

Project Purpose

The project addresses output 2.1 “Physiological relationship between growth/development and environmental variables understood in target crops and improved cropping strategies developed and promoted”. The project also addresses output 2.2. “The physiology of nutrient accumulation, utilisation and recycling within tree-crop based production systems understood and knowledge incorporated into improved strategies for agroforestry production”.

Research Activities

To address the project outputs a wide range of methodologies from both the natural and social sciences were employed. This report provides an overview of the methods used (with additional detail in the appendix) and the reader is referred to the publications of Senevirathna (2001) and Thennakoon (2002) for further details.

Study sites

The present study was restricted to villages in the Wet and Intermediate Zones of Sri Lanka where rubber has been grown for more than a century or its cultivation has recently expanded (i.e. in the last 10 years), respectively. Table 1 shows the districts and villages selected for the study in each agro-climatic zone. With respect to the two villages in Intermediate Zone, *Pallekiruwa* was less developed infrastructurally but was agriculturally more productive than the village of *Bookandayaya*. In the Wet Zone, *Kobawaka* was closer to the *Colombo* main market and had limited agricultural land compared to *Pannila*.

Socio-economic analysis of smallholder cropping systems

General methodology

Field data were collected over a period of 18 months by spending periods of time living in selected villages. Stratified random sampling techniques were used to select representative sub-samples from the total number of households in each village. Households were stratified according to social status using information gathered during a population survey undertaken with the Grama Sevaka, Samurdhi officer (village root level), agricultural research officer and village leaders. A sample of 24 households were selected in each village for detailed studies, representing the largest sample that could be practically studied within the time available and at the level of detail necessary. The sample of 24 households was further stratified according to eight social groups (Appendix 1) and spatial, social and time-related data were collected using various ethnographic techniques, as detailed by Thennakoon (2002).

Table 1 Villages and the number of farmers selected from Kegalle, Kalutura, Moneragala and Hambantota districts in the Wet and Intermediate agro-climatic zones of Sri Lanka for researcher-led experiments.

Agro-climatic zone	District	Village	Number of sites
Wet zone	Kegalle	Pannila	2
	Kalutara	Kobawaka	3
Intermediate zone	Moneragala	Pallekiruwa	7
	Hambantota	Bookendaya	2

Livelihoods analysis

Participatory analysis of livelihood capital assets

Participatory techniques were used to characterise the five capital assets (*i.e.* Physical, Human, Financial, Social and Natural) of rural livelihoods in the four villages. The analysis of capital assets was based on DFID's Sustainable Rural Livelihood guidance sheets (2000), with data gathering methods developed and refined after the researchers had spent 18 months living in the community (Thennakoon, 2002). A series of "key indicators" were selected to best describe each of the five capital assets, some of which were specific to individual villages. For example, Physical assets were assessed according to key indicators such as road and transport, market, electricity, house and toilets, government buildings, agricultural instruments *etc.* Participatory analysis of capital assets began in September 2000 in the four selected villages; *Pallekiruwa* and *Bookandayaya* in Intermediate Zone and *Kobawaka* and *Pannila* in Wet Zone. Based on land availability and sources of income, eight social categories were identified (Appendix 1). Approximately 7 days were spent in each village in order to complete the study of capital assets for (i) individual villages and (ii) social categories. Capital assets were quantified as described in Appendix 1 and using the standardized % values for each asset, “livelihood pentagons” (DFID, 2000) for each village and for each of the social group were constructed.

Land and Labour

Information gathered during the population studies undertaken at the beginning of the study in each village (Thennakoon, 2002) was used to select farmers who grew specific crops of importance. Twenty four households, including a minimum of 3 households for each crop, were selected as a representative sample. Some households grew all selected crops whilst others grew only a few. Data were collected using a range of methods including population studies, seasonal calendars, semi-structured interviews, direct observations and PRAs (Thennakoon, 2002).

Market studies

In addition to the general methods describe above, semi-structured interviews, direct observations, case studies and farm sketches were used to collect data for studies of market accessibility and farm profitability. Farmers in *Pallekiruwa* and *Pannila* used the *Medagama* and *Parakaduwa* markets to sell their products and these were identified as being best representative of local markets in the Intermediate and Wet Zone, respectively. Two types of data were collected (i) market related data (*i.e.* daily, weekly and seasonal price variation and marketing channels) and (ii) data related to villages-level studies (*i.e.* information for benefit/cost analysis of major local crops). Further details can be found in Appendix 1

On-farm Trials of High Density Banana / Rubber Intercropping.

Table 1 summarises the location and number of farm sites used in the on-farm trials. Further details of the design can be found in the Appendix 1 and Senevirathna (2001). The main treatment imposed in the on-farm trials was planting density of banana, with intercrops planted in an additive series of one (RB), two (RBB) and three (RBBB) rows of banana between the rows of rubber.

The sole crop rubber was taken as the control. Planting distance for rubber was 2.4 m x 8.1 m within and between rows. The within row spacing of banana was 2.4-3.0m depending on the variety whilst the between row spacing varied with planting density; 4.05 m for the single, 2.70 m for the double and 2.03 m for the triple rows of banana. In addition to the main treatments, two fertilizer management regimes for banana were applied at the recommended rate (FER) or not at all (NFER).

Measurements included regular recordings of daily rainfall, soil and foliar nutrient analysis and non-destructive growth analysis of rubber and banana with further details provided in Appendix 1.

On-station Experiments of High Density Banana/Rubber Intercropping.

In addition to the on-farm trials results are presented from two on-station experiments. The first was established during the first phase of funding (R5058) to examine the effects of planting density of banana on growth and yield of banana/rubber intercrops. Full details of the experimental design are given by Rodrigo et al. (1997), but briefly the experiment involved three intercrops comprising an additive series of one, two and three rows of banana to a single row of rubber, resulting in densities of 500, 1000 and 1500 banana clumps to 500 rubber plants per hectare, respectively. Girth measurements of rubber were continued after the removal of banana in the fourth year and the effects of intercropping during the immature phase on long-term growth and latex yield of rubber is reported.

A second on-station experiment to investigate the effects of natural shade on physiology and growth of rubber and banana was established on the Dartonfield estate of the Rubber Research Institute of Sri Lanka (RRISL). The experiment comprised four treatments designed to provide low, medium and high shade and an unshaded control of full sunlight. Natural shade treatments were applied by selecting existing mature rubber plantations to provide an average of 33%, 55% and 77% reduction in full sunlight. The different shade levels were achieved as a result of the age and inter-row spacing of rubber, and by selective pruning of branches of mature rubber (Senevirathna, 2001). An open area close to the shaded site was selected for the unshaded control treatment (open). Both rubber and banana were planted in single rows between the existing rows of mature rubber, keeping and intra-row spacing of 3.0 m. In the unshaded control treatment, rubber and banana were planted at an intra- and inter-row spacing of 3.0 m and ca. 4.0 m, respectively. To avoid competition with the roots of the mature rubber trees used to provide natural shade and to minimise variability in rooting conditions, all experimental plants were planted in soil-filled pits lined with a double layer of polythene film of gauge 500 (Musajee Pvt. Ltd., Colombo, Sri Lanka). Soil pits were excavated to a depth of 1.0 m for banana and 1.5 m for rubber and to a diameter of 1.8 m for both. All particles greater than 14 cm^3 were removed from the excavated soil, and the pits were refilled according to the original soil profile. Measurements included non-destructive monitoring of growth together with gas exchange and chlorophyll fluorescence, with full details given by Senevirathna (2001).

Results

Agronomic and physiological processes determining intercrop performance on-farm.

Intercropping, management and fertiliser effects on growth performance of rubber and banana.

The effects of quality of management on growth performance of both rubber and banana is summarised in the Figures 1 and 2, respectively. Stem girth increment of rubber was not significantly influenced by planting density, fertiliser treatment nor agro-climatic zone, but was significantly greater ($p \leq 0.001$) in *Well* compared to *Poor* managed sites (Fig. 1a). No effect of treatment or management practice (*i.e. Well* or *Poor*) was found on relative girth increment of rubber, that is both the intercropped and sole cropped rubber performed similarly (Fig. 1b). In the case of banana, both stem basal girth and plant height at 14 MAP were significantly higher in the *Well* relative to *Poor* managed sites and in the plots where the fertiliser was applied ($p \leq 0.001$; Fig. 2).

Foliar nutrient status of rubber and banana

Foliar %P and %Mg contents of rubber were significantly higher ($p \leq 0.05$) in the IMZ whilst the %N content was higher ($p \leq 0.05$) in the WZ (Table 2). There were no differences in %K and %Ca between agro-climatic zones. Only the %N content was significantly higher ($p \leq 0.05$) in the *Well* managed sites compared to that of *Poor* managed sites; the other nutrients were unaffected by quality of management. Foliage nutrient content of rubber did not significantly differ between fertilised, non-fertilised and sole cropped main plots ($p > 0.05$). In banana only the %P content was significantly higher ($p \leq 0.01$) in the IMZ compared to that of the WZ. No differences in any of the foliar nutrients were observed in either fertilised and non-fertilised treatments or the *Well* and *Poor* managed sites (Table 2). However, the summary of the development of banana plants used for sampling for the foliar nutrient analyses showed significantly higher (p≤0.05) plant height, stem basal girth, number of leaves and leaf area per plant in the *Well* managed and fertilised plants.

Table 2 Summary of the statistical analysis of the effects of agro-climatic zone (ZONE), *Well* or *Poor* management (MANG), fertiliser application to banana (FER) and their interactions on foliar nutrients; nitrogen (N), phosphorus (P), potassium (K), magnesium (Mg) and calcium (Ca) of rubber and banana in the treatment with triple rows of banana between the rows of rubber. Probability values are shown and emboldened where effects are significant at p≤0.05 level and CV is the coefficient of variation (%).

Source of variation	**N**	**P**	**K**	**Mg**	**Ca**
Rubber					
ZONE	**0.017**	**0.048**	0.279	**0.006**	0.672
MANG	**0.025**	0.601	0.866	0.572	0.226
FER	0.403	0.381	0.321	0.134	0.791
ZONE x MANG	0.967	**0.036**	0.806	0.891	**0.047**
ZONE x FER	0.404	0.559	0.896	0.180	0.770
MANG x FER	0.801	0.673	0.285	0.327	0.587
%CV	7.4	11.1	24.8	16.6	29.2
Banana					
ZONE	0.230	**0.003**	0.148	0.935	0.333
MANG	0.069	0.332	0.638	0.289	0.082
FER	0.409	0.224	0.258	0.400	0.228
ZONE x MANG	0.851	0.526	0.749	0.415	**0.040**
ZONE x FER	0.554	0.141	0.394	0.405	0.444
MANG x FER	0.702	0.136	0.086	0.198	0.863
%CV	13.9	10.8	5.7	22.5	22.5

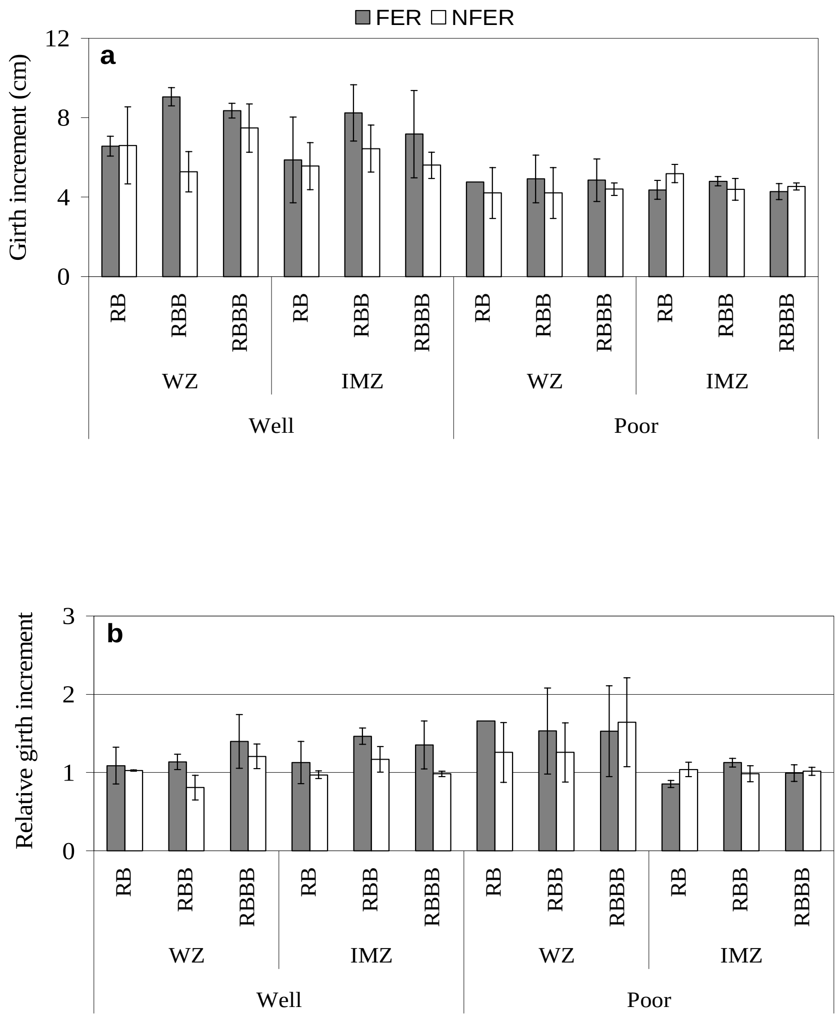

Figure 1 Growth performance of rubber on-farm where (a) is the stem girth increment (measured at a height of 10 cm from the ground) over a 10 month period and (b) is the girth increment relative to the girth increment of sole crop rubber in well (*Well*) and poorly (*Poor*) managed rubber/banana intercrops where RB, RBB and RBBB respectively refer to the single, double and triple rows of banana planted between rubber rows in the wet zone (WZ) and in the intermediate zone (IMZ) of Sri Lanka. FER and NFER represent respectively the sub-plots in which banana was either fertilised or not fertilised. Data represent means ± s.e.m. of an average of 45 and 81 replicate plants per treatment respectively from the WZ and IMZ, and 3 and 4 *Well*, and 2 and 5 *Poor* managed experimental sites in the WZ and IMZ respectively.

