Intercropping boosts smallholder tree crops

RIU

Validated RNRRS Output.

New intercropping systems can double returns from small rubber plantations. Smallholders in Asia—often cultivating less than two acres—produce more than three-quarters of the world's natural rubber. But, because young trees produce no rubber for the first 5-6 years, farmers plant bananas as an intercrop to tide them over. Farmers in Sri Lanka now plant a third more bananas than officially recommended and find they can make twice as much profit. Plus, the higher density of bananas stimulates growth in the young rubber trees. Intercropping has major potential for rural communities of rubber growers. And, although the system was proven on rubber and banana, it is also being applied to maize, upland rice and tea, and in India and Ghana.

Project Ref: **PSP32:**
Topic: **1. Improving Farmers Livelihoods: Better Crops, Systems & Pest Management**
Lead Organisation: **CAZS-NR, UK**
Source: **Plant Sciences Programme**

Document Contents:

Description

PSP32

Research into Use
NR International
Park House
Bradbourne Lane
Aylesford
Kent
ME20 6SN
UK

Geographical regions included:

Sri Lanka,

Target Audiences for this content:

Crop farmers,

A. Description of the research output(s)

1. Working title of output or cluster of outputs.
In addition, you are free to suggest a shorter more imaginative working title/acronym of 20 words or less.

Intercropping of smallholder plantation tree crops.

Improving land use efficiency and income generation of smallholder rubber systems by intercropping.

2. Name of relevant RNRRS Programme(s) commissioning supporting research and also indicate other funding sources, if applicable.

Plant Sciences Research Programme

3. Provide relevant R numbers (and/or programme development/dissemination reference numbers covering supporting research) along with the institutional partners (with individual contact persons (if appropriate)) involved in the project activities. As with the question above, this is primarily to allow for the legacy of the RNRRS to be acknowledged during the RiUP activities.

R5058, R7002, R7212

Partner institutes
UK
CAZS-Natural Resources, University of Wales, Bangor
University of Durham

Sri Lanka
Rubber Research Institute of Sri Lanka (RRISL)
University of Sri Jayawardenapura (USJ)
Rubber Development Department (RDD)

*4. Describe the RNRRS output or cluster of outputs being proposed and when was it produced? **(max. 400 words)**. This requires a clear and concise description of the output(s) and the problem the output(s) aimed to address. Please incorporate and highlight (in bold) key words that would/could be used to select your output when held in a database.*

On-station, on-farm and farmer-led research identified suitable **intercropping interventions** to improve **income generation** and **productivity** of **immature smallholder rubber lands**. Using **banana** as a model crop we determined the optimal planting densities for intercropping immature rubber, tested initially on-station (Rodrigo et al., 1997, 2001a, 2005a, 2005b, Senevirathna et al., 2002a, 2002b, 2003) and later confirmed in farmers' fields under a wide range of climatic and socio-economic conditions (Rodrigo et al. 2001b, 2001c, 2003). Contrary to expectations, planting densities of up to 30% greater than those originally recommended for intercropping had a

beneficial effect on growth of rubber relative to the sole crop. For smallholder, resource-poor rubber growers this: (i) increased the productivity of immature rubber lands by planting an additional crop and at a higher density, (ii) reduced the immature, unproductive period of the rubber plantation, (iii) increased yield return due to improved growth of rubber, (iv) increased girth expansion of the rubber tree which has been related to increased timber volume and (v) secured subsidy payments as a result of the improved rubber growth (Rodrigo et al., 2005a). This research resulted in changes in the official recommendations for rubber intercropping in Sri Lanka.

The PSP research began in 1993 identifying limitations in the existing recommendations for rubber-based intercropping. By 1997, rubber/banana intercropping systems which increase the overall productivity and profitability by over two-fold were developed. In 1998, the market potential for these higher density rubber intercrops was identified and the importance of rubber/banana intercropping in rural communities established. By 2002, a detailed livelihoods analysis of rubber-based cropping systems (Thenakoon, 2002) and wide-scale testing of the intercropping systems (Senevirathna, 2001) were completed.

Traditionally plantation crops, such as rubber, have occupied an important position in the economy of many Asian countries, as a major product for export and through provision of jobs, with natural rubber providing a major income source to over 20 million farmers world wide, most of whom are low income and land-poor. Over 80% of the world's natural rubber is produced in Asia 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 face an initial gap in their income after replanting, which the rubber subsidy only partially fills. This problem can be alleviated by growing shorter-duration annual and perennial crops, for cash or subsistence.

