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Abbreviations

ACIAR	Australian Centre for International Agricultural Research
BSP	Bank South Pacific
CBB	Coffee Berry Borer
CCIL	Cocoa and Coconut Institute Limited
CEC	Cation Exchange Capacity
CGSSP	Coffee Growers Support Service Program
CIC	Coffee Industry Corporation
CLR	Coffee Leaf Rust
CRI	Coffee Research Institute
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DM	Dry Matter
EC	Electrical Conductivity
EHP	Eastern Highlands Province
ENB	East New Britain
FAO	Food and Agriculture Organisation
FDDE	Farmer Demand Driven Extension
FPDA	Fresh Produce Development Agency
GB	Green Bean
HH	Household
JAF	John Allwright Fellowship
K	Kina
LLG	Local Level Government
LSD	Least Significant Difference
masl	meters above sea level
MOP	Muriate of Potash
MPhil	Master of Philosophy
MSS	Monpi Sustainable Services
NARI	National Agricultural Research Institute
NGO	Non-Governmental Organisation
NPK	Nitrogen Phosphorus Potassium
NRM	Nutrient Resources Management
NTC	National Training Council
P & D	Pest and Disease
PGK	Papua New Guinea Kina
PMV	Public Motor Vehicle
PNGOPRA	Papua New Guinea Oil Palm Research Association
PPAP	Productive Partnerships in Agriculture Project

PRAP	Participatory Rural Appraisal and Planning
PSC	Premium Smallholder Coffee
SHP	Southern Highlands Province
SIL	Summer Institute of Linguistics
t	toea
T & V	Training and Visit
TOT	Training of Trainers
TSP	Triple Superphosphate
UNDP	United Nations Development Programme
WHP	Western Highlands Province
WNB	West New Britain

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2 Executive summary

Coffee is the primary source of household income for many highlands communities, where more than 80% of PNG's coffee is produced. However, smallholder production and incomes are well below potential levels and this situation has not changed greatly since the mid-1980s. To date coffee research has largely neglected to examine the role that household socio-economic factors, nutrient management practices and extension services play in affecting smallholder coffee production in PNG. Nor has there been research on the nutrient relationships and pathways between coffee and food crops in the garden system as an integrated whole. Addressing these information gaps is critical for identifying and developing extension strategies for sustainable smallholder production systems.

The research demonstrated that smallholders face multiple and interacting constraints on improving their coffee production. These constraints varied among sites, particularly between remote and accessible coffee growing areas. The most important of these included labour shortages, lack of tools, equipment and farm inputs (particularly labour shortages and inefficiencies), poor market access, prolonged parchment storage in poor conditions and low levels of technical knowledge of farmers regarding coffee husbandry and post-harvest processing. Labour supply constraints in coffee production are, in part, an outcome of the competing demands on the time and labour of smallholder families as they pursue a wide range of subsistence, social, church and cultural activities. They also arise from the underutilisation of family labour due to intra- and inter-household conflict that prevent labour from being deployed and adequately remunerated, and the limited use of labour mobilisation strategies like hired labour to address labour shortages.

Furthermore, the research found major differences in the livelihood priorities and strategies of men and women between locations that have relatively good access to markets and remote locations where market accessibility is very poor and transport costs are high. It is likely that labour investments in coffee have declined in some coffee growing areas with good access to markets and a range of alternative livelihood options in which to invest labour. Some women have been shifting their labour out of coffee to the lucrative fresh food sector because they can obtain better returns on their labour as they have greater control over the income they earn. It is possible that the expansion of commercial vegetable and fruit production in accessible sites and its demands on land and family labour may be at the expense of coffee production. Preliminary findings indicate that cherry sales direct to processors (significant price premium over parchment) and the use of demucilagers (mini wet mills) are a potential strategy for dramatically improving returns to labour through increased productivity and better quality parchment.

The research found that many of the coffee and food gardens were low in essential plant nutrients, especially N, P and K. Leaf nutrient analysis also revealed deficiencies in both Zn and B. Despite these nutrient deficiencies, farmers were losing large quantities of potentially reusable nutrients through inefficient reuse of nutrients (especially N and K) contained in pulp and skin produced during processing to parchment coffee. Effective use of this waste material was typically poor and could be better managed to maintain nutrient levels in coffee gardens. It was also demonstrated that intercropping with fertilised vegetables was an effective means of delivering nutrients to coffee trees. This is particularly important in areas experiencing land pressures and where nutrient depletion risks are greater. Intercropping can also contribute to income diversification, particularly women's income.

The project has filled a gap in the knowledge and understanding of the socio-economic factors and nutrient management practices that affect smallholder coffee production. This information has been used in the drafting of extension training manuals. The manuals seek to improve extension intervention strategies to increase smallholder productivity and

incomes and promote management practices that maintain or improve the nutrient capital of coffee and food gardens. The project findings have also stimulated interest within CIC to explore new research questions and interventions around socio-economics and nutrient management which has the potential to lead to more suitable smallholder extension interventions into the future.

To consolidate and develop the research findings from this project four areas of further work are required: testing, refinement and rollout of the extension training package; further evaluation and testing of demucilagers amongst farmer groups; further investigation of intercropping of coffee with food crops in land-short areas; and promotion of cherry sales to processors in areas with good market access.

3 Background

Coffee Production in Papua New Guinea

Coffee is PNG's second largest agricultural export after oil palm, but employs far more people than oil palm with around 524 000 households (about 2.5 million people) involved in its production (PNG National Census 2011). Coffee is grown in 17 of the country's 22 provinces and over 85% is produced by smallholders (CIC 2008) as part of a food garden/cash crop farming system. Coffee is the primary source of household income for many Highlands communities, especially in remote areas where other income generating activities are limited (Imbun 2014). Average annual foreign exchange revenue from coffee was K511 million from 2008 to 2015 (Bank of PNG 2016). Between 68% and 84% of this total is paid to smallholders (Batt and Murray-Prior 2009:54).

Despite coffee's economic importance for rural livelihoods, national production has stagnated at around one million bags per year and may even be in decline (CIC data). This is despite a rapidly growing population in the highlands coffee growing areas which account for 91% of national production (CIC data). Like cocoa and coconuts, plantation production has declined since the 1980s and smallholders have steadily increased their share of total national production (Figure 3.1).

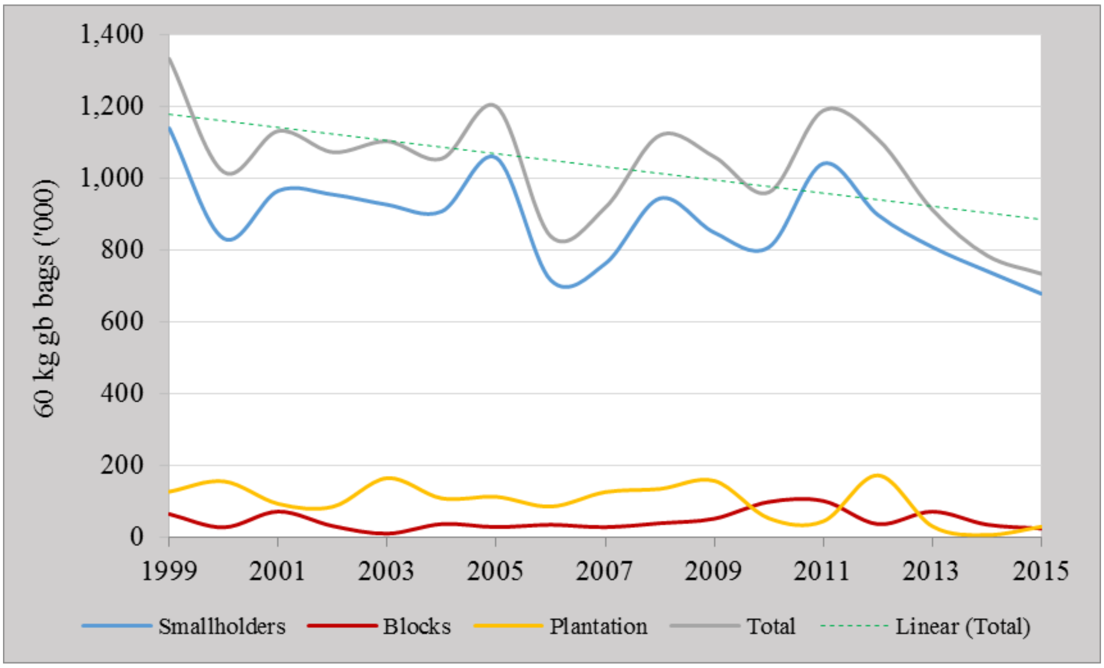


Figure 3.1: Coffee production from 1998 to 2015 (Source: CIC data).

In a review of studies conducted from 1960 to 1995, Bourke and Harwood (2009) estimated smallholders achieved yields of green bean (GB) of 950 kg/ha/yr, while CIC (2007) estimated GB yields of 1100 kg/ha/yr and 750 kg/ha/yr for smallholder rehabilitated and non-rehabilitated coffee respectively. Collett's (1989) estimate of achieved yield of GB was of a similar order at 969 kg/ha/yr, with a harvestable GB yield of 1098 kg/ha/yr. Average plantation yields of GB are almost twice as high as smallholder achieved yields at 1650 kg/ha/yr. Smallholder yields continue to fall and coffee quality remains poor (Quirk *et al* 2007; Batt and Murray-Prior 2009).

Like other smallholder cash crops such as oil palm and cocoa, under-harvesting is likely to be a key factor limiting productivity. Murphy *et al* (2008) reported very high yield losses in coffee production. Although the study did not identify the causes of the high yield losses, it is likely that a significant proportion of losses was due to under-harvesting.

In general, highlands coffee growers, like other PNG smallholder producers of export cash crops, follow a low input-low output system of production. This system is characterised by low labour inputs and a low rate of uptake of new technologies and other extension inputs. A lack of regular pruning of coffee and shade trees, a limited understanding of good husbandry practices and minimal financial reinvestment in smallholder coffee gardens result in low production (Uniquest 2013). Thus production and incomes are well below potential levels and this situation has not changed greatly since the 1980s. The very low yields indicate considerable scope for increasing productivity and incomes through improved maintenance of coffee gardens and higher rates of harvesting.

Previous research has also identified some of the higher-level structural constraints on smallholder coffee production. These include poor and declining market accessibility, high transport costs, limited access to credit, senile coffee stands, land tenure disputes, and law and order problems (Collett 2008, Uniquest 2013; Sengere 2017). Limited access to regular extension advice and training due to under-resourcing of extension services is also a considerable problem as it restricts the flow of new technologies and information to assist smallholders to increase their production (Fleming and Antony 1993 Batt and Murry-Prior 2009; Uniquest 2013). Since 2003, only one to two extension officers are stationed in each of the coffee-growing provinces (CIC 2008). Other factors such as limited supply chain linkages among value chain actors, poor institutional governance and more recently competition from commercial vegetable production for land and labour in villages close to urban centres such as Goroka and Mt Hagen, have constrained coffee production and the expansion of coffee holdings (Murray-Prior *et al* 2008; Collett 2009; Uniquest 2013; Inu 2015; Sengere 2017). Some of these constraints, such as market accessibility, coffee rehabilitation and credit have been recently addressed in a World Bank-funded project in EHP and WHP.

Improving knowledge of the socio-economic factors, nutrient management practices and extension approaches affecting smallholder coffee production

Little is known about the role that household socio-economic factors, nutrient management practices and extension services play in affecting smallholder coffee production in PNG. This project examined how socio-economic factors operating at the household level interact with coffee garden production systems and the broader extension environment (public and commercial) to influence the productivity and incomes of smallholder families. Through developing a better understanding of each of these areas and how they interact, the project aimed to identify and develop ways to improve nutrient management, extension delivery and the mobilisation of labour for coffee production.