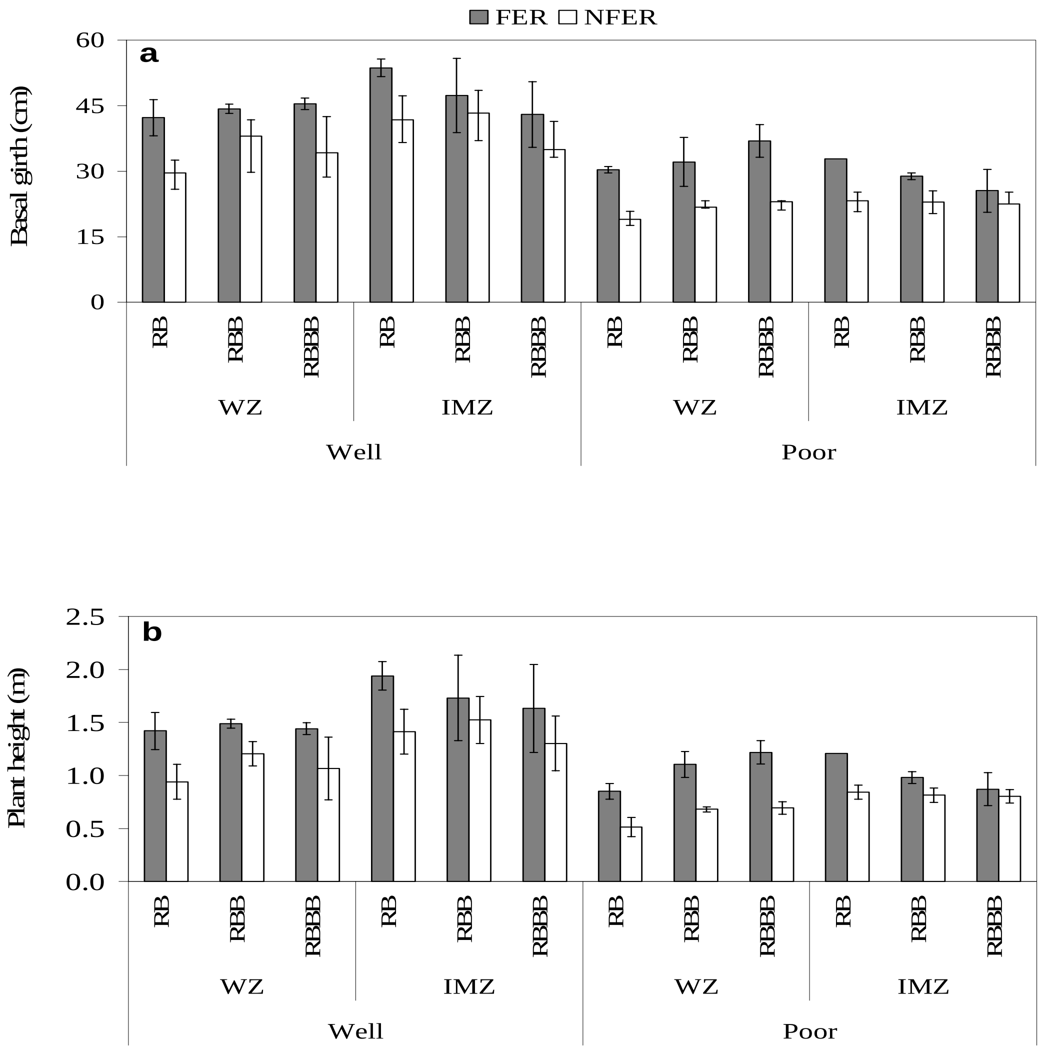

Figure 2 Growth performances of banana on-farm where (a) is the stem basal girth (measured at a height of 10 cm from the ground) and (b) is the plant height at 14 months after planting in well (*Well*) and poorly (*Poor*) managed rubber/banana intercrops farmer fields where RB, RBB and RBBB respectively refer to the single, double and triple rows of banana between two rows of rubber in the wet zone (WZ) and in the intermediate zone (IMZ) of Sri Lanka. FER and NFER represent respectively the sub-plots in which banana was either fertilised or not fertilised. Data represent means ± s.e.m. of an average of 135 and 243 replicate plants per treatment respectively from the WZ and IMZ, and 3 and 4 *Well*, and 2 and 5 *Poor* managed experimental sites from WZ and IMZ respectively.

Effect of shade on photosynthetic performance of rubber and banana

Gas exchange and chlorophyll fluorescence (Fv/Fm) were measured both on-farm and on-station to determine whether the benefits of intercropping could be explained in terms of the beneficial effects of shade on photosynthetic performance. Values of Fv/Fm for both rubber and banana showed a clear depression during the central hours of the day, followed by a recovery towards evening on both clear and overcast days, although the effect was more marked on clear days and in plants grown under full sunlight (Fig. 3). Midday depression of Fv/Fm corresponded with a midday increase in PPFD under both clear and overcast days. Diurnal values of Fv/Fm were always highest in the shaded than unshaded plants ($p<0.05$). The results suggest that photoinhibitory depression of photosynthetic efficiency is less under shaded than clear sky conditions and by implication less in intercropped than sole cropped rubber and banana.

According to the light response curves of photosynthesis measured under on-farm conditions (Fig. 4), intercropped rubber showed higher rates of photosynthesis over the full range of light levels. Differences between intercropped and sole cropped rubber were greatest until high light conditions, and were marginally but consistently higher for crops grown in the Wet than Intermediate Zone. This, together with the diurnal trends in Fv/Fm of shaded and unshaded rubber suggests that the overall benefits of intercropping derive, at least in part, from the beneficial effects of shade in terms of alleviating high radiation stress.

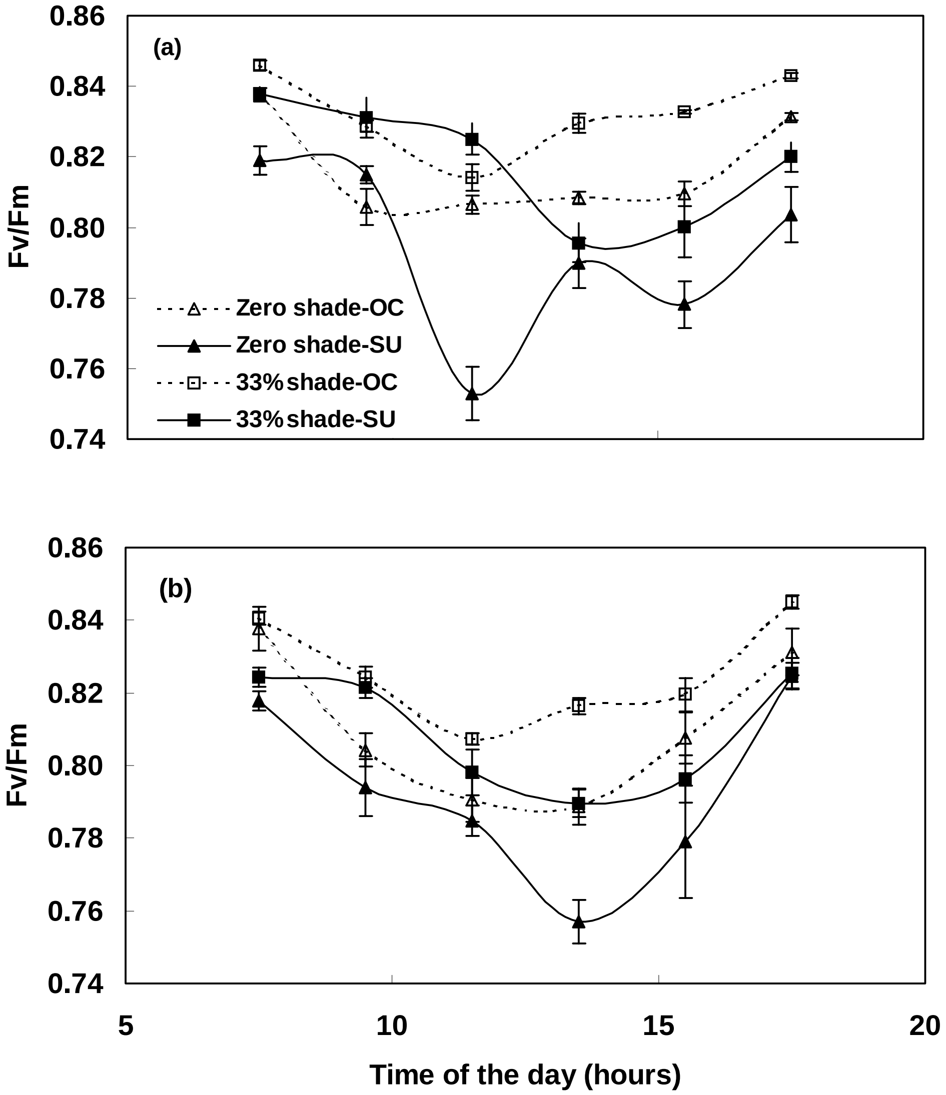

Figure 3 Diurnal variation in F_v/F_m of (a) rubber and (b) banana plants grown under full sunlight (sole crop) and 33% natural shade in an on-station experiment (Senevirathna, 2001). Data represent the mean values ±SE of 5 replicate plants measured on sunny (SU) and overcast (OC) days.

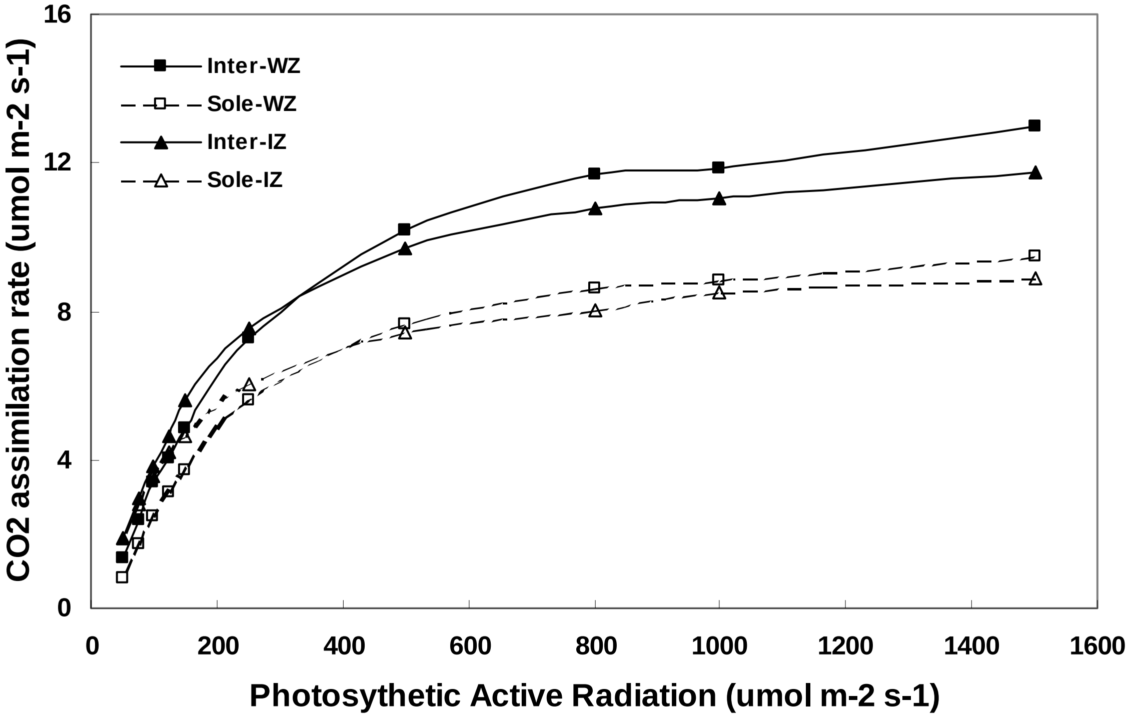

Figure 4 Effect of different environmental conditions on photosynthetic productivity of rubber grown on-farm. Treatment codes are; Inter and Sole represent the plants grown as rubber/banana intercrop and sole crop, respectively, whilst WZ and IZ refer to on-farm trials in the Wet and Intermediate Zones, respectively. Each data point represents the mean of six sets of measurements taken on two plants over two days with three diurnal sets.