In the early 1990s, the choices available to smallholders for intercropping were restricted by the rules for subsidy payments that minimised the risks to rubber and latex productivity rather than increasing the efficiency of smallholder land use. For instance, the recommended planting density of banana in rubber/banana intercropping was only ca. 30% of that of sole-cropped banana. Prior to the onset of this research the RRISL undertook no participatory research, and operated a linear extension programme of transfer of technology. Consequently the needs of smallholder farmers were not fully taken into account when developing recommendations for intercropping of rubber.

5. What is the type of output(s) being described here?
Please tick one or more of the following options.

Product	***Technology***	***Service***	***Process or Methodology***	***Policy***	***Other Please specify***
	x		*x*	*x*	

6. What is the main commodity(ies) upon which the output(s) focussed? Could this output be applied to other commodities, if so, please comment

Although rubber and banana were the main commodities in the process of developing intercropping systems, the model has been applied to other seasonal crops, such as maize and upland rice (Rodrigo et al., 2001c) and plantation tree crops, such as tea (Iqbal, 2003).

7. What production system(s) does/could the output(s) focus upon?
Please tick one or more of the following options. Leave blank if not applicable

Semi-Arid	High potential	Hillsides	Forest-Agriculture	Peri-urban	Land water	Tropical moist forest	Cross-cutting
	x	x	x				x

8. What farming system(s) does the output(s) focus upon?
Please tick one or more of the following options (see Annex B for definitions).
Leave blank if not applicable

Smallholder rainfed humid	Irrigated	Wetland rice based	Smallholder rainfed highland	Smallholder rainfed dry/cold	Dualistic	Coastal artisanal fishing
x			x	x		

*9. How could value be added to the output or additional constraints faced by poor people addressed by clustering this output with research outputs from other sources (RNRRS and non RNRRS)? (**max. 300 words**). Please specify what other outputs your output(s) could be clustered. At this point you should make reference to the circulated list of RNRRS outputs for which proformas are currently being prepared.*

Other interventions could be tested not only in the context of rubber intercropping but also other tree crop systems; for example the outputs have already been adapted to tea intercropping (Iqbal, 2003). This work also indicated some benefits of intercropping on reducing pests and disease and there would be added benefits of clustering these outputs with areas of crop protection and improved crop agronomy, e.g:

Banana IPM (R8342, R7567, R7529, R7972)
Control banana nematodes (R6580)
PVS for chickpea (Prog Dev)
PVS for maize (Prog Dev & R7281)
COB rainy season legumes (Prog Dev)
COB maize (R8099 and Prog Dev)
Seed priming (R7438, R6395)
Nutrient seed priming (R7438, R8221, R8269)

Validation

B. Validation of the research output(s)

***10. How** were the output(s) validated and **who** validated them?*

Please provide brief description of method(s) used and consider application, replication, adaptation and/or adoption in the context of any partner organisation and user groups involved. In addressing the "who" component detail which group(s) did the validation e.g. end users, intermediary organisation, government department, aid organisation, private company etc... This section should also be used to detail, if applicable, to which social group, gender, income category the validation was applied and any increases in productivity observed during validation ***(max. 500 words)****.*

How validated: The outputs (high density rubber/banana intercropping) were validated in two steps. Benefits shown in on-station experiments of high density rubber intercropping were tested on-farm and with different degrees of farmer participation (Rodrigo et al., 2003; Senevirathna, 2001; Stirling et al., 2001). Rubber intercropping trials were evaluated under different management and socio-economic conditions and in two major climatic zones; the Wet and Intermediate Zones where rubber has been grown for more than a century or its cultivation has recently expanded (i.e. in the last 15 years), respectively.. Results confirmed the utility of high density intercropping on smallholdings as did interviews with participating farmers (Detailed information is given below).

Summary of the conclusions drawn up by farmers and researchers at the end of project workshop (Rodrigo et al. 2003).

(a) Agronomic

Rubber/banana intercropping;

- Increasing banana density up to three rows has no affect on the growth of either rubber or banana. However, farmers prefer the two row planting system of banana because it is less intensive to manage, particularly for banana varieties with large canopies such as Ambun and Anamalu. If banana is not maintained/pruned at high densities then yield of banana would be reduced, but not growth of rubber.
- Banana is more sensitive than rubber to competition with weeds. Despite the importance of weeding, farmers tend to prioritise off-farm activities which provide a quick return, resulting in less time for on-farm activities.
- Application of fertilizer is essential for good growth of banana. The option of using organic manure is limited by its availability.
- Application of inorganic fertilizer to banana has no effect on rubber and does not explain the benefits of intercropping on rubber growth.