Four study sites in EHP were selected for data collection (Figure 3.2): Asaro and Bena villages, with relatively good road infrastructure and close access to markets at the nearest urban centre of Goroka; and, Baira and Marawaka, remote villages with no road access and limited access to services.

To date most coffee research has neglected to consider the interaction between coffee, food crops and broader livelihood strategies, and what motivates or constrains smallholders to invest time and labour in coffee production. This project addressed these information and knowledge gaps. There have been some recent ACIAR studies on supply chains in coffee (Batt and Murray-Prior 2009) and in coffee processing (Driscoll *et al* 2010). However, there remains little knowledge of the household socio-economic factors operating at the beginning of the supply chain that affect decisions regarding farm management and the uptake of technologies.

An area of research focus in this study was to investigate how household labour is mobilised in coffee production and the constraints on family labour. Despite smallholder coffee producers depending largely on family labour for harvesting and farm maintenance tasks, there is little knowledge of how household labour dynamics influence coffee production. In PNG, men typically control the income earned from women's labour in commodity production. Studies in the 1980s showed that women's labour input alone in coffee production may not give them secure rights to the income generated from their labour, often resulting in gendered conflicts over women's labour and remuneration (e.g. Strathern 1982; Sexton 1986; Johnson 1988; Overfield 1998). These conflicts over the remuneration of labour can have a negative impact on the quantity and quality of smallholder production. For example, Overfield (1998) in a study of coffee production in the Benabena District, EHP, argued that the poor returns to women's labour constrained the supply of female labour in coffee production to the extent that smallholder production and incomes were reduced significantly.

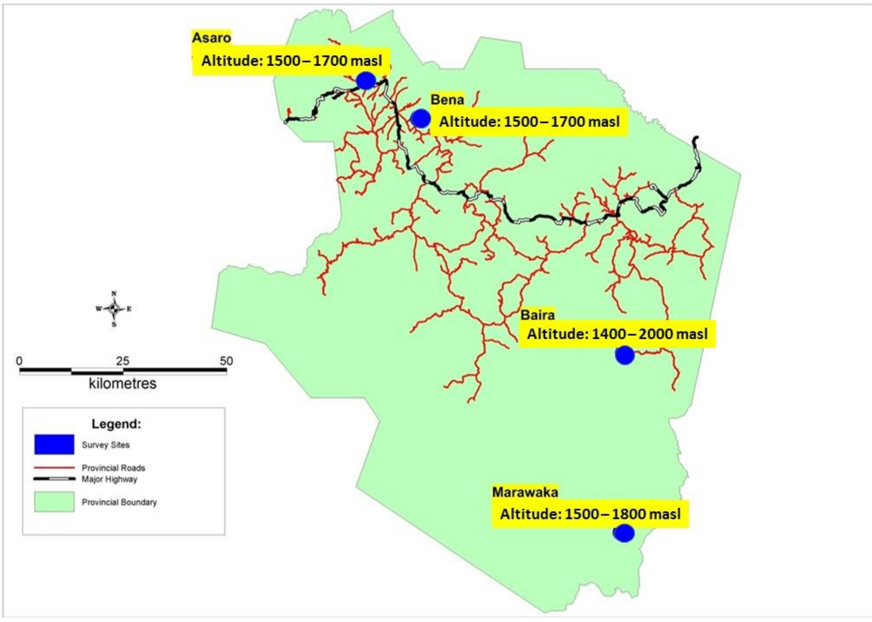


Figure 3.2: Field sites in Eastern Highlands Province

Apart from Overfield's 1998 study, no recent data are available on household labour dynamics based on time allocation studies, and no studies have explored conflicts over labour and land for coffee. Anecdotal evidence suggests inter-generational conflicts are acting as a disincentive for younger people to invest labour in coffee production. Information concerning intra-household gender and generational labour issues and how income from commodity production is distributed within households can provide insights into the factors affecting smallholder productivity, agronomic and farm management strategies and the uptake of extension and new technologies. This project aimed to develop a greater understanding of these factors. Such intra-household information is critical for designing appropriate smallholder extension interventions as illustrated in earlier ACIAR studies in the oil palm industry where successful alternative smallholder payment systems were developed to address gender and inter-generational labour constraints in oil palm production (Curry and Koczberski 2004; Koczberski and Curry 2008).

There are also knowledge gaps in the nutrient management practices of smallholders and the nutrient status of their coffee gardens. This project examined these issues. Although there has been a small amount of work on smallholder coffee blocks (Harding 1991), the nutrient status of smallholder coffee is largely unknown – although it is expected to be low. It is widely recognised that there are many nutrient deficiencies limiting agricultural productivity in PNG in general (Hartemink and Bourke 2000), in other crops (e.g. sweet potato) in coffee growing areas (Bailey *et al* 2009; SMCN/2004/067; SMCN/2005/043) and coffee plantations in particular (Harding and Hombunaka 1998). There is a capacity for change. Yield increases have been demonstrated in sweet potato with increasing rates of applied compost in Southern Highlands Province (SHP) (Floyd *et al* 1987), which suggests a response to improved nutrient management. Although preliminary, more recent results from project SMCN/2004/067 in EHP are consistent with the results of Floyd *et al* (1987).

Furthermore, no work has examined the nutrient relationships and pathways between coffee and food crops in the garden system as an integrated whole. The points in the food/coffee farming system that are vulnerable to loss of nutrients or have the most potential to capture nutrients remain unknown. Nor are there studies that have examined interventions in the food/coffee system that may capture, use and reuse nutrients in the most efficient and productive way. For nitrogen in particular, leaching losses can lead to acidification as can the normal processes of product export. Acidification is an insidious process in that it is usually not noticed until it has permanently modified the soil, usually by reducing nutrient holding capacity and availability of nutrients and thus potential productivity. This project examined the nutrient status of smallholder coffee blocks and the nutrient pathways between coffee and food crops. While knowledge of nutrient status and nutrient pathways will not, of itself, increase productivity, it will inform the socio-economic and extension interventions of the most nutrient-efficient points of intervention that will maintain or enhance the nutrient capital required to support a sustained increase in productivity.

Finally, there have been no recent studies on the effectiveness of extension in addressing low smallholder production. Despite the recent implementation of new extension approaches by public and commercial sector providers, none has been evaluated. In this project these new approaches were examined. In 2004 CIC trialled a new extension approach, PRAP (Participatory Rural Appraisal and Planning) a form of Farmer Demand Driven Extension (FDDE – Section 7), which was a key element of an earlier ACIAR project (Api *et al* 2009; Batt and Murray-Prior 2009). The effectiveness of the new extension approach was evaluated in this project to determine if there was room for improvement, and how it could be scaled-up and remain financially sustainable. Exporter/processors too are moving towards developing reliable coffee sourcing chains to smallholder coffee farmers by forming farmer groups, developing in-house extension and beginning a range of coffee certification options for access to new market opportunities. The project assessed the extent to which these approaches met the needs of farmers and the requirements of the rapidly growing speciality markets like Fairtrade, organic and single origin coffees where quality and sustainable production practices are assuming greater importance for certification (see Batt and Murray-Prior 2007).

Developing new research approaches to understanding smallholder production

This project took on a new research approach to that typically adopted in studies examining the low productivity of smallholders. In previous research there has been a tendency to examine smallholder coffee production in isolation of the broader household livelihood strategies they pursue. This approach has failed to acknowledge that coffee production is embedded in broader agricultural, social and economic systems that influence the decisions made by smallholder families. The methodological approach taken in this project was based on the tenet that coffee production is but one of a range of livelihood strategies smallholders undertake. The approach also integrated nutrient management, extension and socio-economic factors in the examination and analysis of smallholder production. Such an approach aimed to move away from more conventional technical and top-down approaches and single disciplinary perspectives that have been commonly used to examine smallholder productivity.

There were other reasons why the project took a multi-disciplinary and integrated research approach to examining smallholder production: It was considered that such an approach increased the likelihood that the research outcomes would reflect the needs and priorities of smallholders, and therefore be more successful than previous top-down and largely technical initiatives to raise smallholder production and incomes. For example, by placing the analysis of soil fertility and nutrient pathways in its socio-economic context, the project developed good insights into why nutrient pathways are managed, in particular ways, by smallholder families. This has enabled a more informed and accurate assessment of what is, or is not, possible to change to increase smallholder production, and where minor changes in current extension practices may facilitate the adoption of better soil management strategies.

4 Objectives

The project aim was to address low smallholder productivity and incomes through identifying and developing ways to improve nutrient management, extension delivery and the mobilisation of labour for coffee production. Achieving this aim required identifying how different socio-economic factors, household characteristics, marketing and biophysical factors interact to determine smallholder production strategies and the uptake of extension and new technologies. It also required developing a good knowledge base of nutrient status and flows including the points in the coffee-food garden production system most vulnerable to nutrient loss. This information base formed the first two objectives which provided the information for the third objective.

The project's three objectives were to:

1. Identify the main socio-economic factors affecting the productivity of smallholders, including how they interact with nutrient management strategies and the uptake of extension and new technologies to design better targeted intervention strategies to strengthen smallholder livelihoods.
2. Document the current status of soil fertility and the pathways of nutrient movement into, through, and out of smallholder coffee and food gardens to identify points of vulnerability to nutrient loss and points of intervention to maximise nutrient retention or accumulation.
3. Design and test farmer-driven extension initiatives for mobilising labour and improving nutrient acquisition, retention and use in coffee and food gardens to improve the uptake of technologies and extension strategies.

5 Methodology

Location and description of Study Sites

An initial two-week reconnaissance trip was made in 2009 to several coffee growing sites in EHP to assess the diversity of smallholder coffee production systems and assist with the selection of field sites. In consultation with industry personnel, in both the commercial and public sectors, four field sites in Eastern Highlands Province formed the basis of the collection of smallholder socio-economic and nutrient management data: Asaro, Bena, Marawaka and Baira (Figure 3.2; Table 5.1). The villages of Asaro and Bena were categorised as 'accessible' sites as they were within an hour's drive to the provincial capital of Goroka. Baira and Marawaka were categorised as 'remote' because there was no road access and they were a day's walk to markets. Selecting sites based on accessibility to markets allowed the study to examine the influence of access to markets on smallholder coffee production, other livelihood strategies and extension uptake.

Asaro

Three village sites were selected: Kenemba, Nahoma and Okesa. Kenamba and Nahoma are dynamic sites undergoing rapid economic and social change. Population densities are moderate to high, with some households experiencing land-shortages. There are many instances of farmers selling and purchasing land within their village areas: some are also renting land to others in the village for food crop production.

The Asaro sites provided interesting insights into land-use change, coffee management strategies, food crop farming systems and the gendered division of labour in regard to coffee and food production. Coffee and vegetable farming are the main cash income activities which compete for farm families' time, labour and land resources.

Good access to the large urban markets of Goroka, Lae and Madang has provided smallholders with the opportunity to diversify their incomes away from coffee. Many villagers are increasingly engaged in the commercial production of carrots, broccoli, cabbage, bulb onion and potato. These crops are providing regular and relatively good incomes for village households. However, at the time of fieldwork vegetable production was severely affected by an extended drought. The impact of the drought was made worse by the degraded piping infrastructure that previously provided most households at Asaro with access to reticulated water.