Effects of intercropping on growth and yield of mature rubber

Observations made on the on-station experiment established 1993 are summarised here. Vigorous growth was achieved in all treatments as shown by the fact that girth of most trees exceeded 30 cm by 3 years (Table 3). By the end of the fourth year, the majority of trees in the intercrop treatments had girths exceeding 40 cm compared with only 15% in the sole crop. Moreover, trees in the intercrop treatments reached a tappable girth earlier than those in the sole crop. Tappable trees exceeded 60% (which is standard used for commencing tapping) before 5 years after planting in all intercrops treatments, whereas the sole crop rubber required an additional 4 months (Table 3). Averaged over a period of one year and over all treatments, latex yield by weight was ca. 18 g/t/t. However, yield per hectare per year was greatest at the higher densities in the intecrops due to a higher number of tappable trees (Fig. 5).

Table 3 Summary of long-term treatment effects on growth of rubber following removal of the banana intercrop at 48 months after planting. Data are shown in terms of the percentage of trees that (a) fell within a specific girth class and (b) reached tappable girth (i.e. girth > 50 cm) with months after planting. In all cases girth was measured for 40 plants per treatments and at a height of 90 cm. Treatment codes R, BR, BBR and BBBR refer to the sole crop rubber and single, double and triple row rubber/banana intercrops, respectively.

(a)

Treatment	Girth diameter (cm)	**Months after planting**								
		34	38	42	44	47	51	60	64	72
R	<30	100	80	27.5	10	0	0	0	0	0
	30 – 35	0	20	67.5	65	20	2.5	0	0	0
	35 – 40	0	0	5	25	65	27.5	2.5	0	0
	40 – 45	0	0	0	0	15	62.5	15	5	0
	45 – 50	0	0	0	0	0	7.5	57.5	32.5	2.5
BR	<30	90	40	5	2.5	0	0	0	0	0
	30 – 35	10	52.5	52.5	15	5	2.5	0	0	0
	35 – 40	0	7.5	35	67.5	30	2.5	0	0	0
	40 – 45	0	0	7.5	15	55	50	2.5	2.5	0
	45 – 50	0	0	0	0	10	37.5	22.5	10	2.5
BBR	<30	97.5	40	0	0	0	0	0	0	0
	30 – 35	2.5	57.5	62.5	22.5	0	0	0	0	0
	35 – 40	0	2.5	35	65	47.5	10	0	0	0
	40 – 45	0	0	2.5	10	47.5	57.5	0	0	0
	45 – 50	0	0	0	2.5	5	30	35	17.5	5
BBBR	<30	97.5	45	2.5	0	0	0	0	0	0
	30 – 35	2.5	50	62.5	32.5	2.5	0	0	0	0
	35 – 40	0	5	35	62.5	47.5	15	0	0	0
	40 – 45	0	0	0	5	47.5	47.5	5	2.5	0
	45 – 50	0	0	0	0	2.5	37.5	32.5	12.5	2.5

(b)

Treatment	**Months after planting**								
	34	38	42	44	47	51	60	64	72
R	0	0	0	0	0	0	25	62.5	97.5
RB	0	0	0	0	0	7.5	75	87.5	97.5
RBB	0	0	0	0	0	2.5	65	82.5	95
RBBB	0	0	0	0	0	0	62.5	85	97.5

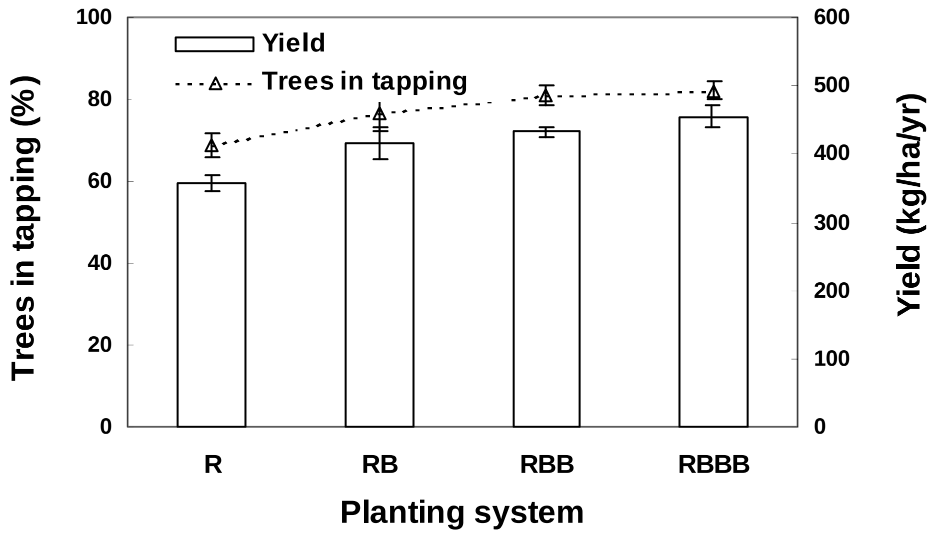

Figure 5 Treatment effects on overall tappability of rubber trees (i.e. % of trees that had reached maturity in treatment plots) after six years growth and the initial annual yield (i.e. first year of tapping). Treatment codes R, RB, RBB and RBBB refer to the sole crop rubber and single, double and triple row rubber/banana intercrops, respectively and bars represent ± Standard Error of the mean of four replicate plots.

Socio-economic and cultural factors influencing smallholder cropping systems, with special reference to rubber.

Association between crops grown by smallholders and land use/ownership.

Within the area under consideration, most crops were grown on privately owned land. Rubber was the only permanent crop grown on crown lands, particularly those abandoned after chena cultivation where it offers an environmentally friendly means of reclaiming forested land that has been cleared for chena cultivation. Paddy was grown on a shared basis due to a lack of suitable low-lying land in the area of study (Fig. 6).

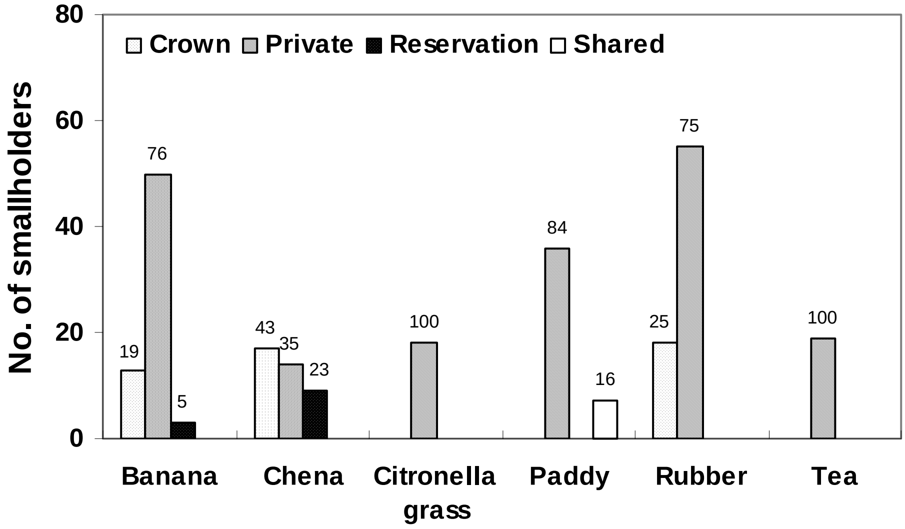

Figure 6 Crops commonly grown by smallholders according to different land-use/ownership systems in the four villages of the Wet and Intermediate Zone. Data labels show the percentage values for each type of land-use type under each crop. Reservations are protected by law and shared systems refer to joint ownerships where cultivation is undertaken by one person at a time or on a shared basis.

Factors influencing decisions to cultivate rubber and rubber-based intercrops

The main reason given by smallholders for cultivating rubber was that it provides a long-term secure income (Fig. 7). Furthermore in the Intermediate Zone, the rubber crop helps to secure land ownership as it serving as a permanent crop on abandoned crown lands after shifting cultivation or preventing others from encroaching lands owned by smallholders. The low international price of rubber was the main reason for not wishing to cultivate rubber, particularly in the Wet Zone.

Smallholders stated that the main benefits that attracted them to intercropping were the supplementary income provided during the immature phase of rubber, ease of weed management and conservation of surface soil moisture, provided that a good market for the produce exists and the rubber land is close by (Fig. 8). In addition, availability and suitability of land for more intensive cropping and farmers' priority for off -farm activities were important determinants of intercropping practices.

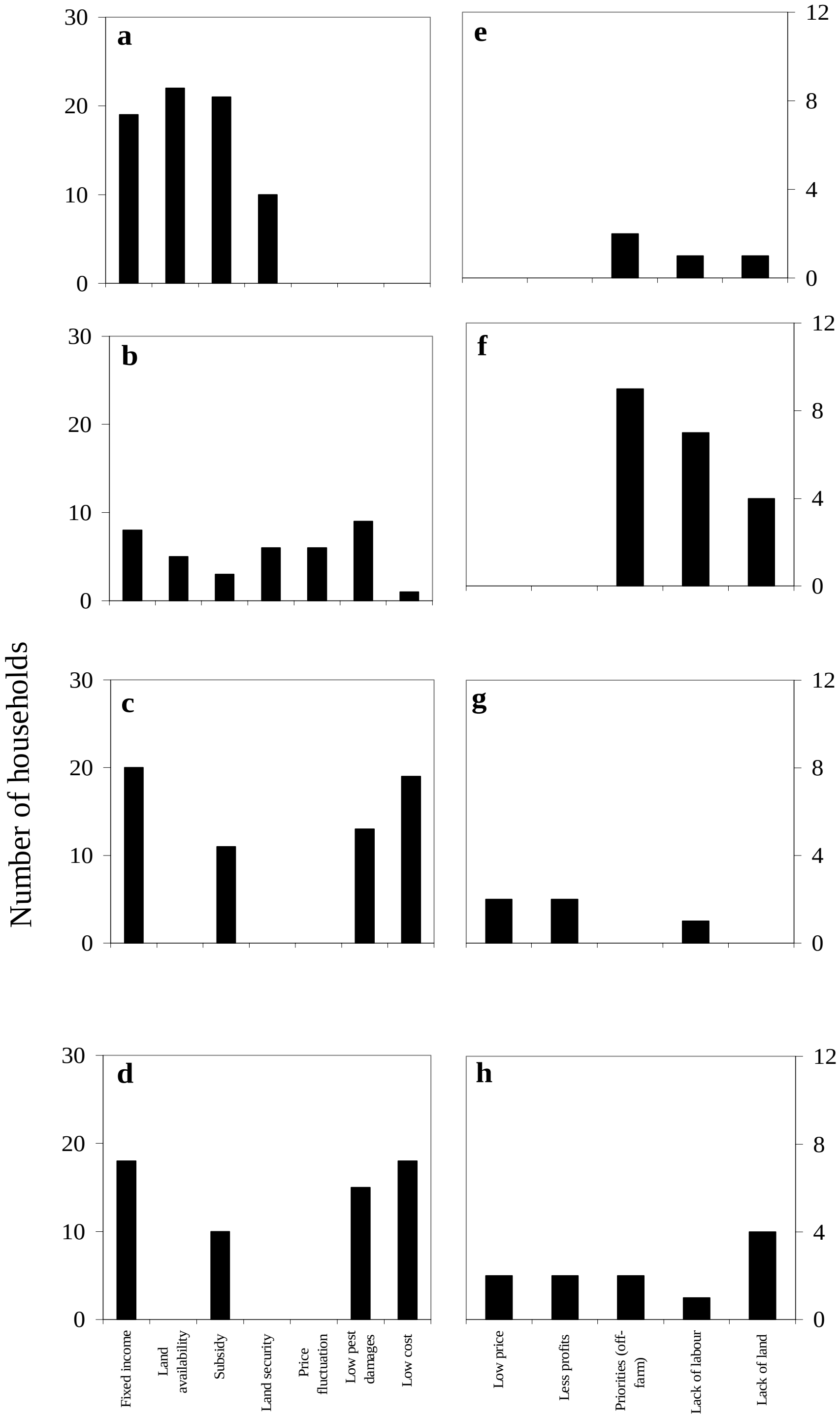

Figure 7 Reasons for adoption (a-d) and non-adoption (e-h) of rubber in the villages of Pallekiruwa (a & e), Bookandayaya (b & f), Kobawaka (c & g) and Pannila (d & h). Data are presented in terms of the number of respondent households under each category of reasons of the total of 24 interviewed in each village.