(b) Sociological context of smallholder rubber cultivation

Rubber in general;

- In new clearings, farmers grow rubber as a means of acquiring crown lands where possible and to secure land ownership.
- Farmers grow rubber because it provides a long-term source of income.
- Farmers from the Intermediate Zone are heavily dependent on the extension service for advice on upkeep of rubber as it has only recently been re-introduced. In general, farmers are dissatisfied with the extension service, quality of planting materials issued and the timing of their distribution.

Intercropping;

- Farmers in the low-income category preferred to grow low-capital and less labour-demanding crops for intercropping. However, if family labour was freely available, then farmers may select high income crops which demand higher labour inputs
- Access to the market and its stability encourage farmers to grow a wider range of intercrops.

Socio-economic and market studies were undertaken by both project and non-project staff in 1997, 1999 and 2000. A detailed analysis of farmer livelihoods in smallholder rubber growing districts was undertaken over a period of 18 months by spending periods of time living in selected villages. Full details of the methods used are provided in the following reports and PhD theses:

1. Gray, A. (1997) Report for the Institute of Terrestrial Ecology (Bangor) on a Visit to Sri Lanka to Assess the Market Impact of a Potential Increase in Production of Banana Resulting from High Density Intercropping of Banana with Rubber. Natural Resources Institute, UK. pp. 33.
2. Janowski, M. (1997) Report on an Analysis of Rural Livelihoods and Poverty in Two Villages in Sri Lanka. Natural Resource Institute, UK. pp.36.
3. Rodrigo V.H.L. (1997). Population density effects on light and water-use of rubber/banana interculture systems. Ph.D. Thesis, University of Wales, Bangor, U.K.
4. Senevirathna, A.M.W.K. (2001). The influence of farmer knowledge, shade and planting density on smallhoder rubber/banana intercropping in Sri Lanka. Ph.D. Thesis, University of Wales, UK.
5. Stirling, C.M, Rodrigo, V.H.L., Sinclair, F.L., Thennakoon, T.M.S.P.K. and Senivirathna, A.M.W.K. (2001). 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.
6. 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.

*11. **Where and when** have the output(s) been validated? Please indicate the places(s) and country(ies), any particular social group targeted and also indicate in which production system and farming system, using the options provided in questions 7 and 8 respectively, above **(max 300 words)**.*

Where and when: Validation of outputs was limited to Sri Lanka and undertaken by both project and non-project staff at various stages during the lifetime of the project (see Q.10). Validation resulted in the Rubber Research

Institute issuing new recommendations for intercropping rubber which have now been adopted by the extension services.

Process: The validation of the outputs was done in farmers' fields in both the Wet and Intermediate Zones of Sri Lanka and for a range of socio-economic groups (see below). Dry regions (Intermediate zone of the country) were considered to be a potential area for further expansion of rubber due to land availability and the fact that farmers in these areas do not have a permanent source of income and so depend on seasonal rainfed crops. Also, villages used were different in infrastructure and in other livelihood assets. Livelihood capital assets of the sites used for validation of outputs are shown below (Fig. 1, Q. 21).

Current Situation

C. Current situation

*12. **How and by whom** are the outputs currently being used? Please give a brief description **(max. 250 words**).*

Outputs were published in peer reviewed journals and bulletins on rubber. Recommendations on rubber-based intercropping were revised and included in new advisory circulars and in the Handbook of the RRISL on rubber agronomy (Rodrigo, 2001). These publications are circulated in other rubber growing countries. In particular, visits made to India and Ghana enabled the findings to be disseminated more widely. Also, the new recommendations have been included in the training programmes of new extension personnel on rubber in Sri Lanka. No studies have been undertaken since 2000 in Sri Lanka nor elsewhere to assess the present level of adoption of high density intercropping.

*13. **Where** are the outputs currently being used? As with Question 11 please indicate place(s) and countries where the outputs are being used **(max. 250 words).***

See the answer for the question 12. The areas are:

- In Sri Lanka, 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.
- Most likely in undeveloped rural communities in other rubber growing countries but the actual figures are unknown.

*14. What is the scale of current use? Indicating how quickly use was established and whether usage is still spreading **(max 250 words).***

There have been no studies conducted after the completion of the project in 2000 and so the scale of adoption in

different zones of the country and at an international level remain unknown.

However, the potential scale of adoption is very large as the outputs can be applied to most rubber lands and ca. 80% of the rubber growers in the world are smallholders. However as identified in this project, the major constraint to uptake is access to effective extension information and advice in the remoter rubber-growing regions of Sri Lanka. The use of participatory on-farm research provided a means of allowing farmers to experience for themselves the potential benefits of high density intercropping so the adoption level of outputs within project and surrounding villages should be high.