Bena

The two hamlets of Sogomi and Safanaga were selected for data collection following the abandonment of the initial choice of study sites due to tribal warfare. Sogomi Village consists of five large hamlets and several smaller ones. Coffee production has traditionally been the major source of income for villagers. However, the area is now renowned for its intensive production of pineapples, and farmers, many of whom are women, can earn between K5,000 and K10,000 per annum from pineapple alone. Most of the youth in the area are very industrious and compete among themselves in pineapple production. Citrus cultivation is also a major income earner for households. Many farmers also produce vegetables for the Goroka, Lae and Madang markets. Vegetable and fruit production compete with coffee for farmers' time, labour and land.

During fieldwork, Bena was badly affected by a prolonged drought and people were dependent on store foods and their distant 'bush' gardens near the rainforest. Village gardens were severely drought affected.

Tribal fighting is a major problem in Bena District. However, Sogomi Village has a reputation as a model community that promotes peace amongst the different Bena tribes.

Additional fieldwork was carried out at Bena by two CIC junior research staff who were awarded John Allwright Fellowships – Susan May Inu and Emma Kiup – both conducted studies related to the project. Their results have been incorporated into this report.

Marawaka

Garupme, Kwasilo, Marawaka (village), Maningiri, Jomuru and Marawaka Station were the main village study sites. Narrow dirt roads between the villages around Marawaka station were well maintained though there was no vehicle access at the time of the study. It is possible in good weather to travel by road from Marawaka to Menyamya (and from there to Lae) in Morobe Province. However, the poorly maintained road is rarely used. The villages are accessible by air. Marawaka station has a well-maintained and well-provisioned school that services the villages.

Coffee is the dominant source of income and farmers face many challenges due to their remoteness. Farmers often carry their coffee to Umpa in Menyama, which is a full day's walk. Transporting coffee by air is K3.20/kg (air fare of K320), making it the most expensive site in transport costs. Alternative income opportunities are very limited and income from local food markets in the area is low at less than K20.00 per person per year. Thus families are highly dependent on coffee for cash income. Incomes are very low relative to the Asaro and Bena farmers.

Families maintain large pig herds. Farmers practise a complex nutrient management system, with pig husbandry an important component of the farming system that is dominated by sweet potato production. A huge amount of effort is expended in fence construction and maintenance to protect food crops from domestic and wild pigs (Plate 5.1).

Many traditional practices continue. For example, polygamy remains common with about one-third of men having two or more wives. Many young boys move out of their parents' house to reside in the '*haus man'* when they reach puberty. Some households still make traditional salt from their salt gardens which they trade with their southern neighbours for bark capes. These bark capes are still commonly worn by young and old (Plate 5.2).

Plate 5.1: Garden fence being constructed.

Plate 5.2: Bark capes worn by young and old.

Baira

Tauriana, the study site at Baira, is located in one of the least developed districts in EHP. The site is very remote without road access and has virtually no government services. Fieldwork at this site was postponed twice because of accessibility problems. In the early stages of the project the airstrip was not usable because of very wet conditions, and it was not possible to walk to Baira because the rivers were swollen and dangerous to cross. The difficult terrain and a population of farmers frustrated by the lack of government services, meant that the participation rate of farmers was significantly lower than at other sites.

Transporting coffee is expensive and done by foot often by hired carriers. Poor accessibility also results in very high costs for foods purchased in village trade stores and severely restricted access to government services, such as health and education, among others. There was no school in the community during the four years of the study period.

Due to limited supply of cash in the village, coffee parchment is regularly used as a medium of exchange. At the time of fieldwork, 60 kg bag parchment was worth K100 in the local exchange economy. Store goods were bought with parchment, and a live chicken could be purchased with 10 kg of parchment. Bags of parchment were also being used for bride price, compensation payments and to settle gambling debts.

There were two types of coffee gardens: high altitude (1800–2000 metres) gardens in forested areas close to the village ('bush' coffee) and lower altitude (1400–1600 metres) and more productive coffee gardens in Imperata dominated grasslands ('kunai' coffee). The different altitudes of the coffee results in slight seasonal differences in harvesting and processing. The 'kunai' coffee is harvested in April-May and the 'bush' coffee is harvested from July to October.

Despite poor accessibility, Baira farmers produced the most coffee per household of all the sites in the coffee season prior to the household surveys being conducted. This is largely explained by their association with Monpi Sustainable Services (MSS). Prior to fieldwork in Baira, some coffee farmers were supplying MSS with certified organic coffee. However, due to a breakdown in their relationship with MSS, farmers ceased supplying coffee to the company. During their partnership with MSS, coffee gardens were expanded and production increased. After MSS's withdrawal from Baira, a private mill operator, located near Ulara (near the Summer Institute of Linguistics (SIL) and Ukarumpa), began buying coffee directly from Baira and assisted with transport. This private sector support encouraged Baira villagers to produce coffee.

Pig husbandry has declined in Baira as people have moved to raising goats. Most of the community now belongs to the Seventh Day Adventist church which has prohibited the consumption of pork.

Table 5.1. Description of study sites

Site	Location and physical characteristics	Socio-economic characteristics
Asaro	Located in the lower Asaro electorate in Daulo District, in the north-west of the province. The floodplains and plains of the Asaro Valley dominate the centre of the district and there are mountains in the north, west and south. Average annual rainfall is between 1800 and 2800 mm. Most of the Asaro Valley is at an altitude of around 1600 metres. Estimated rural population is about 40 000 (2011 Census). Asaro also has access to water reticulated from a dam. Unfortunately the infrastructure has degraded and most of the pipes leak; thus wasting water during critical dry periods.	Good access to large urban centres and markets. Vegetable sales are a growing source of income, especially for women. Rapid population growth
Bena	Located in the Ungai-Bena District, and centred in the Bena Bena Valley at an altitude of around 1600 metres, with the Bismarck Range in the north and Unggi Range in the south-west. Average annual rainfall varies between 1800 and 2800 mm, with Mt. Unggai rising to 2400m in the southwest and Mt. Helwig rising to 2700m in the north. The estimated rural population is over 40 000 today (in 2000 it was 31,000 – Hanson *et al* 2001). Population density is high in parts of the district, but varies considerably. It ranges from moderate (21-60 persons/km^2) to high (61-100 persons/km^2) density.	Good access to large urban centres and markets. Vegetable and fruit sales are a growing source of income for women. Land disputes common. Active church/women's groups
Marawaka	Situated in Yelia LLG region of Obura Wonenara District – the most remote LLG in the district. It is south-east of Goroka. Most people live within the altitude of 1400-1800 metres. Average annual rainfall ranges from 1800 mm in the Ramu hills, to over 4000 mm in the lower Lamari Valley. Estimated rural population for Obura-Wonenara district is around 50 000 (in 2000 it was 45 000 – Hanson *et al* 2001). Population density is moderate and within the range of 21-60 persons/km^2.	Very limited income opportunities apart from coffee. Poor market access. Very low incomes. Pig husbandry important component of agricultural system Education levels are low
Baira	Located in Obura-Wonenara District. Most people in Baira live within the altitude of 1800-2000 masl. There is a moderate to long dry season in the north of the district. Estimated rural population for Obura-Wonenara district is probably over 60 000 (in year 2000 was 45 000 - Hanson *et al* 2001). Population density is moderate (21-60 persons/km^2) to high (61-100 persons/km^2) density.	Very limited income opportunities apart from coffee. Poor market access. Goats common.

Methodological Framework

As outlined in Section 3 this project integrated nutrient management, extension and socio-economic factors in the examination and analysis of smallholder production. This broad and integrated research framework required a mixed method approach focussing data collection at the village and household level.

The methodological framework which guided the study drew on information gathered at a workshop with coffee extension officers in 2009 where the key factors influencing smallholder coffee production systems were identified. A review of the literature also informed the methodological framework. Table 5.2 summarises the six main categories of investigation identified in the workshop and in the literature. The table also outlines how each factor was investigated.

Table 5.2. The main categories of factors affecting smallholder coffee production and key approaches to their investigation.

Category	Description	Approaches to Investigation
Bio-physical environment	Includes climate, soil characteristics, slope, altitude and land degradation.	Identify soil types. Measure and record soil physical, chemical and biological properties of coffee-based farming systems. Assessment of nutrient budgets and pathways of coffee-based farming systems.
Agronomic and farm management practices	Management and maintenance of coffee gardens including intercropping, coffee and food garden nexus, shade control, weeding, nutrient and resource management, harvesting regime, uptake of technologies and farm investments, farmer knowledge and skills, post-harvest practices, seasonal variations in management practices, access to labour and land tenure.	Inspection of smallholder coffee gardens to assess soil and coffee garden maintenance and management practices and intercropping. Surveys and interviews with smallholder households to investigate farmer knowledge, socio-cultural and environmental factors influencing maintenance and management practices, and access to land and labour.
Household labour and labour mobilisation strategies	Household relations of production, household demographics, intra-household decision-making over labour, household gender and inter-generational relations and work roles, coffee harvesting strategies, access to household and extended family labour, remuneration of labour, constraints on the supply of labour, use of hired and reciprocal labour, seasonal variations in labour supply.	Surveys and interviews with smallholder households to investigate intra-household decision-making over labour and gender and inter-generational constraints on labour for coffee harvesting. Time allocation studies to determine coffee harvesting, coffee garden management and nutrient management strategies and how they link to broader household livelihood activities and intra-household relations of production.
Household livelihood activities	Includes the diverse economic and social livelihood activities coffee growers undertake. Takes into account returns to labour by gender for different livelihood activities in the context of market access, seasonal variations, access to land and labour, and socio-cultural obligations.	Household socio-economic survey to document smallholder income activities and access to land and labour. Interviews and focus group meetings with smallholders to explore the linkages between coffee production and broader household livelihood strategies.
Agricultural extension environment	The type, quality and availability of extension, public and commercial sector extension, uptake of extension advice and training by smallholders, and the degree to which extension meets the needs of smallholders.	Evaluation of the effectiveness of CIC and private sector extension strategies for meeting the needs of growers.
Market accessibility	Access to markets and its influence on smallholder coffee production, other livelihood strategies and extension uptake.	Interviews with smallholders, extension providers and exporters to understand the interactions between market accessibility, coffee production, other livelihood strategies and extension uptake.