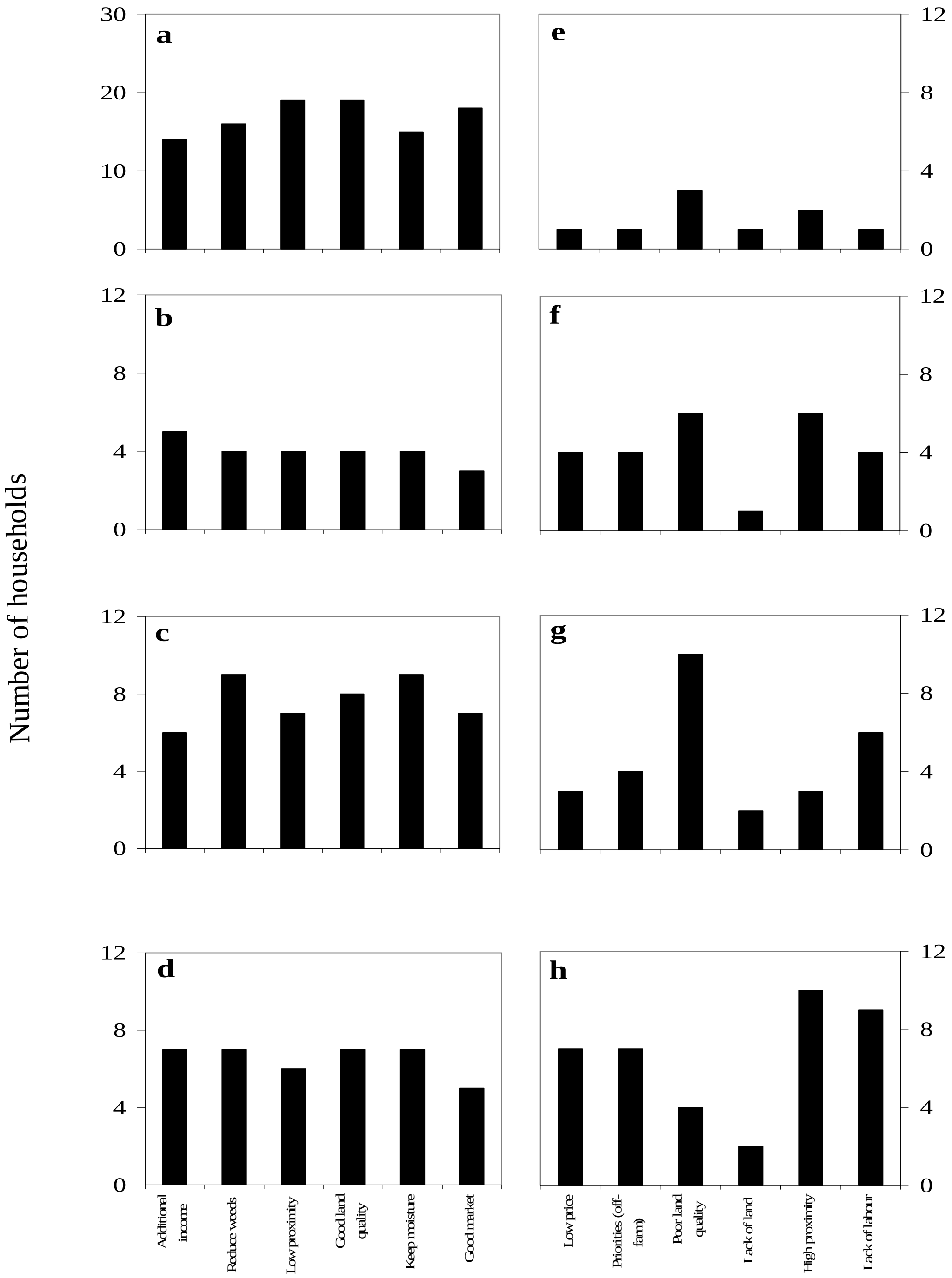

Figure 8 Reasons for adoption (a-d) and non-adoption (e-h) of rubber based intercropping in the villages of Pallekiruwa (a & e), Bookandayaya (b & f), Kobawaka (c & g) and Pannila (d & h). Data are presented in terms of the number of respondent households under each category of reasons of the total of 24 interviewed in each village.

In the wet zone of the country, tea is a major competitor of rubber for land, however rubber appeared to be the crop of choice for resource-poor farmer, with more rubber smallholders falling in to 'Very low' and 'Low' income categories compared with tea growers (Fig. 9).

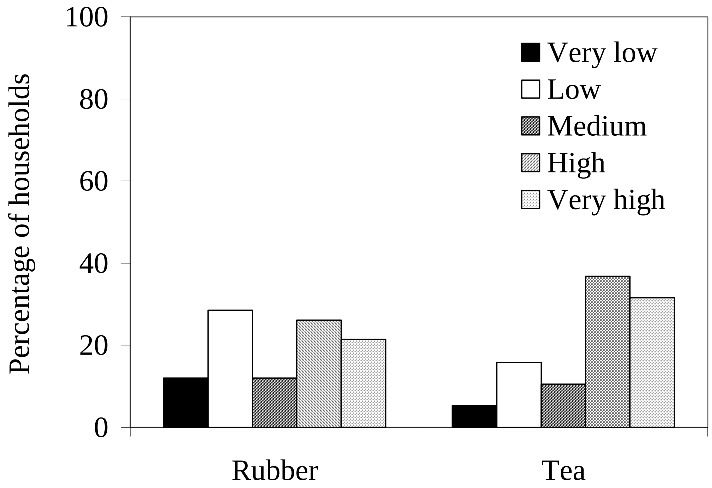

Figure 9 Distribution of rubber and tea smallholdings according to income group, where data are presented in terms of the percentage of the total number of rubber (42) and tea (19) growers sampled in the villages of *Kobawaka* and *Pannila* in the Wet Zone of Sri Lanka.

Labour-use in rubber and associated crops

An analysis of labour-use for different cultivation activities on rubber smallholdings showed that farmers depended both on family labour and hired labour (Thennakoon 2002). However, in the more remote rural areas (e.g. *Pallekiruwa*) where the labour market was not highly developed, shared family labour was predominantly used in cultivation. Though there is no direct financial gain to individuals in the shared labour system, it provides a reasonable opportunity cost for labour within the rural context. In comparison with tea, labour demands and hence labour costs were less for rubber for all phases of growth (Fig. 10).

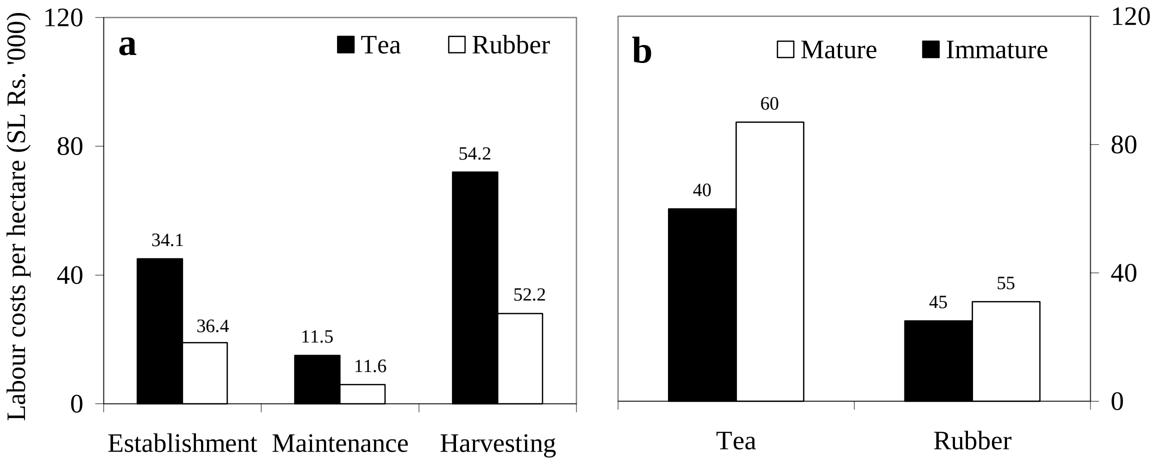

Figure 10 Labour costs per hectare for tea and rubber where (a) is the labour cost according to cultivation activity and (b) is the labour cost during immature and mature upkeep of the plantation. Numbers at the top of the histograms represent the % labour inputs, in terms of labour days, of the total required for tea and rubber.

Financial analysis of crops in smallholder context

A financial analysis was undertaken to compare the profitability of rubber cultivation with that of tea (Fig. 11). As shown by the Net Present Value (NPV), it was clear that overall profitability of growing rubber was well below that of tea, even under the condition where material cost was ignored. Unlike tea growers, all rubber smallholders have the potential to qualify for a subsidy payment from the government (i.e. ca. Rs. 50,000 per hectare, Rs 123 = £1, February, 2002) under which all materials (i.e. plants and fertilizer) during the immature phase are supplied. In contrast, tea smallholders have no subsidies and so have to bear all costs. Being a low cost crop (i.e. ca. 1/3 of the cost for tea), rubber has the advantage over tea in that it is suitable for low-income smallholders, as shown previously in Figure 9. Moreover, among the crops commonly grown by smallholders, the cost of harvesting rubber is greater than only banana, the other low-input smallholder crop (Fig. 12). Both rubber and tea crops have a well-developed marketing system and farmers seldom bear significant costs in terms of transport of produce to the market. Other crops such as pepper, arecanut and banana involve relatively greater costs to transport items for marketing.

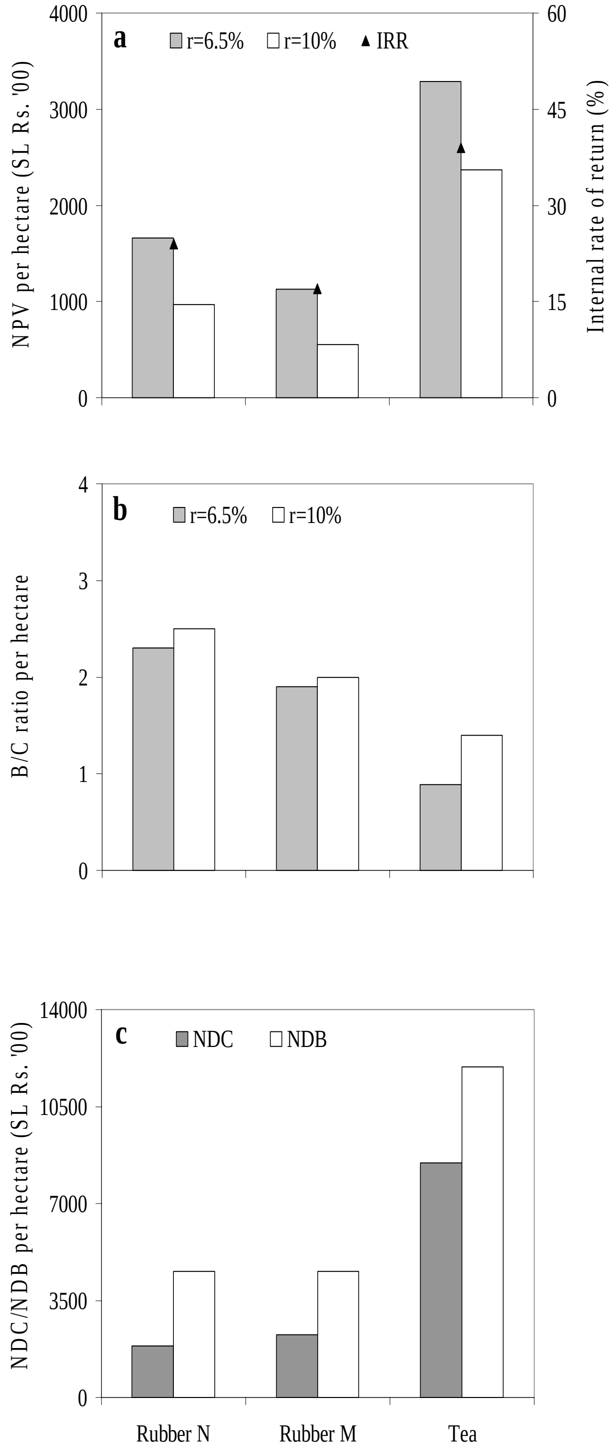

Figure 11 Financial appraisal of rubber where material costs have either been excluded (rubber N) or included (rubber M) and tea expressed in terms of the (a) Net Present Value (NPV) and the Internal Rate of Return (IRR), (b) Benefit/Cost ratio (B/C) at two discount rates (r) of 10 and 6.5% and (c) Net Discounted (at 10%) Benefit (NDB) and Cost (NDC).