15. In your experience what programmes, platforms, policy, institutional structures exist that have assisted with the promotion and/or adoption of the output(s) proposed here and in terms of capacity strengthening what do you see as the key factors of success? ***(max 350 words).***

The Rubber Research Institute of Sri Lanka (RRISL) is responsible for issuing recommendations for rubber cultivation and for education of the extension service. By collaborating with the RRISL throughout the course of this research it has been possible to bring about changes in mindsets with regard to the value of participatory research, both in terms of its scientific value and its importance in tailoring research towards the needs of the end user – the farmer. This, together with the training of RRISL staff through the provision of short courses and PhD programmes has ensured that the participatory and scientific approaches used have become firmly embedded within the institute. Consequently, the adaptive research programme of the RRISL has become increasingly participatory in nature and is in the process of promoting the project outputs in the smallholder sector. This is done in collaboration with the Rubber Development Department (RDD) of Sri Lanka which is the body officially responsible for the technology transfer and rubber cultivation in the smallholder sector.

The success of the outputs was also facilitated by the extensive collaboration between natural scientists and sociologists and between international institutions (i.e. RRISL, University of Sri Jayawardenapura Sri Lanka and Universities of Wales and Durham, UK). Inter-institutional collaboration within Sri Lanka (RRISL and RDD) and at an international level (Rubber Research Institute of India and University of Ghana) has also helped to promote the outputs.

Current Promotion

D. Current promotion/uptake pathways

16. ***Where*** *is promotion currently taking place? Please indicate for each country specified detail what promotion is taking place, by whom and indicate the scale of current promotion* ***(max 200 words).***

Currently, promotion of high density intercropping systems amongst smallholders is undertaken in Sri Lanka by the RRISL and RDD. It is not known the extent to which other countries are promoting the outputs of this research at the farmer-level.

The outputs have also been published internationally and so are available for promotion by research and extension organizations in other countries. For instance, as a result of the high profile of the projects publications, Dr. Rodrigo was invited for a special lecture on rubber intercropping at the Rubber Planters' conference in India (Rodrigo, 2002).

The fundamental knowledge generated by this research and its outputs have stimulated other research. For example, a similar approach was used to address issues in smallholder rubber/tea intercropping systems (Iqbal, 2003). Research outputs have been published in highly respectable international journals and cited by many other researchers. As quoted in the annotated bibliography on rubber based farming systems published by the Rubber Research Institute of India, project outputs have produced the highest number of publications on rubber intercropping (Sujatha *et al*., 2006).

17. What are the current barriers preventing or slowing the adoption of the output(s)? Cover here institutional issues, those relating to policy, marketing, infrastructure, social exclusion etc. ***(max 200 words)****.*

Poor extension is a major constraint to uptake of the project outputs. The farmers most likely to benefit from project outputs are those in the remote regions of the Intermediate Zone that are fully dependent on agriculture for their livelihoods and for who, rubber is a relatively new to crop. These farmers are highly dependent on extension advice.

The organisations involved in promoting the project outputs in Sri Lanka follow the traditional approach to technology transfer which is ineffective. There is no proper system to assess the efficiency of the extension service in the RDD which is responsible for the smallholder sector. Similarly, there is no proper incentive scheme to encourage extension workers to increase their effectiveness with no promotional avenues. This was been evident with other existing technologies of rubber (Rodrigo et al., 2004).

18. What changes are needed to remove/reduce these barriers to adoption? This section could be used to identify perceived capacity related issues ***(max 200 words).***

Improved dialogue with policy makers in all rubber growing countries in order to introduce structural changes and new policies (e.g. making intercropping an essential component of subsidy payments) is required to promote the outputs.

A more rapid dissemination of outputs could be achieved through the introduction of effective extension tools. For example, development of extension manuals and site-specific handbooks in local languages for smallholders, establishment of farmer participatory demonstrations plots and conducting workshops in different parts of the country and in other rubber growing countries would greatly reduce the barriers to adoption. Moreover, publishing a book and making freely available material covering intercropping practices in different rubber growing countries and the participatory approaches used in this project would increase awareness of outputs amongst policy makers, scientists and ultimately extension workers.

19. What lessons have you learnt about the best ways to get the outputs used by the largest number of poor people? ***(max 300 words).***

Using Rogers (2003) diffusion of information as a framework for the lessons learnt:

1. The relative advantage of a technology compared to what it is replacing;
This is extremely high as it provides increased level of land use efficiency and net profits (over 200%).

2. The compatibility of the technology with existing systems and ways of doing things, which is closely related to culture;
As the new technology allows smallholders to select a much wider range of crops and planting densities for intercropping than was originally recommended, the compatibility should be very high.