Data Collection

Data collection was carried out by team members from CIC, NARI, CSIRO and Curtin University. Most data were gathered at the household level with a total of 23 weeks of fieldwork conducted in the four field sites during 2010 to 2012. Three data collection trips were made to Bena, Asaro and Marawaka and two fieldtrips to Baira. Table 5.3 summarises the fieldwork periods and the main data collected at each site. Several inter-related qualitative and quantitative data collection activities were conducted at each site which included:

- Baseline household socio-economic surveys
- Inspection and assessment of coffee gardens
- Interviews and follow-up interviews with households
- Village focus group meetings
- Labour allocation surveys
- Dietary intake surveys
- Assessment of farmer technical knowledge and technical needs
- Coffee and food gardens soil and plant material analysis.
- Interviews with extension officers

Table 5.3 Summary of data collection at the four study sites

Study Site	Fieldwork	Socio-economic data collection	Nutrient Management data collection
Asaro	Three fieldtrips during 2010-2012. Total 6 weeks fieldwork plus day visits for intercropping trials.	Household socio-economic surveys and informal interviews with 103 households. Farmer technical knowledge and farmer technical needs assessment of 103 households. Labour allocation surveys and informal interviews among households over two 10 day periods during the coffee season (32 households) and non-coffee season (11 households). Focus group and community meetings. Dietary intake surveys for 32 households over two 10 day periods during the coffee season and 11 households during the non-coffee season.	Block management assessment of 131 coffee gardens belonging to 103 households. Twenty-four soil, 24 leaf and 18 berry samples were collected from 24 smallholder coffee gardens. Food crop samples (96) from 24 smallholder food gardens. Structured interviews with households on nutrient management strategies on 131 coffee gardens. Nine intercropping and nutrient management trials established.
Bena	Three fieldtrips during 2010-2012. Total 6 weeks fieldwork plus day visits for	Household socio-economic surveys and informal interviews with 91 households. Farmer technical knowledge and technical needs assessment of 91 households.	Block management assessment of 125 coffee gardens belonging to 91 households. Thirty-three soil, 32 leaf and 27 berry samples were collected from 33 smallholder coffee gardens.

	intercropping trials.	Labour allocation surveys and informal interviews among households over two 10 day periods during the coffee (27 households) and non-coffee seasons (11 households). Focus group and community meetings. Dietary intake surveys for 27 households over two 10 day periods during the coffee season and 11 households during the non-coffee season.	Structured interviews with households on nutrient management strategies on 125 coffee gardens. Food crop samples (96) from 33 smallholder gardens. Nine intercropping and nutrient management trials established. An additional 216 soil samples and 129 plant samples were analysed as part of Emma Kiup's JAF.
Marawaka	Three fieldtrips in 2010 2011 and 2012. Total 7 weeks fieldwork	Household socio-economic surveys and informal interviews with 96 households. Farmer technical knowledge and technical needs assessment of 96 households. Labour allocation surveys and informal interviews among 32 households over a 10 day period. Focus group and community meetings. Dietary intake surveys for 32 households over a 10 day period in November 2011.	Block management assessment of 131 coffee gardens belonging to 96 households. Thirty-five soil, 35 leaf and 27 berry samples were collected from 35 smallholder coffee gardens. Food crop samples (56) from 35 smallholder gardens. Structured interviews with households on nutrient management strategies on 130 coffee gardens.
Baira	Two fieldtrips in 2011 and 2012. Total 4 weeks fieldwork.	Household socio-economic surveys and informal interviews with 42 households. Farmer technical knowledge and technical needs assessment of 42 households. Labour allocation surveys and informal interviews among 14 households over a10 day period. Dietary intake surveys for 14 households over a 10 day period in April 2012.	Block management assessment of 55 coffee gardens belonging to 33 households. Twenty-three soil, 24 leaf and 12 berry samples were collected from 23 smallholder coffee gardens. Food crop samples (24) from 23 smallholder gardens. Structured interviews with households on nutrient management strategies on 54 coffee gardens

Field trip 1

During the first round of fieldwork, household selection was done at each site with the help of village and clan leaders. Several meetings were also held with each '*haus lain'* prior to data collection. For each household selected, a household socio-economic survey and a baseline assessment of farmer technical knowledge and technical needs were conducted. For each household this was followed by an inspection and assessment of the closest primary coffee garden to the respondent's house (see Figure 5.1). The primary coffee gardens were inspected for coffee health, shade and ground cover condition, and a selection of coffee trees were measured for height and trunk diameter. Coffee garden boundaries and tenure status were recorded.

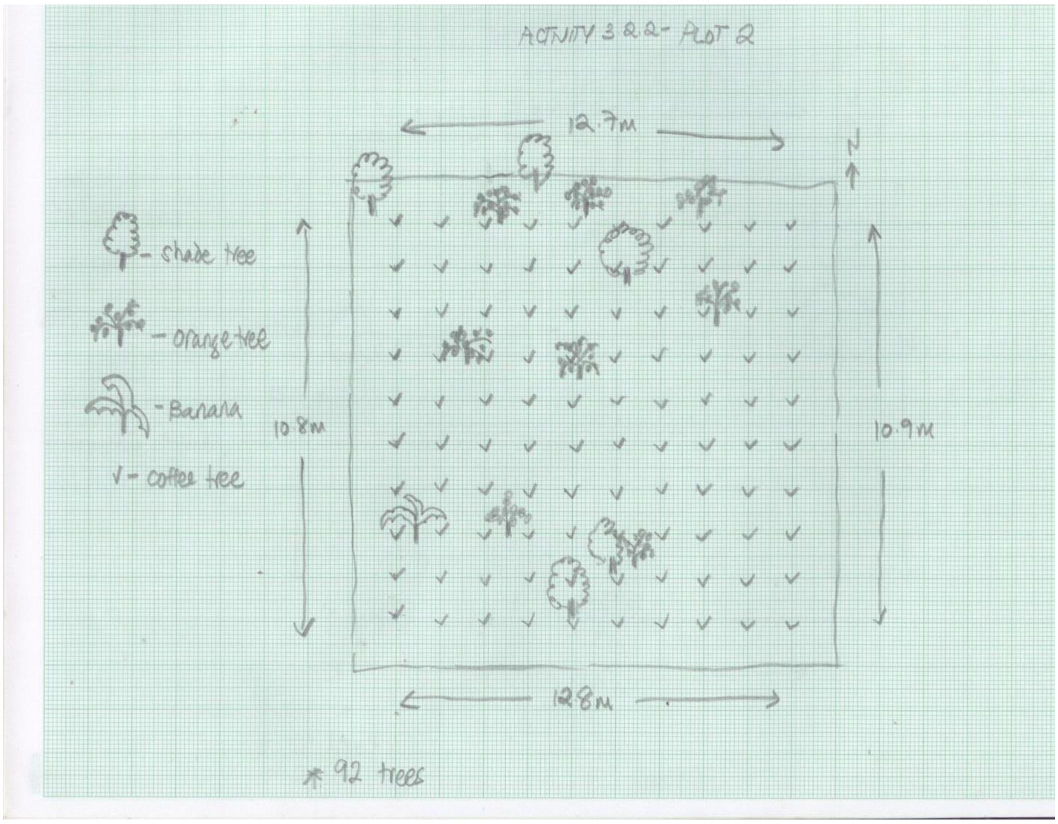


Figure 5.1: Sketch map of a smallholder coffee garden at Bena.

The socio-economic surveys were carried out with both the male and female head of the household present. Information collected included: household demographics; size and age of coffee holdings; agronomic and farm management practices; household labour demands, production costs, perceptions of social, physical and market constraints on coffee production; uptake and quality of extension; land access; subsistence production and production for local markets; and coffee income and other cash income activities. Time spent with a family to complete the household and coffee garden surveys provided the opportunity for informal interviews to take place. Discussions ranged across a broad spectrum of topics which added depth to the data collected in the surveys.

Field trip 2

In the second round of fieldtrips subsets (~30) of the initial households were selected for more intensive data collection. Selection of households was based on household size, age of household heads, number and size of coffee holdings, type of land tenure, and coffee garden maintenance and nutrient management strategies. For a smaller subset (5–16) each household had all coffee gardens located, boundaries recorded and soil, leaf and cherry sampled. Soil samples were, dried, sieved (2 mm) and sent to Australia for analysis of pH, EC, CEC, exchangeable cations, available phosphate, total nitrogen, extractable K, and organic carbon. Some basic soil physical parameters were also assessed to determine the likelihood of run-off and erosion. Coffee leaves and cherries (and components) were dried and sent to Australia. Various food crop samples were also collected opportunistically from food gardens of selected farmers to provide information on nutrient movement. Leaf and vegetable samples were analysed for C, N, P, K, Ca, Mg, S, Fe, Mn, Zn, Cu, B, and Mo. While visiting the coffee gardens, additional management information was gathered through structured and semi-structured interviews with the household heads.

Over a period of 7-10 days farmers were visited every second day to carry out labour allocation surveys to assess household labour allocation, gender division of labour, livelihood activities, labour remuneration, access to and control over household labour and other constraints on labour. Where such activities involved gardens, a further set of questions relating to nutrient management were invoked. During these visits, 24 hour recall dietary surveys were undertaken. The surveys recorded the individual food items consumed by each family member during the daily main meals. Where the food was sourced and if food scraps were used in household food or coffee gardens was also recorded.

Focus group meetings with men and women were also held at all sites to seek clarification and detailed information on household livelihood activities, cultural and social value systems relating to labour and agricultural production, changes in farming systems and nutrient management practices.

Coffee garden inspection data were not collected for Asaro during this trip. They were collected in a subsequent trip.

Fieldtrip 3

In 2012 a third fieldtrip was undertaken by the research team to Asaro, Bena and Marawaka. At Asaro and Bena an additional round of labour allocation surveys and dietary intake surveys were conducted with the same selected households surveyed during fieldtrip 2. The additional data enabled the study to compare labour and diet data during both the coffee and non-coffee season to assess seasonal differences in household economic livelihood activities, labour demands and food consumption patterns.

At Asaro, coffee garden surveys and soil, leaf and vegetable sample collections were completed.

Two focus groups were conducted at Asaro and one at Bena to follow up information collected during fieldtrip 2 and to gather more detailed information on the farming/livelihood systems, labour constraints and the growth of vegetable farming at the two sites.

At Marawaka, garden food crop sampling was done as well as soil bulk density sampling, and soil sampling of minimal/undisturbed areas.

Intercropping trials

Intercropping and nutrient management trials were established at Asaro and Bena. This was to develop the concept that nutrients applied to or supplied-by (legumes) the intercrop would benefit the coffee. Many of the coffee gardens have an open spacing with low levels of shade and are thus amenable to intercropping.

In addition, it was realised that coffee pulp from distant gardens (pulped near the house) would not be returned to those distant gardens because of the weight and volume. However, farmers may be prepared to carry mineral fertiliser to the distant gardens. This trial was to test the concept that pulp from fertilised coffee gardens would be more effective in increasing productivity in food gardens than pulp from unfertilised coffee because of increased nutrient content and biomass.

Three trials were established in each of three farmers' coffee gardens in Asaro and Bena

1. Coffee intercropped with fertilised cabbages. Control, no intervention.
2. Coffee intercropped with beans (legume). Control, no intervention.
3. Food garden fertilised with pulp from fertilised coffee. Control, food garden fertilised with pulp from unfertilised coffee.

Extension assessment

The project also investigated the effectiveness of CIC and private sector extension strategies. Questionnaire surveys were undertaken with: 93 farmers from 9 farmer groups; 15 service providers engaged in training farmers in the FDDE program; and 14 CIC extension staff with experience of the FDDE program. Extension effectiveness was assessed on a number of dimensions including technology uptake, productivity from the perspective of smallholders, institutional support and quality improvement from buyers' perspective.

Demucilagers (mini wet mills)

Demucilagers were initially trialled in 2009 under PHT/2004/017 for the purpose of water conservation. After the trial was completed there was no further work at CIC on the demucilagers, mainly because of the departure of key staff. However, the project team realised that demucilagers had the capacity to improve parchment quality and raise the efficiency of labour.

Three mini wet mills were established with farmer groups supported by AAK. The project team evaluated two of these mini wet mills located at Tolu Village, Banz, Western Highlands Province and at Yonki, Eastern Highlands Province. Data were collected on parchment quality, consistency of product and returns to farmers. Members of the farmer groups were also interviewed about the advantages and disadvantages of the technology. Some preliminary assessment of the potential of nutrient sinks and nutrient recycling was undertaken.

6 Achievements against activities and outputs/milestones

Objective 1: Identify the main socio-economic factors affecting the productivity of smallholders, including how they interact with nutrient management strategies and the uptake of extension and new technologies to design better targeted intervention strategies to strengthen smallholder livelihoods.

