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Farming Systems Research for the Small Farm Rubber Sector

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Smallholding and large-scale plantation agriculture are two distinct farming systems for the production of tropical, perennial export crops. The farm management characteristics of smallholding rubber production are that it is a low input/low output system of agriculture. Rubber estate production is a farming system based on high levels of inputs and outputs. The research requirements of small farm and plantation production technology therefore differ. Rubber research programmes in previous years have concentrated on production techniques appropriate for the estate sector. This neglect of research into the specific needs of peasant farmers has led to generally poor acceptance and uptake of innovations by the smallholding sector. Research programmes that take a farming systems perspective are likely to identify new technologies for increasing the productivity of small rubber growers. New rubber cultivars and farm management practices selected for the specific agro-ecosystems and socio-economic circumstances of smallholding agriculture are more likely to be adopted by peasant farmers compared to production systems designed for plantations. Productivity hence farm incomes may be expected to improve with the implementation of production technologies identified for the small farm sector.

The large-scale plantation sector is an important component of the worldwide natural rubber (NR) industry. *Hevea* rubber is, however, predominantly cultivated by small farmers who derive all or part of their cash income from sales of the crop. The farmers growing rubber typically are recognised as belonging to low income, poverty groups within the national economies of the producing countries. There is widespread appreciation among rural development policy makers that one way of increasing the overall income of rubber farmers is through increases in productivity (output per tree, output per hectare, or output per farmer). One of the main methods by which *Hevea* productivity can be improved is by applied biological research on this economically important crop.

The objectives of the paper are two-fold; firstly to assist scientists to identify research programmes of immediate, direct benefit to the smallholder sector. The second, longer term objective is to contribute to the important debate within the NR industry on how to improve the standard of living of small growers. The paper argues that the main thrust of research in the past has generally been towards improving technologies appropriate to large plantations rather than small-scale producers. The emphasis on large-scale production techniques has led concomitantly to generally poor acceptance and uptake of the new technologies by the smallholding sector, though this differs between countries. An additional factor is that the concentration on estate production methods has led to a top-down approach to technology transfer through rubber smallholder extension services.

The development of the farming systems approach to research problems over the past decade has provided researchers with a valuable new tool for the identification of innovations for specific farm types. It is argued that by adopting a farming systems perspective more suitable technologies may be evolved for the small farm sector. The outcome of research

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programmes determined by farmers' needs (bottom-up approach) rather than the preconceptions of researchers is more likely to be put into practice by smallholders. Productivity hence farm incomes may be expected to improve with the widespread adoption of farmer-oriented rubber production techniques.

DEFINITION OF ESTATE AND SMALLHOLDING AGRICULTURE

Estate or plantation agriculture is defined as the production of rubber (and other perennial export crops) by a strictly supervised, wage-earning labour force in large-scale land units under central management. Smallholding producers of the same commodity crops, on the other hand, are independent decision makers who use family labour, which may work on its own or in conjunction with some hired workers, on small-scale land holdings typically 5 ha and below in size. Land owners of small plots who do not work their land but rent the usufruct to landless peasant farmers are not regarded as smallholders; they belong to a petty rentier class. In this case the tenant farmers or sharecroppers who work the land are the actual smallholders even though they do not possess legal title to the land holdings[1-6].

Small growers of perennial crops on large-scale, centrally managed, tightly controlled, Government financed development projects such as land settlement schemes in Malaysia, and nucleus estate projects in Indonesia, West Africa and other parts of the tropics are not regarded as belonging to the genuine smallholding sector. Projects of this type are generally referred to as organised smallholdings. The technology of production on these management and capital intensive development projects has many features of the plantation mode of production[1,3,4,7-10].

FARMING SYSTEMS RESEARCH

The classification of agricultural systems is complex[11] and a number of studies examine farming patterns on both a world wide and regional basis[12-21]. The standard work on tropical agricultural systems is that of Ruthenberg[5] who takes a multi-dimensional, systems theory perspective[22]. Ruthenberg defines an agricultural system as a distinct type of farm organisation based on cropping pattern and cultural practices, which has been developed in response to the ecological, economic and socio-institutional conditions of differing locations[5]. In taking a systems approach to agricultural production the farm (both small-scale and large-scale) is considered not as a fixed state means of production but as a dynamic institution constantly adapting to changes in its external environment[23].