3. The complexity of the technology in terms of what people need to learn to make it work;
Although the system is complex, the outputs have greatly increased the flexibility of farmers in terms of appropriate choices for intercropping. So, the technology application is understandable to the majority of smallholders.

4. The observability of a technology in terms of how easy it is to demonstrate and observe performance;
The observability is high as the outputs are produced on-farm.

5. The trialability of a technology in terms of how easy it is to test it before deciding to adopt.
Farmers can test the system with limited resources. And also, improved economic returns could be observed even within two years.

Impacts On Poverty

E. Impacts on poverty to date

20. Where have impact studies on poverty in relation to this output or cluster of outputs taken place? This should include any formal poverty impact studies (and it is appreciated that these will not be commonplace) and any less formal studies including any poverty mapping-type or monitoring work which allow for some analysis on impact on poverty to be made. Details of any cost-benefit analyses may also be detailed at this point. Please list studies here.

These studies were confined to Sri Lanka

Impact of the major outputs (i.e. interplanting high density banana with rubber) on rural poverty and market was assessed in Sri Lanka under the project R7002 (Janowski, 1997 and Gray, 1997, respectively). In addition, detailed socioeconomic studies were undertaken on the impact of the project on rural livelihoods (Thennakoon, 2002).

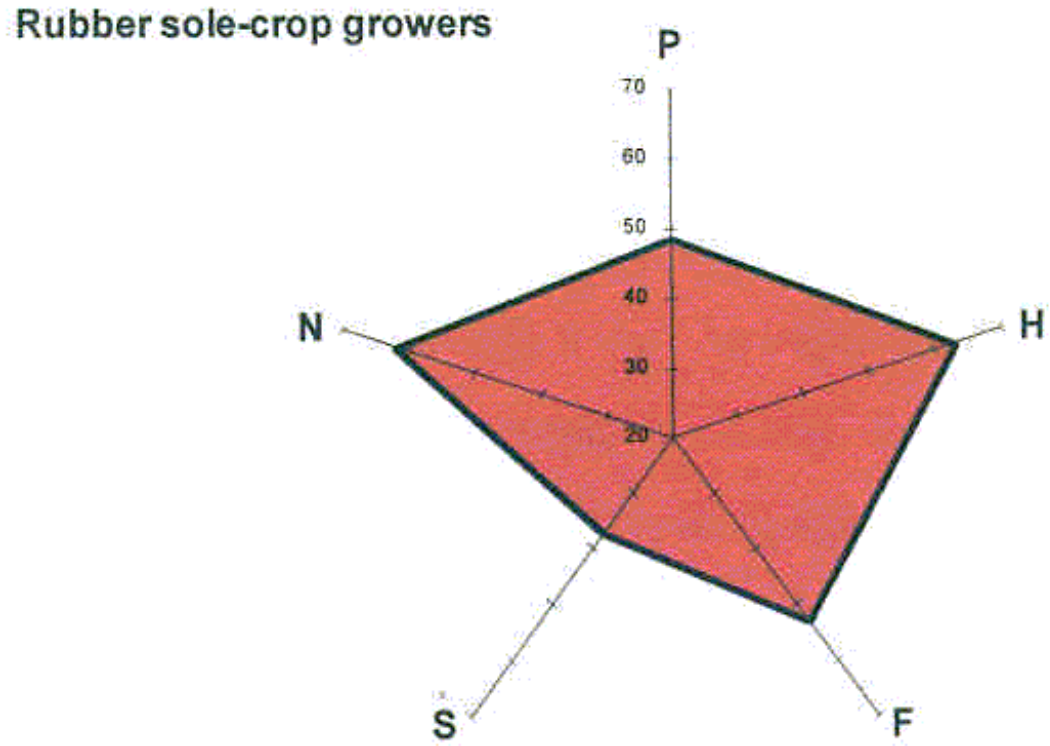
Financial analysis showed the highest potential net profit in the application of the major outputs, i.e. high density banana/rubber intercropping, is ca. Rs. 50,000 (at 4.5% discount rate) per hectare which represents an increase

of more than 350% over the previous recommendation on intercropping (Rodrigo et al. 2001b).