No.	Activity	Outputs/ milestones	Completion date	Comments
1.1	Socio-economic survey of 100 households at 4 sites	Identification of the main demographic and socio-economic characteristics of coffee smallholders and farmer knowledge. Report produced for Activity 2.4	Report prepared to inform Activity 2.4 and Final Report	A substantial amount of socio-economic information was collected from over 330 smallholder households. This will be published in due course. Survey data informed the design and content of the draft extension training package (Objective 3).
1.2	Inspection and assessment of 100 coffee gardens at 4 sites (concurrent with 1.1)	Report documenting coffee garden condition, levels of maintenance and intercropping.	Completed	Garden condition was assessed in the closest garden during the '100 household survey' and in all gardens of the more intensively sampled subset of the 100 households. Soil and plant samples analysed for all gardens of the intensively sampled households at each site (115 in total). These included coffee cherry and its components, coffee leaf, and selected food crops. The data informed the design and content of the draft extension training package (Objective 3).
1.3	Semi-structured interviews with sub-sample of 30 households at 4 sites	Improved knowledge of the factors influencing coffee management practices from the perspective of farmers.	Completed	Information from the interviews informed the design and content of the extension training package (Objective 3).
1.4	Labour allocation surveys of 30 households at 4 sites	Improved understanding of the household level factors affecting the mobilisation of labour for coffee production and other livelihood activities.	Completed	At the Baira site it was extremely difficult to carry out household surveys because of the rugged and deeply dissected terrain between dwellings. However, the team managed to survey 14 households under very trying conditions.
1.5	Baseline survey of farmer technical knowledge and technical needs assessment (incorporated in 1.1)	Report on the status of farmer technical knowledge A report on extension systems in PNG	 Draft report completed	Information from the technical knowledge survey informed the design and content of the extension training package (Objective 3).

1.6	Evaluate the effectiveness of PRAP and commercial sector coffee extension	Report on the effectiveness of PRAP and extension systems in PNG	Surveys were completed for 85 farmers from 9 farmer groups, 15 service providers and 14 extension officers. Draft report written	Feedback on draft report received. Report to be finalised.

Objective 2: Document the current status of soil fertility and the pathways of nutrient movement into, through, and out of smallholder coffee and food gardens to identify points of vulnerability to nutrient loss and points of intervention to maximise nutrient retention or accumulation.

No.	Activity	Outputs/ milestones	Completion date	Comments
2.1	Land use and tenure mapped in 4 study sites	Land use maps and range of land access and tenure types documented.	Completed	Approximately 442 coffee gardens mapped as part of 100 household and 30 household surveys. In a subsample, 119 coffee gardens surveyed in detail. Land tenure was recorded for these coffee gardens across all 4 sites. To map land uses other than coffee proved to be too large a logistical task for the project.
2.2	Establish current soil fertility status of smallholder coffee and vegetable gardens	Soil chemical, biological and physical properties, measured and recorded on initial sites selected. Report produced for Activity 2.4.	Completed	All soil and plant samples (coffee and food) were collected for 119 gardens and analysed for nutrients. Soil, chemical, biological (groundcover) and physical properties assessed for 119 gardens.
2.3	Nutrient pathways estimated at same time and locations as Activity 2.2	Amount, location and movement of nutrients determined in coffee-based farming systems. Report produced for Activity 2.4	Ongoing	A detailed study of nutrient movement in cherry coffee components. Some studies in nutrient concentrations in food crops were conducted. The emphasis shifted to coffee pulp because potential nutrient losses appeared to be high and of consequence to farmers. A complete analysis of shade and coffee prunings and food crops was only partially achieved. Emma Kiup is undertaking an MPhil which involves an analysis of shade and coffee prunings and food crops which complements the outputs of Activity 2.3.

2.4	Research review workshops of findings from Objectives 1 and 2, and refinement of activities for Objective 3	Four community meetings held at each field site. Workshop with extension officers. Workshop with senior industry stakeholders to inform industry and receive their feedback on activities planned for Objectives 3 and 4.	Completed	The objectives were discussed with communities in Bena and Asaro. Discussions were held with key extension officers and industry personnel on Objective 3, particularly on the design of the training modules. The mid-term review provided another opportunity for industry personnel and extension providers to give feedback on Objective 3.

Objective 3: Design and test farmer-driven extension initiatives for mobilising labour and improving nutrient acquisition, retention and use in coffee and food gardens to improve the uptake of technologies and extension strategies.

No.	Activity	Outputs/ milestones	Completion date	Comments
3.1	Investigate and promote benefits of companion plants	Measurement of benefits of other crops on yield and nutrient content of coffee.	Trials completed.	Trials set up at Bena and Asaro.
3.2	Design and test strategies for satisfying the nutrient requirements of both coffee and vegetable gardens	Measurement of benefits on yield and nutrient content of coffee and food crops.	Trials completed.	Trials set up at Bena and Asaro.
3.3	Develop and promote partnerships between the commercial and public sectors that better meet the extension needs of smallholder farmers	New ways of delivering extension adopted by the commercial sector and CIC.	A series of training modules are in draft form.	The draft training package under development will involve CIC in a 'train-the-trainer' role. CIC will train private sector extension officers in the use of the package for delivery of extension to farmer groups. The training package requires more work with CIC and work with Monpi, AAK and CARE International to trial the package.

3.4	Develop protocols with CIC/CRI and commercial sector to simplify process of coffee certification and trial these as part of the extension partnership model	New streamlined protocols developed and in use by CIC/CRI and commercial sector.	Draft module developed.	Discussions were held with Fairtrade about generic certification. A module on certification has been drafted as part of the training package on generic certification. The module incorporates some of the common criteria of the main certification organisations, but requires the incorporation of the NRM and socio-economic project findings relating to environmental and social certification criteria. This 'primer' for certification for farmer groups will be part of the suite of training modules of CIC PRAP programmes.
3.5	Investigation of ways to mobilise labour through payment and other incentives such as broadening income opportunities (e.g. intercropping coffee and food crops)	Enhanced livelihood options in coffee-based farming systems for women and marginal groups.	Completed at Asaro and Bena	Intercropping and nutrient management trials were completed at the Bena and Asaro field sites. Part of the success of the intercropping trial at Bena was evident by the voluntary participation of women. The demucilager (mini wet mill) trials were conducted towards the end of the project. They generated very promising results, but further testing is required. They led to improved and more consistent coffee quality, thereby generating better returns for farmers. Labour time saved in processing coffee can be invested in other livelihood activities, including coffee garden maintenance. The promotion of cherry sales to farmers in accessible sites would free up labour for other livelihood activities such as vegetable production for markets in urban centres, as well as provide more time for coffee garden management. This requires further promotion amongst farmer groups.

7 Key results and discussion

One primary purpose of the research was to gain a fuller understanding of the socio-economic, institutional and environmental factors influencing smallholder productivity and production and to identify potential intervention points to strengthen smallholder production and the efficient use of nutrients. While there has been much speculation and conjecture about the causes of the stagnation and decline of smallholder coffee production in the highlands, there has been little detailed empirical local level research since the village-based fieldwork of Collett (1989) and Overfield (1994). Thus the lack of information concerning smallholder coffee production has been a major barrier to improving coffee farmers' livelihoods.

The discussion is in three parts. It begins with an outline of 'who are our coffee farmers' which provides information on their coffee holdings, production, yields, nutrient status market access and the forms in which coffee is sold. Then socio-demographic characteristics of smallholder households are documented including the range of livelihood strategies they pursue. Recent changes in the livelihood strategies in accessible locations are considered in some detail as significant changes are occurring, particularly regarding the roles and status of women in different livelihood pursuits. These broader livelihood changes sometimes have a negative impact on coffee production. This is followed by a detailed analysis of the constraints on smallholder production including those reported by smallholders themselves, observed by the research team at the different fieldwork locations, and reported to us by industry experts who regularly visit coffee farming communities. These include the high costs of market access in remote areas, farmers' low levels of technical knowledge of coffee husbandry and processing, lack of farm inputs, low levels of labour efficiency, and the key socio-cultural and economic factors constraining the supply of labour. The second section considers the role and effectiveness of extension and why extension has been unable to overcome the constraints on smallholder production. The third section examines the nutrient status of coffee gardens and smallholder nutrient management. The recommendations from the research are presented in Section 9.

1. WHO ARE OUR COFFEE FARMERS?

Smallholder coffee families are predominantly subsistence farmers on communally-owned land residing in rural villages where food gardening, family and clan obligations, church activities, income generation and general household activities are part of their everyday routines. People's lives are very local-level focused. Village infrastructure is generally poor with most communities lacking basic infrastructure such as electricity, reticulated water and serviceable roads. Many communities also lack other government services such as schools, health clinics and agricultural extension services. Apart from education, there has been little improvement in development outcomes since the late 1980s, despite a mineral-led development boom.

Like cocoa growers in PNG (Curry *et al* 2007), coffee farmers follow a low input, low output system of production in both subsistence and cash crop production and rely almost entirely on family labour. Coffee productivity and quality are low and are likely to have been in decline for many years (Sengere 2017).

Smallholder coffee farmers are not a homogenous group. Extension and marketing strategies to improve smallholder livelihoods must therefore take into account the diversity amongst farm families. There are very significant differences between locations that have relatively good access to markets and remote locations where market accessibility is very poor and transport costs are high. There are also major differences in the livelihood priorities and strategies of men and women which are also stratified by market accessibility. Also, economic differentiation in rural PNG is increasing: there are now major differences between families with access to sufficient land to enable them to develop a portfolio of livelihoods and those families who are land short. These differences amongst smallholders are reflected in significant differences between households and locations on a range of criteria including income, household assets, educational outcomes and diet quality. In this section we highlight these factors and how they interact to shape livelihood strategies, including coffee production.

Coffee Production

We begin with an overview of coffee holdings and production. It is important to note that because of poor processing techniques (see below), farmers are paid significantly discounted prices for their parchment coffee. Most smallholders receive Y1 prices for their coffee which are considerably less than those received for higher quality grades (Table 7.1), or if they were to sell cherry rather than parchment. Improving incomes is therefore more than a matter of increasing total production: it is also about identifying ways to improve quality. These issues are the focus of this section and Section 9.

Table 7.1. Prices for parchment per kg of various grades.

Grade	Y3	Y1	PSC	X	A & AA
Price	4.01	6.87	7.52	9.18	9.72
Per cent increase on Y1 price	N/A	N/A	9	33.6	41

(Source: CIC Ltd PNG Industry Operations Division Coffee Report No. 72, March 2008, p.22)

Although most coffee purchased from smallholders is Y1 grade, 26% of exported coffee is classed as PSC grade (Premium Smallholder Coffee). This reflects the work of ‘cleaning’ the coffee by processors and exporters to meet international market requirements. Generally, the consensus amongst long-term coffee processors and exporters in PNG is that smallholder coffee quality has been in decline over at least two decades (for a discussion, see Sengere 2017).

Characteristics of coffee gardens

There was considerable variation between sites in the numbers of coffee gardens owned by households, the areas planted and yields (Table 7.2). At Asaro, Bena and Marawaka around 90% of households had between one and four coffee gardens, whereas at Baira almost 80% had more than four gardens. The average area of coffee per household varied from less than half a hectare at Marawaka to over 1 hectare at Baira. At the accessible sites of Asaro and Bena, it is likely that the average area of coffee per household is declining as land pressures grow and more coffee gardens are subdivided amongst sons, and as coffee gardens are converted to other land uses (Inu 2015). The larger average number of coffee gardens per household at Baira is partly explained by the heavily dissected terrain at Baira and households tending to have scattered coffee gardens across different altitudinal zones (Section 5). At all sites, coffee holdings were relatively small, and yet smallholders consistently reported difficulty mobilising labour, particularly for harvesting (see below). Several growers at Baira recently expanded their coffee holdings because they were competing with other farmers in the village who were also increasing their area under coffee. It is likely that Baira has less land pressures than at the more accessible sites to allow the expansion of coffee, although almost 30% of the gardens were more than a 30 minute walk from the house.