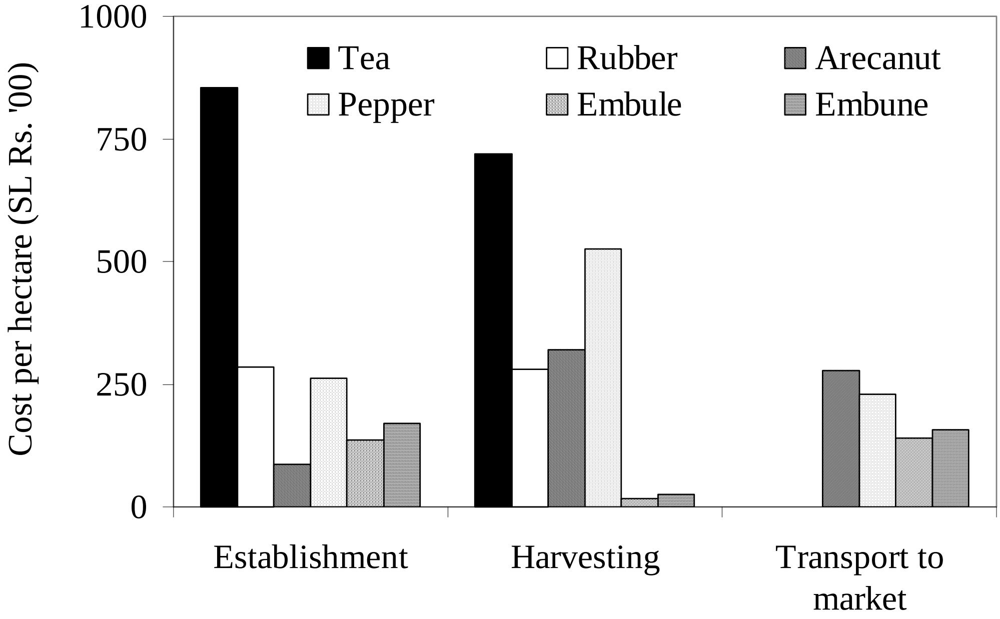

Figure 12 Average costs (including labour and material) involved in major crop activities, i.e. initial crop establishment, harvesting and transport of produce to the nearest market. Embule and Embune are local names for different banana varieties.

Overview of capital assets of smallholders in different rubber growing areas and social groups

Analysis of capital assets indicate that all four rubber growing communities were relatively well-endowed with Natural and Human assets and least well–endowed with Social assets (Fig. 13). Compared with the major rubber growing areas, minor and urban areas in the Wet Zone of Sri Lanka were most lacking in social assets, whereas Social assets were greatest in the Intermediate Zone . The biggest drawback to development in the Intermediate Zone (rural sector) was the lack of infrastructure, as shown by the relatively poor level of Physical assets. Financial assets were also most lacking in this area. In the urbanised areas of the Wet Zone, priorities were for off-farm activities, which provided more lucrative returns and so agriculture, including rubber cultivation has increasingly become marginalized.

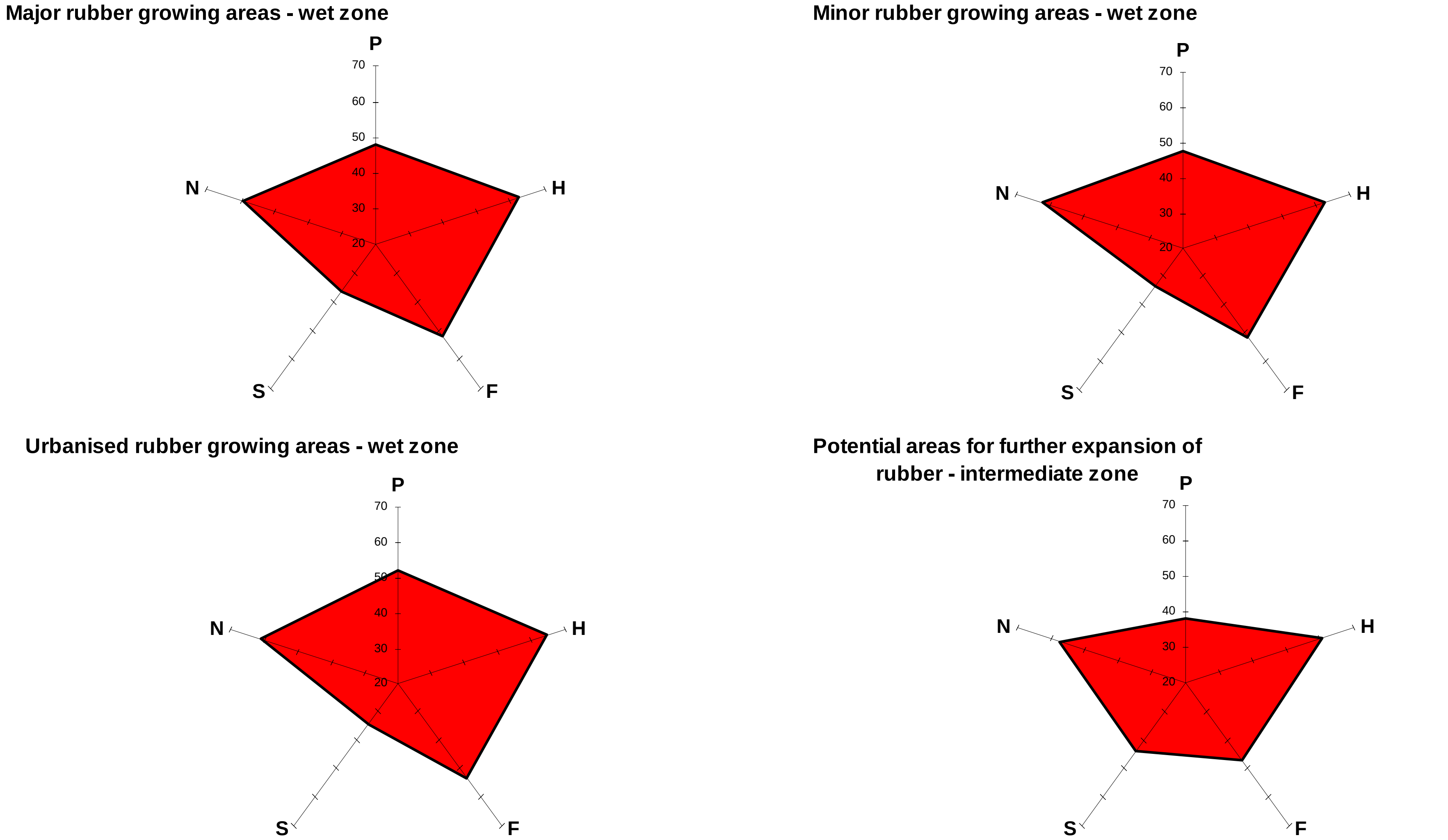

Figure 13 Summary of livelihood capital asset pentagons for four main rubber growing communities in Sri Lanka. Data were gathered from interviews with 697 smallholder farmers in 9 administrative districts of Sri Lanka. The five main capital assets are: Physical (P), Human (H), Finacial (F), Social (S) and Natural (N).

In general, total capital assets of rubber growers were greater than that of non-rubber growers, largely due to the better levels of Natural and Financial assets. Although total assets were comparable amongst smallholders growing rubber as either a sole crop or intercrop, Social assets of intercroppers were greater, and Physical assets less than that of sole croppers. The poorer level of physical assets of intercroppers compared to non-intercroppers reflected the lower level of infrastructural development in the more remote rural areas where farming was a full-time activity and maximum returns from the land (such as through intercropping) were a priority. Despite the lower level of infrastructural development, however, financial assets of rubber intercroppers were similar to those of sole rubber growers (the majority of whom were part-time farmers) and greater than those of non-rubber growers (Fig. 14). This suggests that intercropping of rubber can contribute significantly to financial assets, as observed in previous case studies of smallholder farmers (Rodrigo et al. 2001).

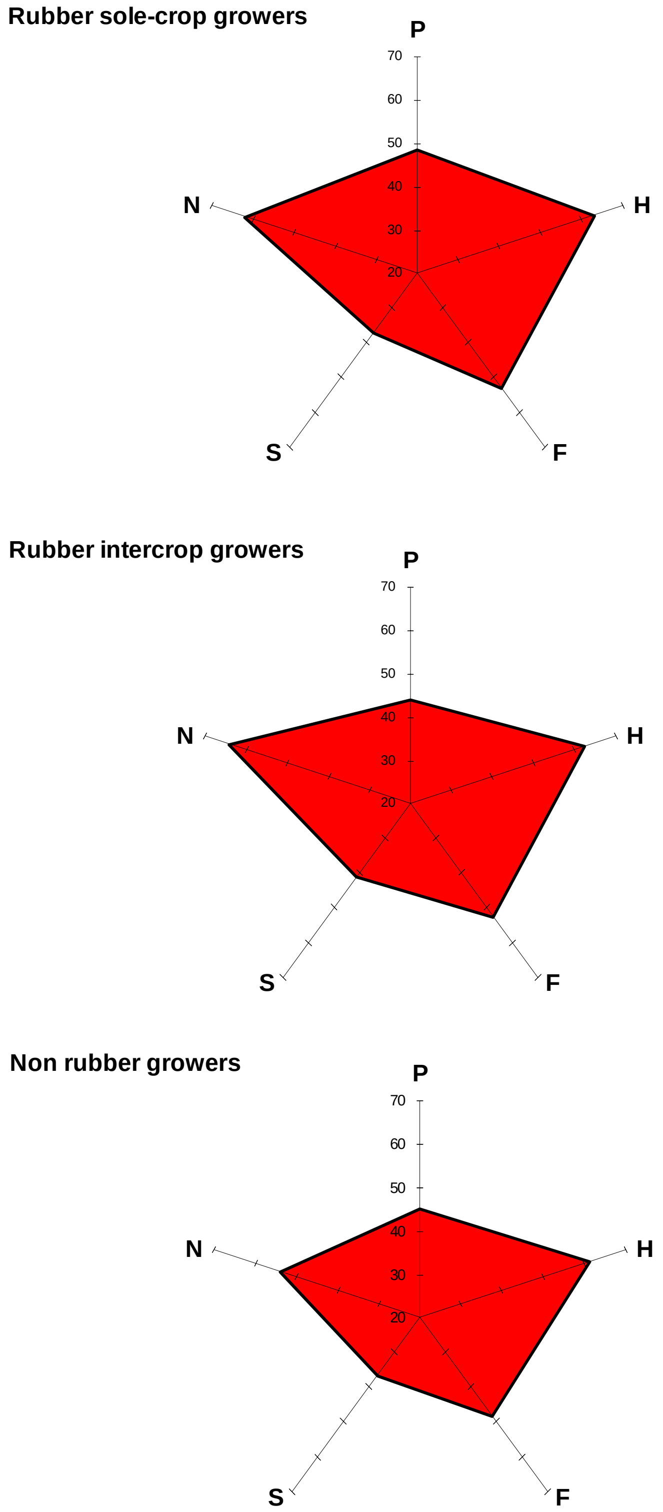

Figure 14 Livelihood capital assets of smallholders farmers cultivating rubber either alone or as an intercrop compared with non-rubber growers. Data were gathered from interviews with 697 smallholder farmers in 9 administrative districts of Sri Lanka. The five main capital assets are: Physical (P), Human (H), Financial (F), Social (S) and Natural (N).

Physical assets did not vary much between social groups these assets generally depend on the locality and to a lesser extent on the status of the individual household (Fig. 15). Although it may be expected that social participation of the poorer members of the community is less than that of others, this was not observed in the present study. Natural assets were closely associated with land availability, hence families belonging to social groups with > 2 acres had the greatest level of Natural assets. It was clear that off-farm activities generally provided a better income than farming, hence households who were only partially dependent on agriculture had a greater level of Financial assets. However, if the land owned was > 2 acres then financial assets were comparable to those of part-time farmers, confirming that agriculture is capable of providing a significant income within the rural context. The number of family dependants had no great influence on capital assets.

Rubber smallholders belonged to a wide range of social groups, but a greater percentage belonged to social groups with > 2 acres and who were full-time farmers (Fig.16). This may reflect the often-stated advantage of growing rubber that it helps secure land property rights. Land availability refers to the total extent of land available to the household and not all of this is planted with rubber. The majority of farmers practising rubber intercropping were full-time farmers with more than 2 acres of land. When land availability was limited to less than 2 acres the tendency was to cultivate crops other than rubber, particularly in the case of part-time farmers.