21. Based on the evidence in the studies listed above, for each country detail how the poor have benefited from the application and/or adoption of the output(s) ***(max. 500 words):***

- *What positive impacts on livelihoods have been recorded and over what time period have these impacts been observed? These impacts should be recorded against the capital assets (human, social, natural, physical and, financial) of the livelihoods framework;*
- *For whom i.e. which type of person (gender, poverty group (see glossary for definitions) has there been a positive impact;*
- *Indicate the number of people who have realised a positive impact on their livelihood;*
- *Using whatever appropriate indicator was used detail what was the average percentage increase recorded*

The livelihood analysis (Stirling et al. 2001) showed that social assets of farmers using project outputs (i.e. rubber intercropping) were greater than those that did not (Fig. 1). The opposite was true for physical assets as those farmers who adopted intercropping were living in the most remote rural areas where farming was a full-time activity and maximum returns from the land was a priority. Financial assets of rubber farmers who adopted intercropping were as high as those of non-intercroppers suggesting that intercropping of rubber can contribute significantly to financial assets (Fig. 2), as observed in previous case studies of smallholder farmers (Rodrigo et al. 2001c).


Rubber sole-crop growers
P
70
60
50
40
30
20
N
H
S
F

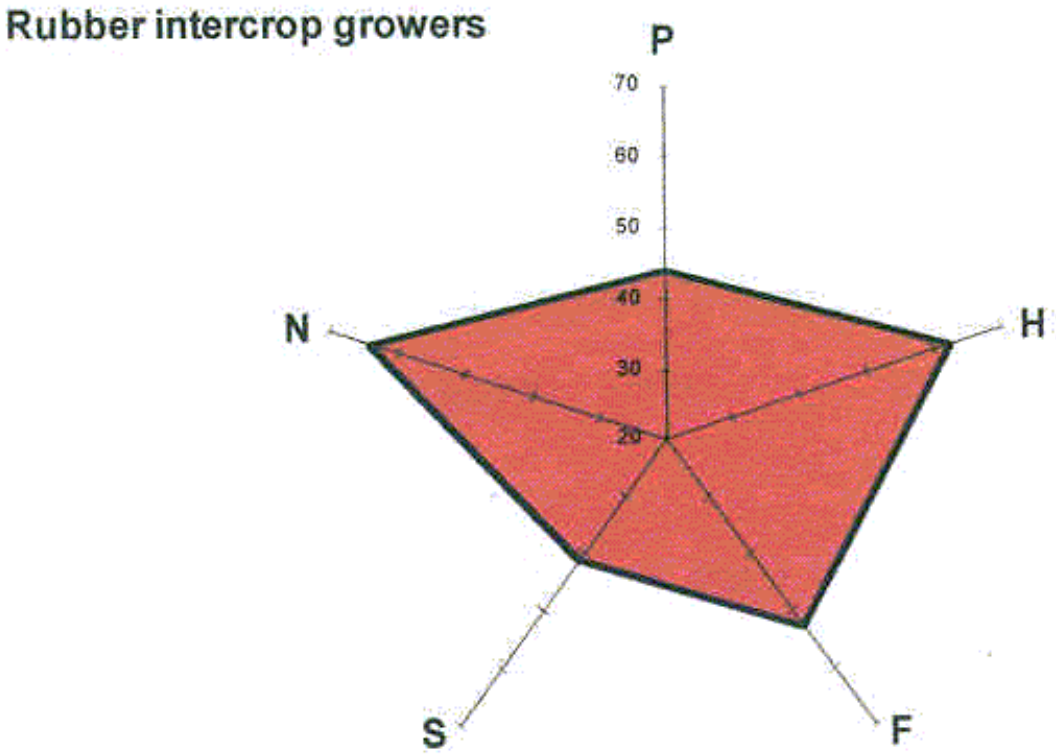


Figure 1 Livelihood capital assets of smallholder farmers cultivating rubber either alone or as an intercrop. Data were gathered from interviews with 697 smallholder farmers in 9 administrative districts of Sri Lanka. The five main capital assets are: Physical (P), Human (H), Financial (F), Social (S) and Natural (N).