There was also considerable variation in the median number of bags produced per household at each site. The starkest difference was between the two remote sites: Baira produced 10.5 bags of parchment per household compared with 4 bags per household at Marawaka. A combination of factors explain this difference. First, during fieldwork, a private mill operator located near Ulara (near SIL and Ukarumpa) began buying coffee directly from Baira and assisted with transport. The increase in production was likely to reflect improved market access at the time of the survey as well as the encouragement that this processor gave to Baira villagers to produce. This illustrates the impact of improved market accessibility and private sector support on household coffee production. Some villagers at Baira suggested in interviews that gambling debts were also driving the increase in production among a few smallholders. Gambling was a significant leisure activity at the time of fieldwork (see below) and some gamblers were borrowing money from relatives living in town to repay their gambling debts. Debts were repaid in bags of coffee, which led some smallholders to increase their production to repay these debts. The combination of improved market access, support from the private sector and pressure to repay gambling debts led to an increase in production.

Table 7.2. Coffee garden characteristics and household production (kg of parchment) by site.

Site	Year	Median No. gardens/ household	Average area/ household (ha)	Average yield/ha/yr (kg of parchment)	Average production/ household (kg of parchment)	Production per adult equivalent (kg of parchment)
Asaro	Current ACIAR project	2	0.72	-	-	-
Bena	Current ACIAR project	3	0.61	522	317	75.4
Baira	Current ACIAR project	6	1.06	766	812	137.7
Marawaka	Current ACIAR project	2	0.38	696	267	39.2
EHP*	2013 (UniQuest)	-	0.82	386	-	-
Bena	1994 (Overfield)	-	0.43	1360	-	-
	1992 (Collett)	-	0.43	1211	-	-
Kainantu	1984 (Harding)	-	-	1038	-	-
Six provinces	1978 (Munnull & Densley)	-	-	938	-	-

(*several districts including: Goroka rural, Henganofi, Kainantu, Tairora and Okapa).

Yields

Yields per hectare at our study sites are considerably lower than yield data recorded at other sites in the Highlands, the exception being the 2013 UniQuest data which estimated slightly lower yields than the present study (Table 7.2). Therefore, yields estimated for more recent studies are aligned with anecdotal evidence from industry experts that smallholder yields have been declining through time.

Understanding why yields are lower at the study sites than those reported in other, earlier studies is a difficult question to answer. Collett's (1992) work at Bena found a relationship between the condition of coffee blocks and yields. It is possible that labour investments in coffee maintenance and other inputs may have declined, especially in coffee growing areas such as Bena and Asaro that have good access to markets and therefore a range of livelihood options in which to invest their labour in addition to coffee (see below).

Senile planting material

One factor contributing to the lower yields is the relatively old and ageing coffee tree stock (Table 7.3). Over half of coffee gardens at all four sites were planted prior to 1990, and at Marawaka only 13% had been planted since 2000. At the accessible sites, the limited planting of new coffee trees in the last decade is likely to reflect rising land pressures and the difficulty of accessing land to plant perennial crops like coffee which tie up land for long periods. Access to land to plant perennial cash crops is therefore likely to be more tightly controlled than access to land for temporary food crops.

Table 7.3. Percentage of gardens planted by age.

	Accessible Sites		Inaccessible Sites	
Year Planted	Asaro	Bena	Baira	Marawaka
Before 1980	28	20	23	29
Before 1990	59	49	49	53
1991-2000	22	28	30	33
2001-2005	9	13	7	6
After 2005	10	11	13	7

The senescence of the stock of coffee trees is compounded by the low quality source of planting material for infill where old coffee trees have died. Many farmers complained that their coffee trees did not yield well. Often this was because farmers used low quality volunteer seedlings obtained from under their worst performing trees in their coffee gardens. The low producing trees are often not harvested nor maintained (no grass slashing) and coffee seedlings sprout under them from unharvested beans that have fallen to the ground. The best trees are more likely to be fully harvested and better maintained: typically there are no volunteer seedlings under them. Hence, through time a coffee garden can be transformed from a potentially high yielding coffee garden to a low yielding one. Some industry experts with considerable experience working with famers reported that this problem is widespread (John Leahy, pers comm; see also Giovannucci and Hunt 2009).

Coffee varieties

There are six commercial varieties of Arabica coffee grown in PNG (Table 7.4). They are all considered to be high yielding by world standards and of excellent quality, although Mundo Novo has a smaller bean size which is a less desirable attribute on world markets (Tom Kukhang, CIC pers comm). Apart from Catimor, these commercial varieties are not resistant to Coffee Leaf Rust (CLR), which is a problem in parts of the highlands. The dwarf varieties, Catimor and Caturra, and the tall variety, Arusha, to a lesser extent, require good coffee management. Under the low input, low output system of production, the more robust and hardier, taller varieties are preferred, especially Typica, and Munda Nova in areas where CLR is not present.

Table 7.4. Varieties of Arabica and specific characteristics.

Coffee varieties	Height	Features relevant to smallholders
1. Typica	Tall	Hardy variety and able to withstand drought. Low management inputs required.
2. Bourbon	Tall	Not as hardy a variety as Typica. Requires good level of coffee management.

3. Arusha	Tall	Not as hardy as Typica. Requires good level of coffee management.
4. Mundo Novo	Tall	Susceptible to Coffee Leaf Rust (CLR) and Pink Disease. Not recommended in areas where CLR is a problem.
5. Caturra	Dwarf	Requires high levels of management input. Not resistant to CLR, thus not recommended in areas with CLR risks.
6. Catimor	Dwarf	CLR tolerant. Requires good level of management. Not recommended except where CLR is a serious problem.

There is greater diversity of coffee planting material in the accessible sites with roughly similar proportions of Typica, Arusha and Bourbon (Figures 7.1a and 7.1b). In contrast, in the remote sites there is a much greater reliance on a single coffee variety: two-thirds of coffee trees at Baira are Typica, while three-quarters of the coffee trees at Marawaka are Arusha. In the accessible sites located nearer to services there is better access to new planting material for farmers while this is much less so in remote locations. Moreover, infill planting material in remote locations is much more likely to be sourced from volunteer seedlings from under old coffee trees which, as stated above, may be contributing to lower tree productivity through time.

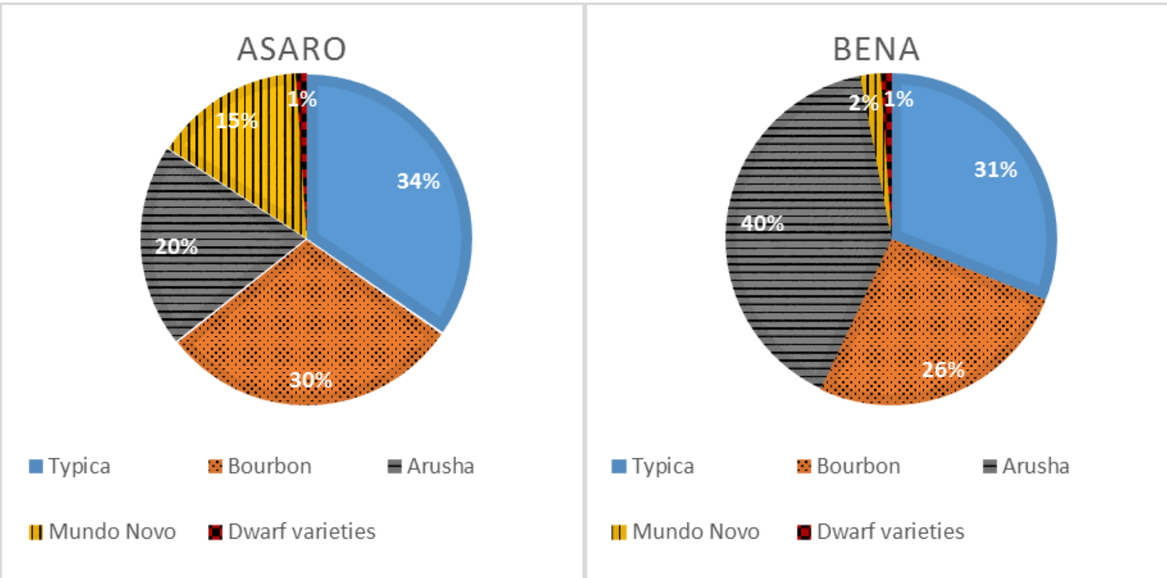


Figure 7.1a Proportions of different coffee varieties at each accessible site (Percent of households).

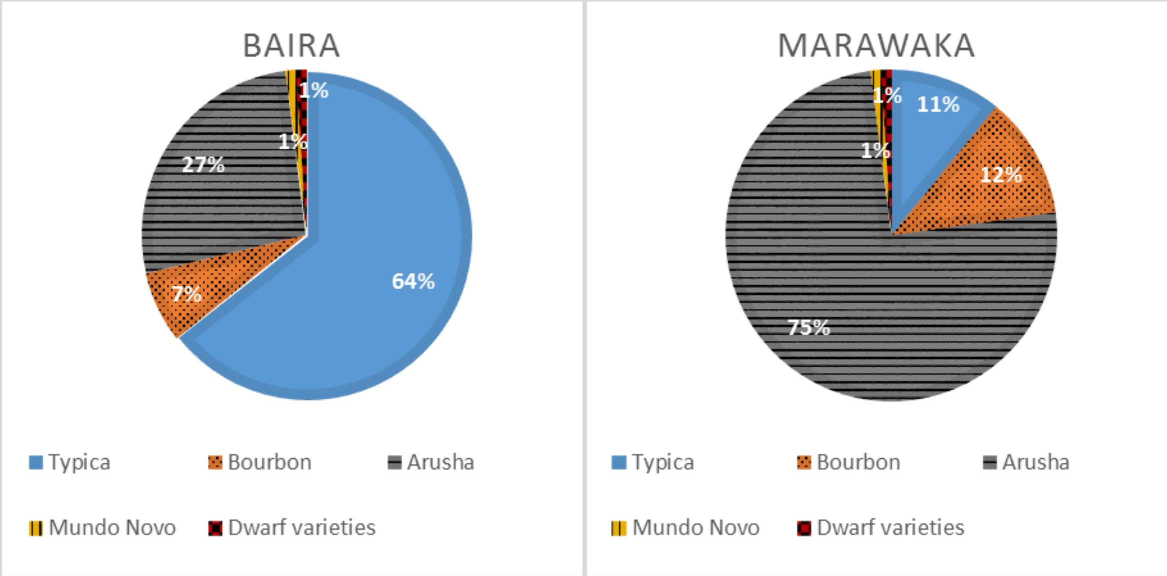


Figure 7.1b Proportions of different coffee varieties at each remote site (Percent of households).

Dwarf varieties of coffee, which are planted at a higher density and yield more coffee per hectare, have not proven popular amongst smallholders (Figures 7.1a and Figure 7.1b). They require much higher levels of management input than the taller varieties. The high labour demands make these varieties inappropriate for smallholders following a low input, low output production strategy, particularly with regards to labour inputs.