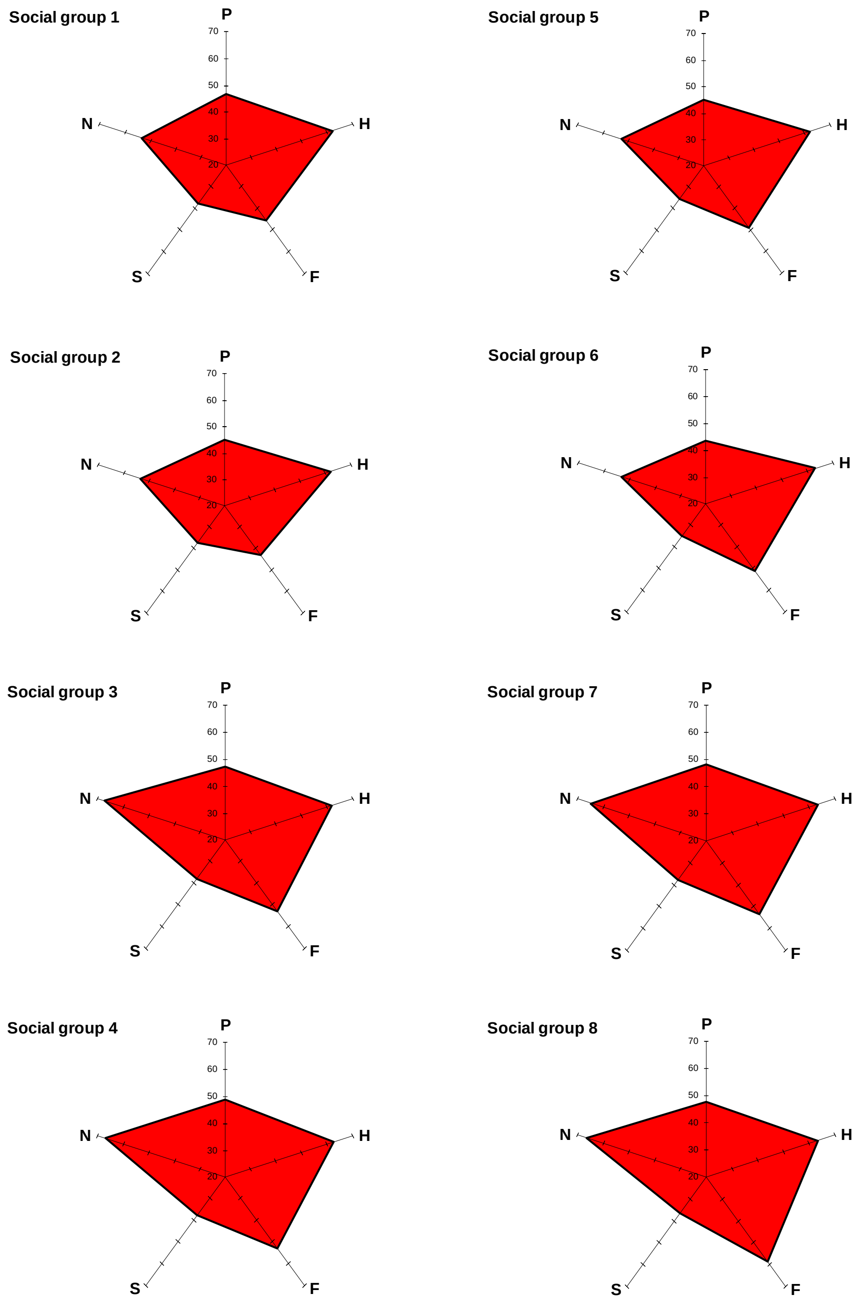

Figure 15 Livelihood capital assets of different social groups in rubber growing areas of Sri Lanka. Data were gathered from interviews with 697 smallholder farmers in 9 administrative districts of Sri Lanka. The five main capital assets are: Physical (P), Human (H), Financial (F), Social (S) and Natural (N).

Codes for the social groups are; households with 1) Fulltime farmers with ≤ 2 ac and with ≤ 3 family dependants, 2) Fulltime farmers with ≤ 2 ac lands and with > 3 family dependants, 3) Fulltime farmers with > 2 ac lands and with ≤ 3 family dependants, 4) Fulltime farmers with > 2 ac lands and with > 3 family dependants, 5) Part-time farmers with ≤ 2 ac lands and with ≤ 3 family dependants, 6.) Part-time farmers with ≤ 2 ac lands and with > 3 family dependants, 7.) Part-time farmers with > 2 ac lands and with ≤ 3 family dependants, and 8.) Part-time farmers with > 2 ac lands and with > 3 family dependants.

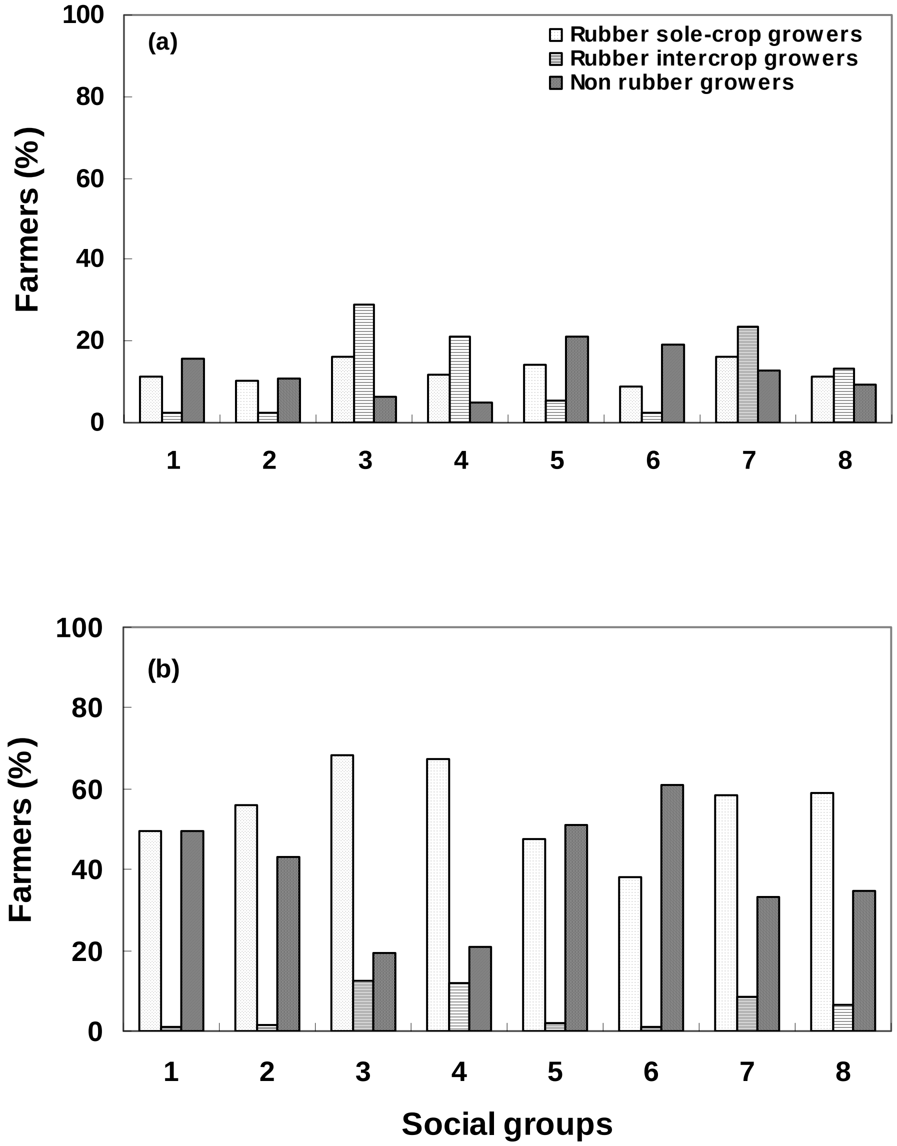

Figure 16. Distribution across social groups of farmers practising rubber-based and non rubber-based cropping systems. Data are presented as (a) the % distribution across all social categories and (b) % distribution within an individual social group with a total of 697 farmers interviewed in 9 administrative districts of Sri Lanka.

Contribution of Outputs

Traditionally, the performance of smallholder rubber has been considered inferior to that produced by the estate sector and governments have attempted to raise productivity by promoting monoculture-based plantation practice. The outputs of this project show this approach to be severely misguided and in the case of smallholders, rubber-based intercropping systems can be developed that are not only compatible with, but also improve the productivity of traditional systems. High density intercropping of rubber offers a win win scenario; rubber can be successfully integrated with traditional cropping systems to provide many benefits to smallholders including earlier and greater latex yield, an additional income from the intercrop and better security of subsidy payments and property rights. Indeed the greatest interest in uptake of rubber intercropping was amongst full-time farmers in the Intermediate Zone of Sri Lanka, one of the poorest regions of the country. Furthermore, indirect benefits accrue from the introduction of trees to traditional annual and perennial cropping systems where soil fertility and erosion are a major limitation to productivity.

Dissemination Activities

Dissemination Workshop

An end of project workshop was held over two days during 2-3 April 2001 at the training centre of the Rubber Development Department of Sri Lanka. The workshop involved morning discussion groups and afternoon field trip and participants included farmers, extension and technical staff from the rubber producing sectors of Sri Lanka. The discussion groups resulted in the production of a list of main observations and conclusions on rubber intercropping (Table 4). The following is a brief summary of the conclusions. In the Intermediate Zone, the majority of villages are remote and smallholders have few options other than to work and depend on the land for their livelihoods. Because of their dependency on the land, these smallholders cannot withstand the long immature period of rubber without an income and so intercropping on rubber lands with traditional chena crops is common place, at least for first few years. This explains the high level of interest paid by farmers to the on-farm intercropping trials in the villages of the Intermediate Zone (Appendix 2). Damage by animals was greater for trials in the Wet than Intermediate Zone and this was not because wild animals were more abundant, rather it reflected the greater interest of farmers in the Intermediate Zone (Appendix 2). Also, smallholders were emphatic about the benefits of intercropping of rubber, particularly with banana, in terms of the cooling effect on the young rubber plants resulting an improved growth. These observations were strongly supported by the physiological measurements of photosynthetic productivity made both on-farm and on-station (see Figs. 3 & 4).

Farmers preferred the two row planting system of banana over both the single and triple rows and were of the opinion that should the three row system be practised, banana clumps must be maintained/pruned properly, which is not the case for some smallholders. This is particularly important for banana varieties with large canopies such as Ambun and Anamalu. If banana was over crowded, smallholders believed that this would affect the yield of banana, but not growth of rubber.

Table 4 List of the main (a) agronomic and (b) socio-economic observations and conclusions from on-farm studies drawn up by farmers and researchers at the end of project workshop.

(a) Agronomic
Intercropping in general; • an useful practical means of providing an additional income during the immature phase of rubber. This is not as important in the Wet Zone *vis a' vis* the Intermediate Zone as farmers depend more on off- than on on-farm activities. • has no adverse effect on growth of rubber, instead facilitates an increased growth rate of rubber. • protects rubber plants from heavy sunlight.
Rubber/banana intercropping; • increasing banana density up to three rows has no affect on the growth of either rubber or banana. However, farmers' preferred the two row planting system of banana as they were of the opinion that should the three row system be practised, banana clumps must be maintained/pruned properly which is not the case for many smallholders. This was particularly important for banana varieties with large canopies such as Ambun, Anamalu. If banana was over crowded, it would affect the yield of banana, but not on growth of rubber. • growth of banana is much more sensitive than rubber to competition from weeds. Although weeding is important, farmers tend to prioritise off-farm activities which provide a quick return, resulting in less time for on-farm activities. • application of inorganic fertilizer is essential for good growth of banana. • Availability of organic manure in sufficient quantities has become increasingly limited even in rural Sri Lanka. • Application of inorganic fertilizer to banana has no effect on rubber and does not explain the benefits of intercropping on rubber growth.

Table 4 *cont.*

(b) Sociological context of smallholder rubber cultivation
Rubber in general; • Farmers grow rubber as a means of acquiring crown lands where possible and to secure land ownership where it is loosely held. • Knowledge of rubber plays a significant role in the success of rubber cultivation. This is extremely important in the Intermediate Zone (IZ) where farmers have less experience of rubber. Since farmers from IZ have no mature rubber, they demanded more knowledge on immature upkeep of rubber and also expressed their dissatisfaction with the extension service, quality of planting materials issued and the timing of their distribution.
Intercropping; • The greater the distance between the homestead and land, the less intensive the cultivation inputs and so the poorer the growth. • Farmers in the low-income category preferred to grow low capital and less labour demanding crops. If family labour was freely available, then farmers may select high-income crops, which demand higher labour inputs. • Farmers with additional income sources pay less attention to intercrops. • Access to the market and its stability encourage farmers to grow a wider range of crops.
Homegardens; • Crop diversity depends on the period of residency such that the longer the period the more diverse the range of crops grown. • Increase in the size of homestead increases the total number of crops, but decreases the number of crops per unit area.