The concept of an organisation as a system in which a number of interdependent variables interact with each other, and with the environment, is known as an open system[24]. In their analysis of organisations, Katz and Kahn[25] consider that nine characteristics define all open systems. For the purposes of this analysis three of the more important characteristics of open systems may be taken as:

INPUT → THROUGHPUT → OUTPUT.

Open systems use inputs from the external environment and transform them within the organisation into some form of product or output which is returned into the environment. Thus a rubber smallholding takes sunlight, air, water and mineral elements from the physical environment, and utilising manual labour and management skills together with the technology of rubber production (the input) transforms them within the organisation structure of the farm (the throughout) into raw rubber (the output) which is sold at the farmgate and returned to the external environment. The basic characteristics of a rubber smallholding when viewed as an open system are shown in diagrammatic form in *Figure 1*.

The World Bank[22] regards studying the farm as a system rather than addressing only its technical or economic dimensions as a substantial step forward in the overall area of agricultural research. There is however no general agreement on what constitutes farming systems research[22,26] although most workers in

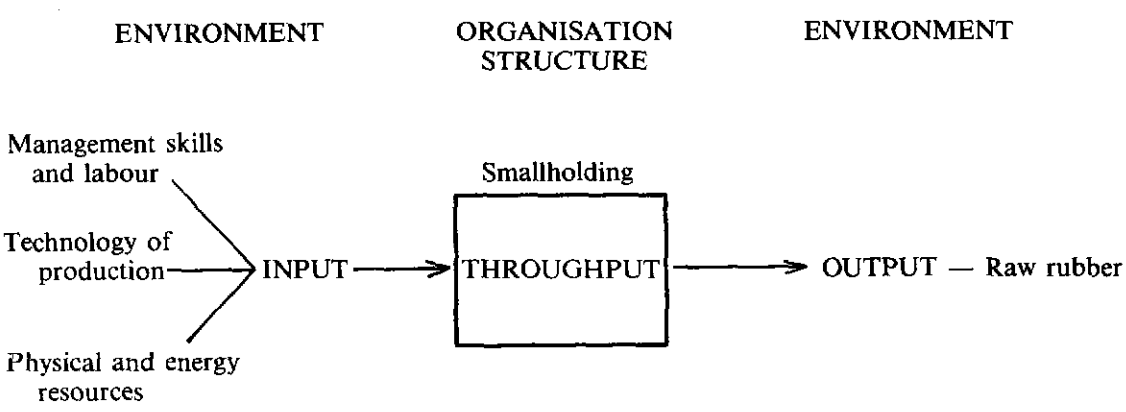

Figure 1. Rubber smallholding as an open system.

the field accept that the farming systems research approach:

- Regards the farm as a system
- Involves the farmers in the diagnosis of the farming system and verification of recommended new practices or inputs
- Is multi-disciplinary and holistic in perspective
- Accepts that the research is applied and aimed at generating near-term viable technologies.

The longer term objective of farming systems research is to design inputs and techniques tailored to the needs of specific agroecosystems and particular socio-economic niches[27].

CHARACTERISTICS OF SMALLHOLDING PRODUCTION

Socio-economic Factors

The general socio-economic characteristics of small farmers in the tropics have been summarised as follows:

- They are poor and have little ready cash.
- Loans to them are usually unavailable or expensive.
- They are conscious of an uncertain environment, of cash shortage, and of family responsibilities and therefore,
- They are risk-averse.
- They often suffer cyclical labour shortage and under-employment.
- They may have opportunities for competing off-farm employment.
- They are economically rational but not necessarily profit-maximising because;
- They have their own scales of utility.
- They live in countries in which the social infrastructure of markets, supplies, and communications is often weak and not to be relied upon.
- They live in societies which normally have clear codes as to what is socially acceptable and what is not[22].