There are other characteristics of dwarf coffee types that smallholders do not like and which deter them from adopting these recent varieties. First, dieback is often a problem. In the low input production system, farmers rarely apply fertiliser so the densely planted, potentially high yielding dwarf varieties experience nutrient stress leading to dieback. Second, coffee cherries are packed in compact clusters on the branch which makes the harvesting of individual ripe cherries more difficult and time consuming (Charmetant 1994). Third, smaller tree varieties mean that harvesters must bend over to pick coffee and growers claim they are more likely to experience back problems. With the taller varieties, harvesters simply bend the branches downward to pick them, thereby keeping their backs straight. Fourth, growers complain that the high planting density means that access for harvesting is more difficult. This makes the coffee gardens cold and damp environments in which to work in the early morning. The taller varieties planted at lower density are more accessible for harvesting, and air circulation is better creating a warmer and drier working environment during harvesting.

Forms in which coffee is sold

The majority of coffee is sold in parchment form (Figure 7.2). Understandably, because of distance from markets, parchment sales dominated at the remote sites of Baira and Marawaka. At the accessible sites, it is surprising that more coffee wasn't sold as cherry to processors, given the large price premium paid to growers for cherry over parchment. Processors are willing to pay a premium for cherry because when they, rather than smallholders, process cherry, quality parchment is assured. We calculated a price premium of 32% for cherry over parchment. This premium was similar to Batt and Murray-Prior's (2009) figure of 34%, calculated using an earlier set of data. At Asaro, 40% of households sold some coffee as cherry while at Bena just 7% of households did so. However, these cherry sales were to village-based processors and therefore did not fetch the price premium that large-scale processors pay.

Not one interviewee in the accessible sites was aware of the price premium paid for cherry. Farmers appeared not to take into account the 5:1 conversion ratio from cherry to parchment. It was clear that the very different volume to weight ratios of wet cherry and dry parchment made it difficult for farmers to understand the price premium. Not only were farmers missing out on a substantial price premium by not selling cherry, they were also expending a lot of unnecessary labour in processing cherry into parchment - labour that could have been redirected to other livelihood activities or to coffee garden maintenance (Section 9).

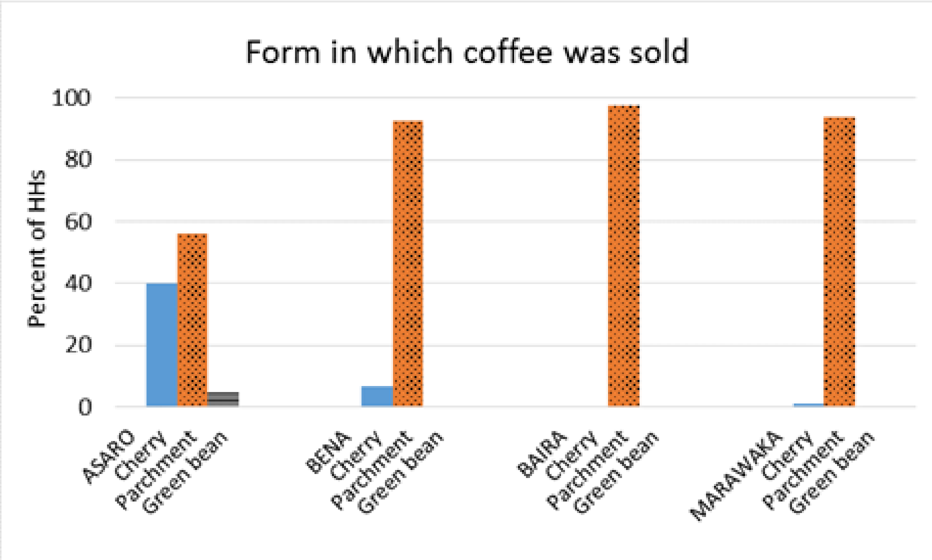


Figure 7.2. Form in which coffee was sold at each site.

A major hurdle for coffee producers throughout most of the Highlands, but particularly in remote locations, is the transport of parchment coffee to market (Plate 7.1). For example, because there is no direct road access to Baira or Marawaka, the main way coffee farmers cart their coffee to buyers in town is by foot over very mountainous terrain and over very long distances. The problem of market access is discussed further below.

Plate 7.1. Growers in remote locations often need to carry their coffee long distances to markets (Photo credit: Joeri Kalwij, MSS).

Household Socio-demographic Characteristics

In the study sites labour for agricultural production is drawn almost entirely from the family. The demographic characteristics of households are therefore important for determining the supply of labour for production. Demographic data were collected from each household involved in the study to determine numbers of adults and children, their gender and marital status as well as education levels and residential status. Children, twelve years and older, were classified as adults because at that age children are making a significant contribution to household economic activities including subsistence food gardening and other livelihood pursuits.

Family size, the age and gender composition of the household are important factors determining the potential amount of labour available for coffee production. However, other factors such as intra-household relations, particularly gender relations, have a significant influence on the willingness of family members to contribute labour to production.

The average family size at the remote sites of Baira and Marawaka was more than one and a half times larger than that of the more accessible sites of Asaro and Bena (Figure 7.3). This is likely to be partly attributable to the higher education levels of women in accessible sites and the influence of modernisation on values like family planning. It is also likely that at the remote sites, better educated adults, who would tend to have smaller families, have moved elsewhere for employment (Figure 7.4).

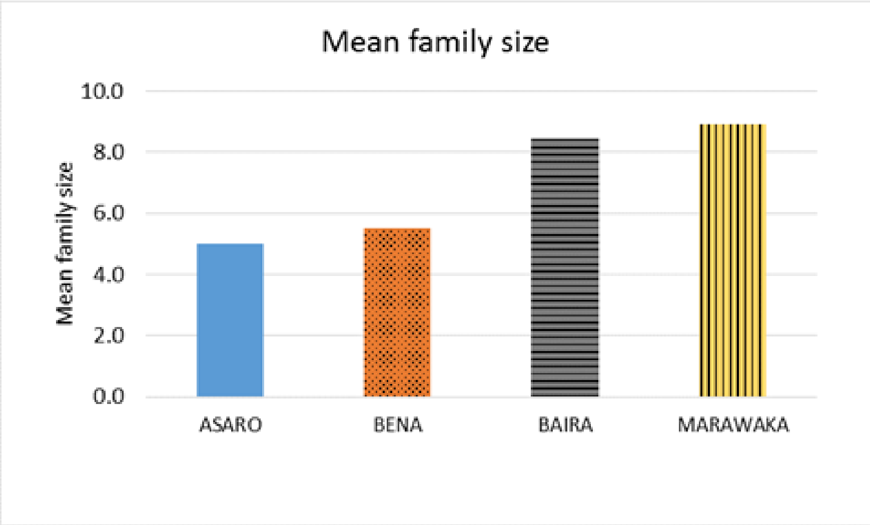


Figure 7.3. Mean family size by field site (includes residents and those living away).

A higher proportion of the population live away at the remote sites than the accessible sites (Figure 7.4). It is common for residents in remote villages to leave to seek education, employment and other services. With no school at Baira, many children lived with relatives in town where they attended school: 30% of the school age cohort lived away.

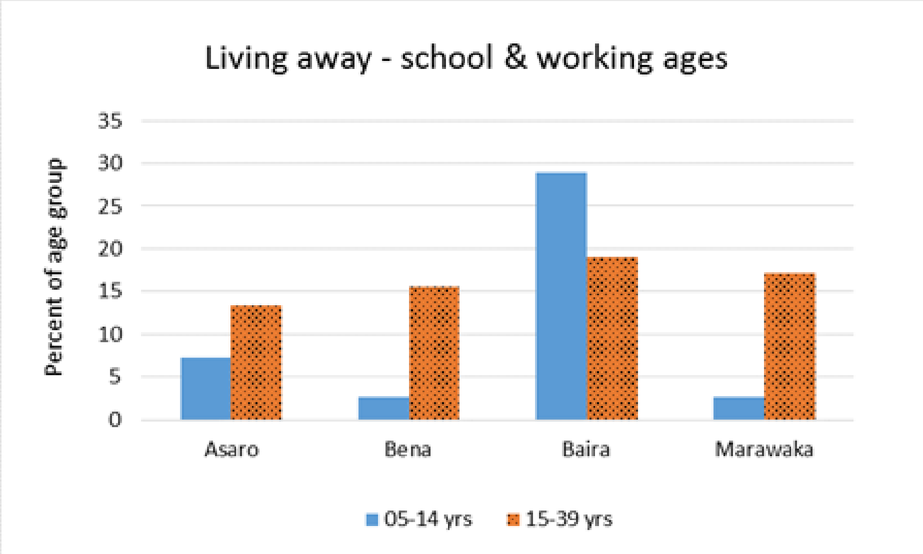


Figure 7.4. Percentage of school age and working age cohorts living away.

Education has been shown to be related to economic development, agricultural innovation and poverty reduction. Improved education for women is also strongly associated with lower fertility rates, reduced infant mortality, better child health and improved household economic status (Rowe *et al* 2005; Boyle *et al* 2006). In PNG the average years of schooling received by people aged 25 years and older is just 3.9 years (UNDP 2014), with a marked gender difference (e.g. Gannicott and Avalos 1994; Gibson and Rozelle 2004; Kare and Sermel 2013; Ryan *et al* 2017). As anticipated, education levels were lower in remote sites than in accessible sites (Table 7.5). Overall, the data for all sites combined are similar to the PNG rural average.

Table 7.5. Average education level (years of schooling) of people 25 years and older not currently going to school.

Location	Male		Female		Total	
	No.	Average	No.	Average	No.	Average
Asaro	66	4.8	42	3.1	108	4.2
Bena	63	4.5	60	2.7	123	3.7
Baira	34	2.2	33	0.8	67	1.6
Marawaka	55	3.4	54	0.4	109	1.9
Total	218	4.0	189	1.8	407	3.0

There are very large disparities in educational outcomes along gender lines and between accessible and remote locations (Table 7.5). In accessible sites, men's education levels are 1.6 times that of women whereas in remote sites, the gender gap expands to 4.7 times. The large education and gender disparities between remote and accessible sites has significant implications for developing strategies to improve coffee production and develop sustainable livelihoods. These points are discussed further below.

Household assets

In all four field sites, especially the remote sites of Baira and Marawaka, people owned few modern assets and household goods (Table 7.6). All households have access to land for temporary food gardens. Similar to many areas of PNG, usufruct rights to land for gardening are flexible and temporary access does not undermine the ownership rights of the customary landowning group. Therefore land-short relatives and other village lineages do not have problems gaining temporary access to gardening land. Perennial cash crops like coffee are a different matter and access is more tightly controlled. A few households in accessible sites did not have coffee gardens due to shortages of land.

Housing quality and ownership rates of many assets were greater for households at accessible sites than at the more remote sites (Table 7.6). Of note are differences between remote and accessible sites in rates of ownership of DVD players, mobile phones, generators, kerosene stoves, mosquito nets and mattresses. Marawaka was particularly impoverished in terms of household assets. For example, only one-fifth of households had a kerosene lamp compared with 87% of households at accessible sites, and only 25% of Marawaka households had a mattress compared with 88% of households in accessible sites. Savings capacity is also likely to be more constrained in remote locations because few households have bank accounts.

Such stark differences in household assets between remote and accessible sites clearly highlight the lower quality of life of remote areas. The findings also reflect the lower household incomes in remote sites (see Table 7.7). The lack of mosquito nets in remote locations would have health implications and affect the productive capacity of people who are already likely to be nutritionally stressed. Low rates of mobile phone ownership in remote locations also mean that the existing accessible and remote divide is widened because accessible populations are able to capitalise on this new technology through better access to market information and phone banking (see Curry *et al* 2016).