Initiating the Wider Dissemination of Rubber Intercropping

Wider dissemination of project outputs were initiated through visits to India and Ghana and discussion with scientists and extension staff responsible for rubber cultivation in the government department and university sector. As a result of these discussions, scientists in the Rubber Research Institute of India conducted PRAs to determine the present status and requirements for smallholder rubber intercropping research in India. In addition, several scientists from Ghana have undertaken a fact finding visits to the Rubber Research Institute of Sri Lanka.

List of Dissemination Outputs

Extension material

Rubber based intercrops. Advisory Circular No. 2001/01. Rubber Research Institute of Sri Lanka.

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Rodrigo, V.H.L., Stirling, C.M., Teklehaimanot, Z. and Nugawela, A. (2001). Intercropping with banana to improve fractional interception and radiation-use efficiency of immature rubber plantations. Field Crops Research, **69**, 237-249.

Rodrigo, V.H.L., Thennakoon, S. and Stirling, C.M. (2001). Priorities and objectives of smallholder rubber growers and the contribution of intercropping to livelihood strategies: a case study from Sri Lanka. Outlook on Agriculture, **30**(4), 261-266.

Others (magazines, bulletins, conferences, etc.)

Rodrigo, V.H.L. and Stirling, C.M. (2000). Optimising planting density of banana to improve resource use efficiency and productivity of smallholder rubber lands in Sri Lanka. XXI IUFRO World Congress, Kuala Lumpur, Malaysia-Abstracts, Vol. 2, pp 100.

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Stirling, C.M., Rodrigo, V.H.L., Marzano, M., Thennakoon, S., Sillitoe, P., Senivirathna, A.M.W.K. and Sinclair, F.L. (2001). Developing rubber-based cropping systems that improve not only latex yield but also the livelihoods of the rural poor; a case study in Sri Lanka. *The Rubber International Magazine*, **3(25)**, 83-89.

Rodrigo, V.H.L. (2001). Rubber based intercropping systems. In: ‘Handbook of rubber. Volume 1, Agronomy’. Eds. L.M.K. Tillekeratne and A. Nugawela, Rubber Research Institute of Sri Lanka. pp. 139-155.

Stirling, C.M. (2001). A greener future with *Hevea brasiliensis*. In: ‘Handbook of rubber. Volume 1, Agronomy’. Eds. L.M.K. Tillekeratne and A. Nugawela, Rubber Research Institute of Sri Lanka. pp. 207-210.

Internal Reports

Jayasundera MW (1998) A survey of smallholder rubber intercropping in selected villages of the Intermediate and Wet Zones of Sri Lanka. Pp. 12

Rodrigo VHL (1998) Preliminary data collection for selected villages for PRA activities. Pp. 15

Thenakoon S (1998) Report on the village surveys relating to intercropping on rubber smallholdings in Monargala and Kalutura districts. Pp. 73

Marzano M (2001) Five capital assets and rural livelihood analyses of villagers in Therrapahuwa G.S. Division of Sri Lanka. Pp. 102.

Rodrigo VHL, Thenakoon S & Stirling CM (2001) Technology transfer and identification of constraints in rubber-based intercrops through adaptive research with farmer participation: a success story in Sri Lanka. Workshop Report, Rubber Research Institute, Agalawatta. June 2001. Pp. 9.

Further Research and Dissemination

The impact of this project on the livelihoods of smallholder rubber growers will be dependent mainly on how effective the outputs are disseminated and to assist this process, the following key activities have been identified.

- Continued monitoring of uptake of rubber intercropping by smallholders, particularly in the Intermediate Zone, and completion of analysis of growth and yield of banana/rubber intercrops on-farm.

  This would provide statistics regarding the level of spontaneous adoption of rubber intercropping together with a unique data set summarising the long-term effects of intercropping under smallholder condition.

- The development of pictorial extension material for smallholders in remote rural communities where access to extension personnel is limited.

  Proposal submitted to FAO Technical Cooperation Programme.

- The development of appropriate planting protocols for rubber in the drier soils of marginal rubber growing areas in order to reduce plant mortality during establishment.

  Proposal submitted to FAO Technical Cooperation Programme.

- Wider access to research outputs through publications and development of web site.

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Thennakoon, T.M.S.P.K. (2002). Socio-economic and cultural factors influencing smallholder farming systems in Sri Lanka, Ph.D. Thesis, University of Wales, UK (*In Preparation*).

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This project would not have been possible without the cooperation of farmers in villages of the Wet and Intermediate Zone of Sri Lanka, to whom we are indebted. We would also like to express our appreciation to the village level extension and government agents, namely the Agricultural Development, Samurdhi and Gramasevaka officers. We are grateful for the assistance of the staff of both Rubber Research Institute (RRISL) and Rubber Development Department (RDD) of Sri Lanka, in particular, technical assistance given by Mr. P.D. Pathirana, Mr. W. Karunatillake and Ms. E.S. Munasinghe of the RRISL and Mr. W.K. Jayasinghe of the RDD and Mrs. W. Wijesuriya of the RRISL for her invaluable assistance in data analyses. In production of extension materials, assistance given by Mrs. N. Senevirathna and Mr. R. Amerathuga is appreciated. Finally, we wish to thank Dr Michelle Jones and Mrs Karen Cooper of SAFS UWB for their highly efficient administrative support.

Appendix 1: Further details of methodology

Study sites

Sri Lanka is divided into three major agro-ecological zones termed the Wet, Intermediate and Dry Zones. The Wet Zone comprises the south-west region of the island and receives a mean annual rainfall >2500 mm. The Intermediate Zone has an annual mean rainfall of between 2500 and 1750mm, whilst the northern and eastern sectors of the island are principally classified as the Dry Zone and have a mean annual rainfall <1750 mm. The present study was restricted to villages in the Wet and Intermediate Zones and villages from two districts within each zone were selected for the study based on information gathered during preliminary surveys (Jayasundera, 1998; Rodrigo, 2001; Thennakoon, 1998) and from the Rubber Development Board. The main criteria used in the selection of villages were (i) that agriculture provided a major source of income to the community, (ii) a significant proportion of households were interested in new planting or re-planting of rubber, (iii) that communities encompassed the full range of livelihood status' involved in smallholder rubber cultivation and (iv) that quality and access to the extension services differed widely between villages.

Livelihood analysis

Social groups

Eight social groups were identified, based on observations made during the detailed ethnographic studies and included;

1. Fully depend on agriculture; own ≤ 2 ac; with ≤ 3 family members
2. Fully depend on agriculture; own ≤ 2 ac; with >3 family members
3. Fully depend on agriculture; own >2 ac; with ≤ 3 family members
4. Fully depend on agriculture; own >2 ac; with >3 family members
5. Partially depend on agriculture; own ≤2 ac; with ≤ 3 family members
6. Partially depend on agriculture; own ≤2 ac; with >3 family members

7. Partially depend on agriculture; own > 2 ac; with ≤ 3 family members
8. Partially depend on agriculture; own > 2 ac; with >3 family members

Village survey of capital assets

To determine the differences in five capital assets amongst the different social groups, participants in the first group gathering were divided into 4 social groups using indicators (*i.e.* land availability and sources of income). Key indicators used to asses five capital assets and methods of ranking and scoring were explained in Singhalese to participants, using sketching materials (a large flip chart and colour markers). Once farmers had a full understanding of the key indicators together with their determinants and five capital assets, it was feasible to begin ranking and scoring**.** Farmers were asked to identify and rank in relation to the availability, appropriate indicators for each capital asset. Similarly, farmers were requested to score the ranked key indicators by allocating the highest mark to the first indicator and then score other indicators relative to this. The maximum number allocated to the first indicator was decided by farmers after group discussion and was ≤ 500. In this way the numbers used had meaning to farmers and avoided the problem that if the researchers allocated a top score of, for example, 100 the participants struggled to allocate subsequent marks according to the relative importance of each indicator, as found during preliminary exercises (Thennakoon, 2002). Following the first ranking and scoring exercise, farmers were requested to rank and then score the five capital assets on a separate paper, as done for the key indicators for each capital asset (Thennakoon, 2002).

Quantification of capital assets in rubber growing area

The scores given to individual indicators and assets differed between villages, for example the score for the top ranking indicator ranged from 65-125 in different villages. In an attempt to standardise scoring across villages, capital assets were ranked at the village level according to availability such that “low”, “medium” and “high” availability were allocated scores of 30, 60 and 90, respectively. This ranking exercise was undertaken by a researcher who had spent 18 months living and working in all four villages and allowed individual scores allocated by farmers to be standardised across villages using the formal below, The scores allocated to each indicator were converted to percentages based on the sum of scores of key indicators under each asset.

$$VAV = (X_1/X_2)^* X_3$$

VAV = village adjusted value

X_1 is the individual score for each indicator (allocated by participants)

X_2 is the sum of scores for each capital asset (allocated by participants)

X_3 is the level of marks given by researcher where villages were ranked according to the level of each capital asset *i.e.* Low (30), Medium (60) and High (90).

Marks of each indicator in each village were pooled to find out the range and the values for maxima and minima fixed with the assumption that villages used in the preliminary livelihood analysis have covered the rubber growing villages of full spectrum livelihood assets.

Survey:

Having understood the key indicators and their determinants of the rural livelihood components (through detailed anthropological works), a questionnaire based RRA was conducted in rubber growing areas (falling under four categories) in order to assess the rural livelihood (i.e. Rubber growing areas of Major, Minor and Urbanised in the wet zone and Potential areas for future expansion of rubber in the intermediate zone).

Total number of villages for the RRA were restricted to 30 and allocated to each district depending on the number of rubber extension divisions whilst keeping three villages as the minimum. Twenty four farmers from each village were then interviewed from eight social categories (1-8 depending on land size and occupation); three per each category where possible. Practical limitations resulted less number of farmer interviews in few villages, hence total number of farmers interviewed was 697.

Building up the level of indicators and assets

Values for each indicator of respective capital asset were calculated using the values given to all determinants of each indicator, their relative importance and the values set for minima and maxima in the preliminary study (NB. values were always within the limits of minima and maxima). The percentage importance of each determinant of particular indicator was assessed with the experience gained in the field by the researcher. The relative abundance of each determinant was assessed and valued from 0 to 100, e.g. 0, 25, 50, 75, 100, then weighted with the % importance. For instance, if two determinants build up a indicator with equal representation, then 50% was given to each, else more important determinant scores 65% whilst next 35%. Values for each indicator was adjusted within the range decided before and summed up in order to build up the asset. Values of indicators were added together to build up the value for each capital asset.

Marks ranges for indicators and their determinants;

Physical assets was a function of road & transport, energy source, housing, markets and extension with given marks of 9-61.

Road & transport (2-17) - type of road (45%) . mode of transport (30%). distance to motorable road (25%)

Energy source (1-17) - type of energy used for illumination & leisure (65%). Cooking (35%)

Housing (3-16) - condition of the house

Markets (3-11) - distance to market

Human assets was a function of health, education, labour and extension with given marks of 22-84.

Health (3-16) - long-term disability (65%) . distance to a reliable place for short-term ailments (35%)

Education (6-32) - educational level of senior households (e.g. husband/wife)

Labour (7-25) - availability of family labour (50%). feasibility of obtaining additional labour inputs (50%)

Extension (6-11) - dependency on outside information services

Financial assets was a function of ready cash, savings and access to credits with given marks of 30-90.

Ready cash (7-13) - type of income source (35%). Reliability (65%)

Savings (11-37) - type of saving

Access to credits (12-40) - scale of the credits

Social assets was a function of village societies & common activities and help from relatives/neighbours with given marks of 27-60.

Village societies & common activities (22-41) - membership in village societies (35%) . level of functioning (65%)

Help from relatives/neighbours (5-19%) - dependency on help

Natural assets was a function of lands and water with given marks of 30-78.

Lands (14-49%) - extent of agricultural lands . type/intensity of cultivation

Water (16-29%) - distance to water for agriculture . seasonality in water availability

Market studies

Medagama and *Parakaduwa* were the main markets used by farmers in *Pallekiruwa* and *Pannila* and were selected as being best representative of local markets in the Intermediate and Wet Zone, respectively. Two types of data were collected (i) market related data (*i.e.* daily, weekly and seasonal price variation and marketing channels) and (ii) data related to villages-level studies (*i.e.* information for benefit/cost analysis of major local crops). The village–level study involved two types of benefit/cost analyses, the first for plantation crops rubber and tea and the second for local crops; arecanut, pepper and banana. Stratified random sampling was used to obtain a representative sample for the marketing survey. The total participants in the marketing systems of the two selected markets were divided into sub-groups, according to the different key players involved in transportation of products from the farm gate to the consumer. The total number of participants in *Medagama* market included 170 producers and 68 buyers of which 8 were village collectors, 30 were intermediate collectors and the remaining 30 were distant wholesalers. To provide a reasonable sub-sample, 18% of producers and 50% of buyers (*i.e.* from each of the 3 different categories) were randomly selected for the survey.