Smallholder producers of perennial crops are inherently weak in husbandry by comparison with the performance of estates which leads to losses in yields[5]. Tree crop farmers rarely attain the high standards of farming found in plantations, the quality of their products is generally low and they are slow to adopt new methods[15,16]. Perennial peasant agriculture is typically characterised by small and often uneconomic holdings, lack of capital, poor

standards of crop husbandry, low levels of productivity, simple processing methods and poor quality produce which all-in-all result in low farm incomes. An important consequence of low levels of production technology especially low yields and poor quality produce, is the generation of low farm incomes despite the fact that unpaid family labour is employed[5,15,16,28]

The characteristics of the smallholding rubber sector are similar to those described for other small-scale tree crop farmers. The peasant system of rubber smallholdings suffers from several defects including poor yields and inferior quality of products compared to the estate mode of production. The typical small producer finds it difficult to take advantage of new technologies and economies of scale. Rubber farmers generally lack facilities for upgrading their processed rubber and face problems in the marketing of their produce. Labour performance in the smallholding sector is observed to be less productive than in plantations[8,29-35].

The crux of the matter, taking a socio-economic perspective, hinges on the low income of rubber smallholder families which is a resultant factor of low productivity and the small size of their holdings. Poor standards of production technology result in the smallholding sector being inferior to the estate sector so that independent small farmers are left behind in the overall development of the NR industry[6,34].

Poor Yields

Yield data from large estates are easily recorded and the figures have a high degree of accuracy. The collection of yield figures from a large number of independent smallholdings, on the other hand, is difficult and it is generally acknowledged that data from this sector are less reliable than from estate sources. Nevertheless, published figures from a number of producing countries show that yields from smallholdings are about 30% to 50% lower than estate yields *(Table 1)*. The same trend in productivity is discernible when yields from the plantation and small farm sectors are compared for other commodity crops that enter into the world export trade. *Table 2* illustrates the point.

Low Cost Production

The fact that peasant production can still compete with estates, despite obviously poor cultivation and husbandry techniques is considered by Ruthenberg to be explained by low costs of production. The recurrent cost

TABLE 1. RUBBER ESTATE AND SMALLHOLDING YIELDS

Country	Yield (kg/ha)	
	Estate	Smallholding
Malaysia[29] (peninsula)	1 428	1 050
Malaysia[35] (peninsula)	1 194	727
Indonesia[29]	1 284[a]	504
Indonesia[36]	850-950	350
Sri Lanka[29]	1 112[a]	750
Sri Lanka[37]	1 000	450
Papua New Guinea[38]	500-600	200-600
	1 400 best managed	
Liberia[39]	1 200	400-600
Liberia[40]	1 250-1 350	470
Nigeria[40]	900-1 000	500-800

[a]State-owned plantations

TABLE 2. ESTATE AND SMALLHOLDING YIELDS (OTHER CROPS)

Crop	Country	Yield (kg/ha)	
		Estate	Smallholding
Oil palm[41]	Papua New Guinea	2 286	748
Coconut[42]	Papua New Guinea	900	500
Cocoa[43]	Papua New Guinea	300–700	250
Cocoa[44]	Malaysia	1 080	850
Cocoa[45]	West Africa	785–841	183–221
Tea[46]	Kenya	2 230	851
Coffee[47]	Kenya	1 078	633
Coffee[48,49]	Papua New Guinea	2 000	700

schedules of estates and smallholdings are different since most of the labour employed by small farmers is either unpaid family labour or receives far less than the rates laid down by minimum wage legislation that apply on estates[5].

Ruthenberg argues that the whole situation is different as far as costs are concerned between plantations and small farms. He notes that a large-scale estate must bear an investment cost for land clearing and crop establishment; workers' houses, hospital, roads and other infrastructure; and the factory. In family holdings there is no expenditure on expensive infrastructure nor is there investment in capital intensive processing equipment. Estates must bear the cost of clearance work, whilst on smallholdings the land is in any case cleared to grow subsistence crops. It costs little extra for farmers to set plants of a future perennial crop in the cleared land. Intercropping the perennial crop with arable food crops in the early years bridges the period when there is no harvest. These combined benefits give the smallholder a distinct cost advantage[5].