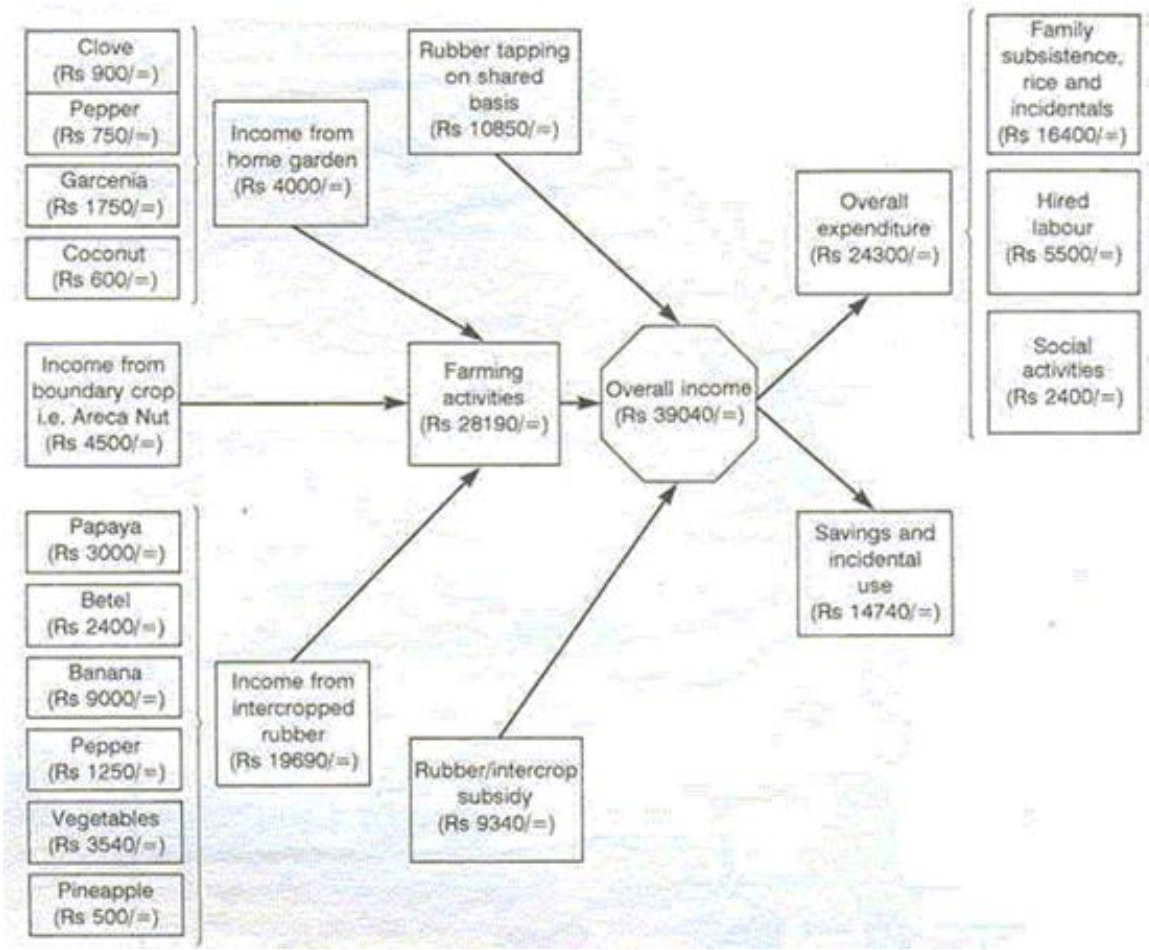


Figure 2. Cash flow depicting the source of annual income and expenditure of a smallholder farmer practising rubber-based intercropping (Rodrigo et al. 2003)

Environmental Impact

H. Environmental impact

24. What are the direct and indirect environmental benefits related to the output(s) and their outcome(s)? ***(max 300 words)***

This could include direct benefits from the application of the technology or policy action with local governments or multinational agencies to create environmentally sound policies or programmes. Any supporting and appropriate evidence can be provided in the form of an annex.

Direct and indirect benefits:

- The adoption of intercropping systems will reduce the pressure on land for agricultural production with increased productivity.
- The adoption also increases ground cover and so protects the soil from erosion.
- Improved organic matter production in the system will contribute to soil organic matter improving the edaphic environment and maintaining the long-term sustainability of agricultural lands.
- Potential use of low level of fertilizer and agro chemicals with the adoption of outputs will reduce pollution aspects of the environment.

25. Are there any adverse environmental impacts related to the output(s) and their outcome(s)? ***(max 100 words)***

It is very unlikely to have any adverse environmental impacts.

26. Do the outputs increase the capacity of poor people to cope with the effects of climate change, reduce the risks of natural disasters and increase their resilience? ***(max 200 words)***

Increased food production and income by intercropping will help buffer the poor against the adverse effects of climatic variation.

Intercropping provides improved growth of rubber plants hence earlier maturity and this increases the resilience of farmers by providing earlier, higher and steady income.

Crop diversification through intercropping is a means of coping with climate change because different crop durations increases efficiency of resource use and reduces the risks from natural disasters such as diseases and pests.

Annex

References

Gray, A. (1997). Report for the Institute of Terrestrial Ecology (Bangor) on a Visit to Sri Lanka to Assess the Market Impact of a Potential Increase in Production of Banana Resulting from High Density Intercropping of Banana with Rubber. Natural Resources Institute, UK. pp. 33.

Janowski, M. (1997). Report on an Analysis of Rural Livelihoods and Poverty in Two Villages in Sri Lanka. Natural Resource Institute, UK. pp.36.