Sampling methods used to select respondents in the *Parakaduwa* market differed from those of *Medagama*, because relatively few key players were involved in transportation of products from the farm gate to consumers in *Parakaduwa*. Intermediate and distant wholesalers were not involved in the marketing system of *Parakaduwa* apart from 5 village collectors (for banana) and 3 boutique owners (for rubber and home garden crops). The number of producers compared with buyers was large and so a sub-sample of 18% of producers out of a total of 377 was selected together with 100% of buyers (*i.e.* intermediate collectors and village boutique owners). A checklist was used to interview sellers and buyers regarding the total amount of production, transport methods, marketing costs and efficiency, marketing losses and seasonality of production. In addition to the marketing analysis, a financial assessment was made of the profitability of the crops, rubber, tea, banana, arecanut and pepper. For this assessment, 24 smallholdings cultivating a range of crops were selected as a representative sample in each village (*i.e. Pannila* and *Pallekiruwa*). Crops grown on smallholdings differed between villages and in the case of *Pannila*, tea and rubber were the predominant crops whereas in *Pallekiruwa*, pepper, banana and arecanut were the main crops grown.

Farmer preference for different varieties of banana was assessed using the total number of banana clumps in each of the 24 households sampled in selected villages (*i.e. Pallekiruwa* and *Pannila*). While the farm sketches (Thennakoon, 2002) were drawn, the number of banana clumps was counted separately for each variety, and these data were used to assess farmer preference for each variety. Profitability of different varieties of banana was calculated using the formulae described by Thennakoon (2002). Finally, apart from the financial analysis of marketing and profitability, to assess factors influencing marketing efficiency (*i.e.* insufficient space in the market, road barriers during the transportation *etc.*), semi-structured interviews and direct observation of the marketing system were undertaken during several visits at different times of the year.

On-farm field trials of high density banana/rubber intercropping

Information relating to the number of applications and approved number of permits on re-planting and new-planting of rubber in Kegalle and Kalutura regions of the wet zone, and Moneragala and Hamnantota regions of the intermediate zone were gathered from the relevant offices of the Rubber Development Department (RDD). The planting season for rubber in the WZ and in the IZ is May/June and October/November respectively, coinciding with the Southwest and Northeast monsoon rains. In the selection of villages, the number of re-planting and new-planting of rubber in 1999 was taken into consideration. Preliminary farmer interviews were then undertaken in the selected villages, in order to identify those farmers who were willing to intercrop banana with rubber. In agreement with these farmers they were assigned specific planting, fertiliser application and management regimes according to the design of the on-farm trials. Farmers who had at least 0.4 ha for re-planting or new planting were selected in order to accommodate the treatments. Where there were insufficient numbers of 1999 plantings, 1998 planted rubber lands were selected depending on the availability.

Treatments were arranged in a Split-Plot design at each experimental site. Within an area of 0.4 ha., *ca.* 200 rubber plants (clone RRIC 100) were planted at spacings of 2.4 m x 8.1 m within- and between-rows. The main treatments of one, two and three rows of banana were arranged proportionately depending on the number of rows of rubber at the site. Each main plot was divided into sub plots according to the fertiliser management regimes imposed (*i.e.* FER and NFER). It was not possible to incorporate all the possible combinations of main (RB, RBB and RBBB) and sub plots (FER and NFER) at a single experimental site due to the limited land available. Therefore, the main and sub plots were applied to accommodate at least 4 combinations of main and sub plots at each experimental site.

Plant material and establishment

Farmers themselves planted the rubber trees provided by the Rubber Development Department (RDD), in the holes dug to a length, width and depth of 0.60 m x 0.60 m x 0.75 m and keeping within- and between-row spaces of 2.4 m x 8.1 m. The most common varieties of banana in the WZ and IMZ are “embul” and “kolikuttu” respectively, and so farmers were given the freedom to choose which of these two varieties they preferred for the intercropping studies in the RLE. Rhizomes with a pseudostem of *ca.* 0.3 m length were supplied to farmers depending on the number of plants that can be incorporated in the site and were planted in the holes dug to a length, width and depth of 0.6 m x 0.6 m x 0.6 m according to the design of the main plots.

Crop husbandry

Prior to planting, roots of the banana suckers were trimmed and treated with a solution of 2.5 g l^{-1} of Carbofuran (Curaterr) and 2.5 g l^{-1} of Captan for 10 minutes and kept for seven days to prevent insect infestation and fungal attack (Department of Agriculture, Sri Lanka, 1995). The recommended mixture of fertiliser by the Department of Agriculture, Sri Lanka, 1995 at a rate of 450g per plant at four monthly intervals was applied to the fertilised treatment of banana (FER). Fertiliser for banana was supplied to farmers and the application was done under the supervision of the researcher. Recommended annual amounts of fertilisers for rubber by the RRISL were supplied to farmers by the relevant RDD offices under the rubber subsidy scheme. Farmers were left with the responsibility of managing their intercrops including weeding, protecting plants from animals and watering when necessary.

Weather data

Daily rainfall data were recorded at one of the experimental sites in each of the selected villages between April 2000 and May 2001. Locally made rain gauges (NERD, Sri Lanka) were installed close to the experiments of the selected farmers and those farmers were given instructions on how to take readings and how to record. Data were checked and taken from farmers’ recordings at *ca.* 1-2 month intervals when visits were made to the experimental sites.

Soil and foliar nutrient analyses

Analysis of N, P, K, Mg Ca, pH, organic carbon content and texture of soil were carried out for the 0-0.15 m and 0.15-0.30 m depths at each experimental site prior to planting. In order to provide representative measurements, samples were taken from the four corners and from the middle of each plot and were pooled together for all the analyses. Analysis of K, Mg and Ca was done using the ammonium acetate exchangeable (pH=4.8) method, N, P and organic carbon were analysed with an auto-analyser (Bran and Lubbe Analyser System, UK) using the Modified Bray II and Walkley-Black methods respectively (Singh and Ratnasingam, 1971a). Bulk density of the soil was measured by taking soil core samples from 0-0.15 m and 0.15-0.30 m depths and from four corners and the middle of each plot.

In order to determine whether high density intercropping had any effect on the nutrient status of rubber and banana, foliar nutrient analyses were carried out in the RBBB and sole crop rubber main plots. From the RBBB main plot, FER and NFER sub-plots were selected in order to account for the effect of fertiliser application to banana. Two trees randomly selected from each crop from the FER and NFER treatments and in addition, two rubber trees from the sole crop rubber were sampled. Five leaves (3 leaflets per leaf) of rubber were harvested from the topmost, fully matured, green leaf whorl from each plant. In the case of banana, two leaf samples (*ca.* 0.3 m x 0.3 m) from both sides of the midrib of the topmost, fully matured, green leaf (second or third leaf at the top of the canopy) from each plant were harvested. Samples were collected and placed in perforated polythene bags to prevent moisture condensation, labelled and then brought to the laboratory within 24 hours. Samples, which could not be brought to the laboratory within 24 hours, were kept at *ca.* 10 ^{o}C to minimise desiccation and deterioration (Samarappuli and Dissanayake, 1993).

Two well (*Well*) and two poorly (*Poor*) managed experimental sites from both the wet and intermediate zones were selected for nutrient analyses. *Well* and *Poor* managements were determined based on visual observations of farmers' interest in weeding and general upkeep of their plantations (fencing, protection from animal *etc.*). Plant height, stem girth at 10 cm height from the ground, total leaf number and the leaf area of the sampled plants were measured before the sampling.

Petioles were removed from each leaf and a representative sub sample from each treatment was then cut into small pieces, and oven-dried at 80 ^{o}C for 24 hours. Dried leaf samples were ground and packed in airtight polythene bags and stored in an air-conditioned room for analyses. A sample of 0.2 g was treated with 5 ml of Se/H_2SO_4 mixture and 1 ml of H_2O_2. Then, the samples were digested at 400 ^{o}C for two hours in a digestion block. The digest was made up to 50 ml with demineralised water. This solution was used to determine N, P, K, Ca and Mg concentrations. N, P and K were determined simultaneously by the Auto Analyser (Bran and Lubbe Analyser System, UK) and Ca and Mg were determined by Atomic Absorption Spectrophotometry (GBC, Australia) (Singh and Ratnasingam, 1971b).

Growth analyses

Stem girth at a height of 10 cm from the ground for both rubber and banana was recorded for each treatment and at each experimental site at approximately six-monthly intervals. Plants in the boundary row separating two banana densities were avoided. In addition, plant height of banana was measured at six-monthly intervals and yield (kg plant-1) was calculated based on the price obtained for fruit.

As planting and measurement (stem girth and height) dates were different in the WZ and IMZ, girth and height of banana at 14 months after planting (MAP) was taken for the comparison between the agro-climatic zones and sites. In the case of rubber, girth increment (GI) for a 10-month period was calculated in order to compare the growth performance of rubber between zones and sites. To compare the growth performances of intercropped and sole crop rubber, relative girth increment (RGI) of treatments, *i.e.* the GI of the treatments relative to the GI of the sole crop was calculated using equation below. There was a 4-5 months difference in planting dates between the agro-climatic zones and also $1/5^{th}$ and $5/9^{th}$ of the sites from the wet and intermediate zones, respectively were planted in 1998. Analysis of pooled data, however, would have introduced minimal errors, as the growth of rubber is linear with age up to *ca.* 6 years from planting (Rodrigo and Stirling, unpublished data).

$$RGI = GI\ (treatment)/GI\ (sole\ crop)$$

Data analysis

For the analyses of stem basal girth and height of banana, and GI and RGI of rubber, a split plot design (SAS Institute Inc., Cary, NC, USA) was used and as data were unbalanced, the General linear model (GLM) was performed for the analyses. Mean separation of treatments was performed with the least square mean (LSMEANS) for the comparison of treatment effects. For the foliar nutrient analyses, analysis of variance (ANOVA) was used whilst the mean separation of treatments was done using the Duncan’s multiple range test (DMRT).

Appendix 2: Results from On-Farm Trials

Table 1: Summary of the overall performance of on-farm trails for individual farmers in four villages of the Wet and Intermediate Zones of Sri Lanka.

(a)	Level of weeding	Damage by animals	Record maintenance	Personal interest	Growth of Rubber	Growth of Banana
Pannila;						
Farmer 1	Good	Severe	Good	Good	Good	Good
Farmer 2	Intermediate	Severe	Good	Intermediate	Intermediate	Intermediate
Farmer 3	Poor	Intermediate	Intermediate	Poor	Intermediate	Poor
Farmer 4	Poor	Intermediate	Good	Poor	Intermediate	Nil
Kobawaka;						
Farmer 1	Intermediate	Nil	Intermediate	Intermediate	Good	Intermediate
Farmer 2	Poor	Nil	Good	Poor	Intermediate	Poor
Farmer 3	Intermediate	Nil	Poor	Intermediate	Good	Intermediate
Bookandayaya;						
Farmer 1	Intermediate	Nil	Poor	Intermediate	Intermediate	Good
Farmer 2	Poor	Nil	Poor	Poor	Intermediate	Nil
Farmer 3	Intermediate	Nil	Good	Intermediate	Intermediate	Good
Pallekiruwa;						
Farmer 1	Poor	Nil	Poor	Poor	Intermediate	Poor
Farmer 2	Intermediate	Nil	Good	Intermediate	Good	Intermediate
Farmer 3	Intermediate	Nil	Good	Poor	Good	Poor
Farmer 4	Good	Nil	Good	Good	Good	Good
Farmer 5	Intermediate	Nil	Good	Intermediate	Good	Intermediate
Farmer 6	Poor	Nil	Good	Poor	Good	Poor
Farmer 7	Good	Nil	Good	Intermediate	Good	Intermediate
Farmer 8	Good	Nil	Good	Good	Good	Good

Table 2: Overview of the performance of on-farm trials in the Wet and Intermediate (Intermed.) Zones of Sri Lanka. Five levels of ranking (together with the % of smallholders) were used where G=Good, I=Intermediate, P=Poor, N=Nil and S=Severe and values shown in the parenthesis represent the absolute number of smallholders each particular category.

	Level of weeding	**Damage by animals**	**Record maintenance**	**Personal interest**	**Growth of Rubber**	**Growth of Banana**
Wet Zone	G-14.3%(1) I-42.8%(3) P-42.8%(3)	S-28.6%(2) I-28.6%(2) N-42.8%(3)	G-57.1%(4) I-28.6%(2) P-14.3%(1)	G-14.3%(1) I-42.8%(3) P-42.8%(3)	G-42.8%(3) I-57.1%(4)	G-14.3%(1) I-42.8%(3) P-28.6%(2) N-14.3%(1)
Intermed. **Zone**	G-27.3%(3) I-45.4%(5) P-27.3%(3)	N-100%(11)	G-72.7%(8) P-27.3%(3)	G-18.2%(2) I-45.4%(5) P-36.4%(4)	G-53.6%(7) I-36.4%(4)	G-36.46%(4) I-27.3%(3) P-27.3%(3) N-9.1%(1)