The competitive advantage of smallholders over estates for rubber production because of greater economy of resources, particularly labour, has been stressed by Bauer[50–55]. This viewpoint has been challenged by Benham and Silcock who question the argument that estates compare unfavourably with smallholdings that employ family labour[56,57]. Courtenay is also of the opinion that is extremely difficult to compare with any certainty the true productivities of smallholders and estates. Thus Courtenay writes that it is likely that the differences, even with a crop like rubber where real competition is feasible, are not invariably in the smallholder's favour[1]. Grigg similarly takes the viewpoint that it is difficult to make a convincing economic case for the superiority of the smallholding over the plantation and that the latter's efficient farming methods and power of earning foreign exchange seem to be powerful assets to a developing country[15].

Low Risk

Smallholders are more resilient to trade depression than estates since farmers tend to be highly price elastic with their inputs. In times when producer prices fall peasant farmers cease production and neglect their crop. The farmer has his cash earnings reduced in this period but he still has his livelihood from subsistence cultivation. When commodity prices increase the trees are harvested once again, and farm incomes rise accordingly[5,58].

In contrast, estates tend to maintain husbandry and production levels, irrespective of ups and downs in commodity prices. Ruthenberg considers these differences explicable by the relatively short time horizon of smallholders compared to the long-term view taken by plantations[5]. Another important reason why estates continue production is the large fixed

costs in overheads and labour wages that have to be paid irrespective of world market price fluctuations.

CHARACTERISTICS OF ESTATE PRODUCTION

The farm management advantages of growing perennial tree crops on a large scale do not lie in the labour economy. The use of labour-saving equipment is important only with perennial field crops like sugarcane, and where harvesting can be fully mechanised as on the tea plantations in the Western Highlands of Papua New Guinea. The competitiveness of plantations growing rubber and other tree crops in relation to smallholdings with their cheap production methods is based on:

- The rapid and consistent use of technical advances in crop production
- The more efficient organisation of delivery of the crop to the processing factory
- The more efficient processing of the product
- The better access to markets and capital[5].

Large plantation enterprises take advantage of modern technology and typically operate their own in-house experiment stations or contribute financially to the maintenance of a national research institute. Innovations and advances in agricultural methods and processing technology are rapidly applied on the estates. The skilled supervision of labour, and scientific management of land and the crop, by professional managers and agricultural specialists result in high standards of crop production and concomitant high yields. Compared to smallholdings, plantations harvest larger quantities per hectare. Furthermore, the high degree of control in handling a perishable commodity results in raw materials of considerably better quality being delivered to the estate factory.

Processing of the crop is carried out to high standards so that the quality of the end product can be sold at advantageous prices. Large size makes for economies of scale especially in the use of complex, expensive processing equipment and transport facilities. By-products and residues being sold off to local manufacturers, or used as fuel in the processing factory, or returned to the land as fertiliser, are used efficiently.

All told, a return per hectare or per worker is obtained that is typically greater than that from small farmers. Plantations, therefore, produce high net earnings of foreign exchange and a high taxable income which can be used for general economic development[1,4,5,15–19,31,35,58–72].

AGRICULTURE SYSTEMS PERSPECTIVE

It is argued that the estate sector is a high productivity/high quality/high income producer of export commodity crops while the opposite holds true for small farm producers. Peasant production of perennial crops tends to be characterised by low levels of yield and quality of produce which lead to poor returns per worker, per hectare and per tonne of output; consequently to low family incomes. Smallholders are low cost producers compared to plantations. Nevertheless, they are inefficient producers of export crops because low yields and poor quality caused by low input cultural techniques and reliance on low standards in processing technology result in low farm incomes to the family and loss in export earnings to the nation.

Although plantations have high fixed costs brought about by the employment of professional management and specialists such as processing engineers, agricultural scientists and accountants, and large numbers of hired workers, they are efficient producers. The efficiency of plantations is due to high yields, the processing of a good quality end-product attracting premium prices, and the spreading of fixed costs over a large land area. Plantations are the innovators in the introduction of new crop varieties, new cultural methods and improved agricultural produce. The relevant economic aspect of these innovations is that rising wages can be absorbed by higher yields per hectare and improved output per worker.