Iqbal, S.M.M. (2003). Factors limiting productivity and adoption of rubber/tea intercropping in the low country wet zone of Sri Lanka, Doctor of Philosophy, July 2003, University of Essex/Writtle College, UK.

Rodrigo, V.H.L. (1997). Population density effects on rubber/banana interculture systems. PhD Thesis, University of Essex, UK.

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.

Rodrigo, V.H.L. (2002). Rubber based intercrops for improved productivity: the best available today. In Global competitiveness of Indian Rubber Plantations Industry: Rubber Planters' Conference India 2002 (Ed. C. K. Jacob), Rubber Research Institute of India, Kottayam, India, pp. 24-25.

Rodrigo, V.H.L., Wickramarathna, N.A.A.D. and Vidanapathirana, R.D. (2004). Productivity and tapper shortage in rubber plantations: how low frequency tapping can address the shortage of tappers in rubber plantations of Sri Lanka. Proceedings of the first symposium on plantation crop research, July 8-9 2004, BMICH, Colombo. pp. 32-42.

Rodrigo, V.H.L., Stirling, C.M., Teklehaimanot, Z. & Nugawela, A. (1997). The effect of planting density on growth and development of component crops in rubber/banana intercropping systems. *Field Crops Research*, **52**, 95-108.

Rodrigo, V.H.L., Stirling, C.M., Teklehaimanot, Z. & Nugawela, A. (2001a). 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., Stirling, C.M., Naranpanawa, R.M.A.K.B. & Herath, P.H.M.U. (2001b). Intercropping of immature rubber; present status in Sri Lanka and financial analysis of rubber intercrops planted with three densities of banana. *Agroforestry Systems,* **51**, 35-48.

Rodrigo, V.H.L., Thennakoon, S. & Stirling, C.M. (2001c). 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.

Rodrigo, V.H.L., Stirling, C.M., Thennakoon, S., Senivirathna, A.M.W.K. & Pathirana, P.D. (2003). Technology refinement of rubber/banana intercropping using a farmer participatory approach. *Tropical Agricultural Research and Extension*, **6**, 77-84.

Rodrigo, V.H.L., Stirling, C.M., Silva, T.U.K. & Pathirana, P.D. (2005a). The growth and yield of rubber at maturity is improved by intercropping with banana during the early stage of rubber cultivation. *Field Crops Research,* **91**, 23-33.

Rodrigo, V.H.L., Stirling, C.M., Teklehaimanot, Z., Samarasekera, R.K. & Pathirana, P.A.D. (2005b). Interplanting banana at high densities with immature rubber crop for improved water use. *Agron. Suntain. Dev.* , **25**, 45-54.

Rogers, E.M. (2003). Diffussion of innovations. 5th Edition. New York: Free Press.

Senevirathna, A.M.W.K. (2001). The influence of farmer knowledge, shade and planting density on smallholder rubber/banana intercropping in Sri Lanka. PhD thesis, University of Wales, Bangor, UK.

Senevirathna, A.M.W.K., Stirling, C.M., Rodrigo, V.H.L., Karunathilake, P.K.W. & Pathirana, P.D. (2002a). Is shade important in rubber based cropping systems? Part 1. effect of shade on growth, dry matter partitioning and adaptation of rubber and banana. *J. Rubb. Res. Ins. Sri Lanka,* **85**, 27-38.

Senevirathna, A.M.W.K., Stirling, C.M., Rodrigo, V.H.L., Karunathilake, P.K.W. & Pathirana, P.D. (2002b). Is shade important in rubber based cropping systems? Part 2. photosynthetic performance of rubber and banana under natural shade. *J. Rubb. Res. Ins. Sri Lanka,* **85**, 39-52.

Senevirathna, A.M.W.K., Stirling, C.M. & Rodrigo, V.H.L. (2003). Growth, photosynthetic performance and

shade adaptation of rubber (*Hevea brasiliensis*) grown in natural shade. *Tree Physiology,* **23**, 705-712.

Stirling, C.M., Rodrigo, V.H.L., Sinclair, F.L., Thennakoon, T.M.S.P.K. and Senivirathna, A.M.W.K. (2001). 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.

Sujatha, V.R., Thomas, K.K. & Jose, M. (2006). Rubber-based farming systems; an annotated bibliography. Library and documentation Centre, Rubber Research Institute of India, Kerala, India.

Thennakoon, T.M.S.P.K. (2002). Influence of crop profitability, market, labour and land on smallholder cropping systems rubber growing areas of Sri Lanka, Doctor of Philosophy, July 2002, University of Wales, UK.