It is argued that although small growers are low cost producers they are not necessarily price efficient producers when efficiency is measured in monetary terms. This is because family cash incomes and export revenues generated from sales of the commodity crop are low. Another way of measuring efficiency, however, is in terms of labour energy inputs and calorific energy outputs. In the complex, mixed, multi-storey, small farm cropping systems characteristic of oil palm, coconut, cocoa and coffee farming in many parts of the tropics total production measured as calorific values is high. Rubber trees are grown in pure stands but rubber is, on many holdings, only part of a mixed cropping system. Rubber farmers may also grow cereals, other field crops and fruit trees as part of their total farm enterprise. In these mixed farms the energy value of home-grown foodstuffs consumed by the family is substantial while the monetary value of luxury crops (such as betel vine and areca nuts, kola nuts, or tobacco) may be great.

Hevea rubber is planted as a monocrop on both smallholdings and estates unlike, for example, peasant and plantation cultivation of oil palm in West Africa. However, the farm management systems followed by the two sectors of the NR industry are different. Smallholders typically plant their trees at high densities, neglect the immature plants, tap the trees intensively, and use minimal fertiliser and other agrichemical inputs. The estate sector, on the other hand, plants trees at lower densities, maintains each tree individually during immaturity, exploits the mature trees by using a number of sophisticated tapping systems, and has high agricultural standards based on the use of agricultural chemicals, fertilisers and skilled management inputs.

The viewpoint is put forward that plantation and smallholding crop production technologies may be regarded as two separate farming systems. It is argued that plantations are not very large-scale smallholdings; nor are smallholdings very small plantations. In a nutshell the plantation mode of production is characterised by a high input/high output system of agriculture. The main feature of smallholdings is a production system based on low inputs and low outputs for the cultivation and processing of the same export crops. Support for this proposition comes from the World Bank in a recent review of its role as a development institution. Experience of World Bank lending for tree crop agricultural projects has revealed that different production technologies are needed for estates and for small village plots[73].

RESEARCH BIAS

If plantation agriculture and peasant farming are distinct agricultural production systems it follows that the research requirements of plantation and smallholding agriculture differ. Barlow and Peries[74] have reviewed research programmes in the major rubber-producing countries and have concluded that until recently there has been an almost exclusive concentration on techniques and technologies appropriate for large-scale plantations. They argue that, because of the emphasis on capital intensive, labour-saving innovations, the new technologies are not generally suitable for small rubber farms. A similar situation is reported in the field of coconut research where efforts to increase production have been based on a high input technology inappropriate for smallholders[75]. Indeed a general feature of tropical perennial export crop research is that research and development programmes tend to be controlled by the industry[22] which typically is dominated by plantation company interests[76]. For example, research into oil palm husbandry and palm oil processing in South-East Asia, the main production area is carried out almost exclusively by in-house research stations belonging to large estate groups.

The bias against the small farmer in tropical agricultural research is not, however, restricted to rubber and other export commodity crops. Three factors that influence the rate and bias of technical change against the small grower have been identified by a study carried out by the Consultative Group in International Agricultural Research (CGIAR). The first is the difficulty of society (including political decision-makers) in perceiving the expected payoffs

from research which places the scientist in a position of having to create the demand for his future work. Secondly, there is the predisposition for scientists to seek peer recognition through scientific achievements instead of seeking maximum impact on civil society through technological advances. And the third, is the tendency for scientists to link up with the groups in society with the greatest financing capacity, typically the more aggressive producer associations[77].

The result of the bias to large-scale production methods has been that technologies adapted for rubber smallholders have tended to come as a spillover from research carried out on the estate sector[78]. The transmission of the results of research through specialised extension and advisory services has also tended to be a top/down process[22] typically by the introduction of scaled-down versions of plantation techniques. An alternative approach, (implemented with some degree of success in Malaysia) is the collectivisation of adjacent smallholder plots into tracts of land large enough for plantation-scale technology to be applied[32,33,35,79,80]. In the case of scattered, non-collectivised, independent smallholdings the acceptance of the new technologies has been poor[79,81] because the outcome of tree crop research programmes generally has not been tailored to the specific needs of small farmers[22,74,75]. Simmonds suggests that the reason why new production methods proposed by agricultural research have not been adopted is that generally the innovations are unsuitable for the socio-economic circumstances of the farmers[22].

It is argued by Simmonds that compared to traditional research methodology, a research programme taking a farming systems perspective is likely to be successful in identifying suitable technologies for small farmers in the tree crop sector[22]. There is a growing awareness that the smallholding has to be the focus of research programmes and that researchers should work specifically to solve the farmers' problems. The emphasis is on production techniques for small farmers to be able to maximise production with low cost inputs and management practices rather than aim for the highest yield potential[43,74,75,78,82]

DISCUSSION

The adaptation of temperate zone farm management economics to small farmers in the tropics indicates that the farmers are poor, economically rational (but not necessarily profit maximising), risk-averse and subject to high interest rates. They are ready enough, however, to adopt innovations that they themselves perceive to be economically attractive. Many innovations (new exploitation methods, for example) proposed by rubber research institutes have not been adopted readily by the majority of smallholders. Other new techniques, such as herbicide usage for weed control, have been taken up by many small growers. It is argued that the reason for the low uptake of new technologies is because research programmes have generally in the past been oriented towards the large-scale estate sector. This technology which is satisfactory for plantation agriculture has tended to be imposed by extension services on smallholders who may have neither the funds nor the skills to implement successfully the recommended programmes.

Farming systems research is an approach that focuses specifically on methods to solve farmers' problems and which regards the farm as a production organisation (including, importantly, the socio-economic aspects), which reacts with its external environment. Large-scale plantation and small-scale peasant production of perennial crops are regarded as two distinct agricultural systems when a systems perspective is employed. Small farm production technology is a low input/low output system; plantation agriculture, on the other hand, is a high input/high output production system. It follows that the technology suitable for plantations is unlikely to be appropriate for smallholdings. It should prove possible, however, to formulate production technology recommendations suitable for both small farms and large plantations if a systems approach is taken in devising research programmes.

The adoption of a farming systems research approach to *Hevea* production begins with the basic premise that estate and smallholding farm management practices have marked differences and that the technology suitable for one sector is unlikely to be appropriate for the other.

Research programmes for the rubber plantation sector need to be tailored to a high technology mode of production. The objective in breeding programmes for example will be yield maximisation given plantation standards of inputs and management. The goals of a smallholder oriented programme in contrast should be to achieve the highest possible yields in a farming system using only small amounts of capital and few purchased inputs. Breeding for resistance to a wide range of diseases at the expense of the highest yield potential, for example, is considered to be of greater priority in a research project designed for smallholders compared to one for estates.

The implication of this argument is that a two-pronged approach needs to be taken in the formulation of applied research programmes for the rubber industry. Research into the productivity of *Hevea* over the past six decades has been oriented almost totally towards the high input estate mode of production. This programme has been remarkably successful in raising the yields obtained on plantations from between 250–500 kg per hectare for unselected seedlings to 2000–2500 kg per hectare with the latest generation of commercially available high-yielding clones. A research and development programme based on a farming systems perspective could, it is suggested, raise productivity in the smallholder sector by a similar order of magnitude. It is argued, for example, that rubber-breeding programmes would have as their main objective the selection of new generation cultivars responsive to the management system of smallholders. The planting material selected for the small farm sector should, for example, give moderate yields (say 1000–1500 kg per hectare) under the following management regime:

- Close density planting
- Responsive to intensive tapping systems e.g. half-spiral/daily
- Standard fertiliser application while immature but no fertiliser during maturity
- Intercropping and/or a mixed grass interrow during immaturity.

Besides being vigorous in the immature phase and giving moderately high yields when in tapping the new material should also be strongly resistant to the major leaf, stem and tapping panel diseases.

The adoption of a farming systems perspective to research needs for the small farm sector is likely to identify suitable new technologies for increasing production and productivity in smallholdings. Low input methods of production are needed rather than models that emphasise the maximisation of production. There is a need to develop improved cultivars and farm management practices that produce moderate yields but which require only low management skills and few cost inputs. This adaptive approach to village farming systems allows farmers to test progressively various adjustments to their initial low-level input technology. The addition of improvements to the base of the existing technology in a sequential learning process where farmers acquire information and skills over time through a gradient concept is likely to be readily adopted[8,83]. Smallholders who move gradually to a higher technological plane of improved rubber planting material and new, low input farming practices will secure much better yields and in consequence earn higher gross incomes and enhance their standard of living.

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