Table 7.6. Proportions of households at each site owning different types of assets.

Household assets	Percent of households			
	Asaro	Bena	Baira	Marawaka
Permanent/semi-permanent house	45	27	4	16
Radio	40	33	27	6
Television	17	15	10	1
DVD Player	12	15	5	1
Mobile Phone	62	71	20	5
Car	6	7	0	0
Truck PMV	8	1	2	0
Bicycle	4	8	0	0
Generator	17	16	10	1
Solar System	2	2	5	1
Coleman Lamp	25	8	7	2
Kerosene Lamp	84	90	78	19
Battery Lamp	34	36	44	5
Kerosene Stove	17	13	2	3
Mosquito Net	82	72	51	2

Mattress	84	93	93	25
Bank Account	30	35	10	13
Poultry	12	10	15	9
Pigs	83	85	17	63
Goats	0	15	7	0

Household income and livelihoods

Coffee was an important income source for most households at the four field sites. However, coffee smallholders in the study are similar to smallholder producers elsewhere in PNG in that they are engaged in a range of livelihood and social activities that draw on their labour and time. Activities like food gardening, raising pigs, maintaining social and kinship networks, operating small retail businesses, seeking medical care, childcare, domestic chores, and church and community activities all draw on people's time. They are also a central part of everyday village life. Coffee production is but one of the many livelihood activities smallholders pursue and, indeed, women typically spend much more time in food gardening than in coffee production (see below).

Incomes from coffee during the coffee flush period at the accessible sites of Asaro and Bena were double that of Marawaka (Table 7.7). The remote site of Baira was atypical in that it had for several years been receiving private sector support including extension and facilitated market access (Section 3). In the non-flush period, non-coffee income, which was largely local marketing of food crops, was much lower at the remote sites (mean K1.26/day) than at the accessible sites (mean K10.08/day). Moreover, a higher proportion of households in remote sites than in accessible sites did not receive any income during the non-coffee season. At Baira less than a third of households earned income during the survey period in the non-flush period, while all households at Bena earned some income over the survey period (Figure 7.5).

Although selling fresh produce was important at all sites, there was an enormous difference in the quantities of produce sold and income earned between remote and accessible sites. For example, at Bena, vegetable, pineapple and citrus production were intensive and produced for the markets at Goroka, Lae, Mt Hagen and Madang. Some people were earning very high incomes from pineapple production (over K5,000 per annum from pineapple production alone). Large-scale food gardening at Bena was leading some men and women to shift their labour from coffee to vegetable production where they perceived higher returns to labour (Inu 2015). Women had a dominant role in these livelihood activities and many were earning high incomes from these sources. The much lower cash incomes in Marawaka, and in the non-flush periods at the two remote sites has, of course, implications for nutritional status, educational opportunities, farm inputs, labour productivity and smallholders' capacity to innovate. These issues are discussed further below and in Section 8.

Table 7.7. Incomes reported during survey period

Income	Asaro	Bena	Baira	Marawaka
Average household income from parchment sales for the 2009-2010 coffee season	K1,260	K1,190	K2,030	K513
Mean household income/day (excluding coffee)	K7.01	K13.16	K1.79	K0.73

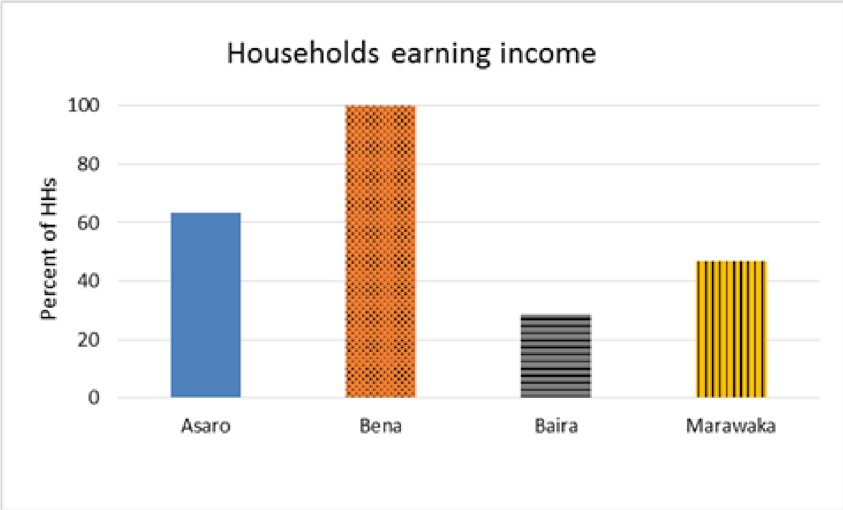


Figure 7.5. Per cent of households earning an income during survey in non-flush season.

The diversification of income and livelihood activities of smallholders can be gauged by the average number of income sources per household. At the remote sites of Marawaka and Baira the average number of income sources per household was 2.0 and at Asaro and Bena it was 2.7. Unsurprisingly, market access provides more livelihood options for households and thus greater income and food security.

Figure 7.6 shows the range of income sources for Bena and Marawaka. Bena's broader range of income sources reflects not only better roads and access to commercial centres, but also the income opportunities associated with the larger flow of cash in locations with high market accessibility and near town. For example, small-scale retailing of mobile phone cards, CD sales, and bakeries all indicate the greater volume of money flowing through the community. The more diverse and higher incomes in accessible sites such as Bena are also reflected in the better quality housing and higher ownership rates of general household assets (Table 7.6).

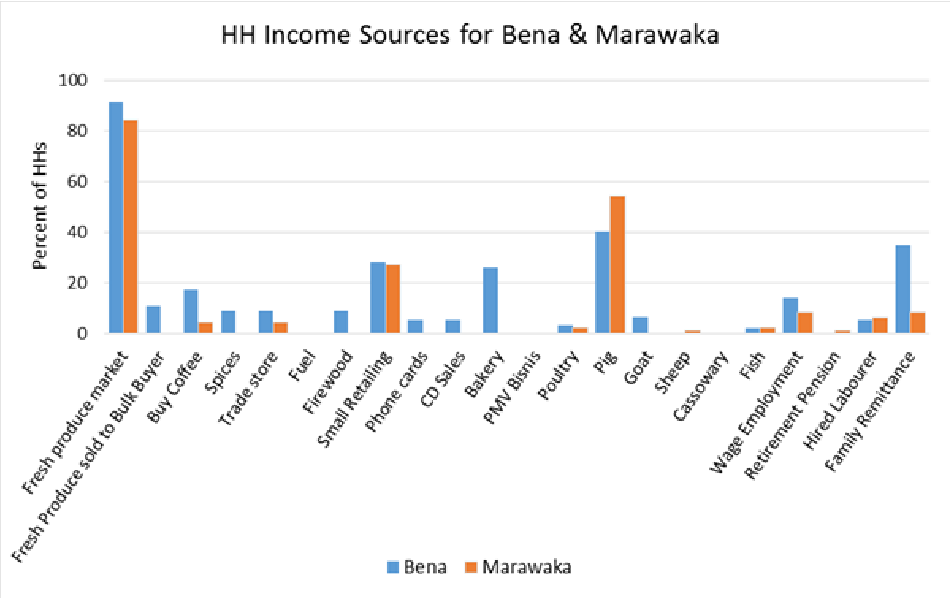


Figure 7.6. Household income sources for Bena and Marawaka.

It was not surprising that households at accessible sites earned income from a wider range of sources than households at Marawaka and Baira. However, it was expected that the range of income sources at Bena and Asaro would be higher. For crops like oil palm and cocoa, smallholders tend to have a higher average number of income sources per household: over four for cocoa smallholders near Kokopo, ENB; and, more than three for oil palm smallholders in WNB (Koczberski *et al* 2001; Curry *et al* 2007). It is possible that coffee farmers at Bena and Asaro have fewer income sources than cocoa and oil palm growers because the income they earn from commercial vegetable/fruit production together with that of coffee, provides them with sufficient cash income to meet most of their immediate financial needs. In contrast, for cocoa and oil palm smallholders, there is no single income earning activity, outside of cocoa or oil palm that is generating sufficiently high enough income to meet all of their household needs. Therefore, they are compelled to rely on several low-income and irregular/seasonal income-earning activities to maintain household economic security. It appears that coffee farmers at Bena and Asaro are investing their labour in high value food crops. This has implications for the opportunity cost of labour, especially female labour, and therefore the motivation to invest labour in coffee production (see below for further discussion).

Income diversification and gender

Income by gender provides interesting findings. Women at Asaro and Bena ranked income from vegetable and fruit production as their main income source, while women at the remote sites of Baira and Marawaka ranked coffee as their most important income source (Table 7.8). The results reflect the relatively high incomes to be earned from vegetables and fruit in locations near urban markets and the lack of livelihood options in locations remote from markets. At Baira and Marawaka, both men and women relied heavily on coffee as their main source of income because there are few alternative income sources that will generate the income of coffee. For men, with the exception of

Bena where sales of garden produce came in ahead of coffee, coffee was ranked as the primary income source.

Table 7.8. The top three ranked income sources by gender.

Gender	Asaro	Bena	Baira	Marawaka
Female	1. Sale of garden produce (63%) 2. Coffee 3. Livestock	1. Sale of garden produce (56%) 2. Coffee 3. Retail	1. Coffee (98%) 2. Sale of garden produce 3. Retail	1. Coffee (65%) 2. Sale of garden produce 3. Livestock
Male	1. Coffee (85%) 2. Sale of garden produce 3. Livestock	1. Sale of garden produce (36%) 2. Coffee 3. Retail	1. Coffee (100%) 2. Sale of garden produce 3. Retail	1. Coffee (79%) 2. Livestock 3. Sale of garden produce

The importance of food and fruit production for women in accessible sites can be explained by several factors. First, women are confident that their labour efforts in food production for markets will be rewarded through controlling the income they earn. Married women/unmarried daughters in Bena grow pineapples and European vegetables as cash crops independently of their husbands/fathers (Inu 2015; Curry *et al* in press). Thus there are strong economic incentives for women to commit labour to vegetable and fruit production. Men tend to control the income from coffee and there is uncertainty for women that they will receive a fair share of the income for their labour contributions. This uncertainty over payment of women's labour in coffee is one of the key drivers of women's emphasis on vegetable and fruit production in areas with high market accessibility.

Studies in oil palm and cocoa have also shown that when remuneration of women's labour is uncertain, they often withdraw all or part of the labour from export crop production, and redirect it to activities where they have greater control over the income generated from their labour (e.g. food production for urban markets) (Koczberski 2007; Curry *et al* 2007).

Given the high cash demands of everyday life, payment certainty of labour is an important consideration for women when it comes to deciding where they will allocate their labour. In households where there is an unequal distribution of coffee income between the husband and wife, and there are good alternative income sources (i.e. at the accessible sites), then some women will shift their labour out of coffee to these alternative livelihood pursuits. This is happening at Asaro and Bena.

Second, a major advantage for women marketing vegetable and fruits in the highlands is that the income is not as strongly seasonal as coffee. Although pineapple is fixed seasonally, women can stagger vegetable production to ensure a regular and reasonably good income throughout the year. Fortuitously, the peak labour demand periods for coffee and pineapple are asynchronous (Figure 7.7). Vegetables can be grown year round which allows women to time their heaviest work in vegetable production to coincide with the low labour demand periods for coffee and pineapples (Figure 7.7). The flexible timing of vegetable production also allows Bena women to maximise production during high market demand periods for vegetables such as school graduation ceremonies, Mother's Day, Easter and Christmas.

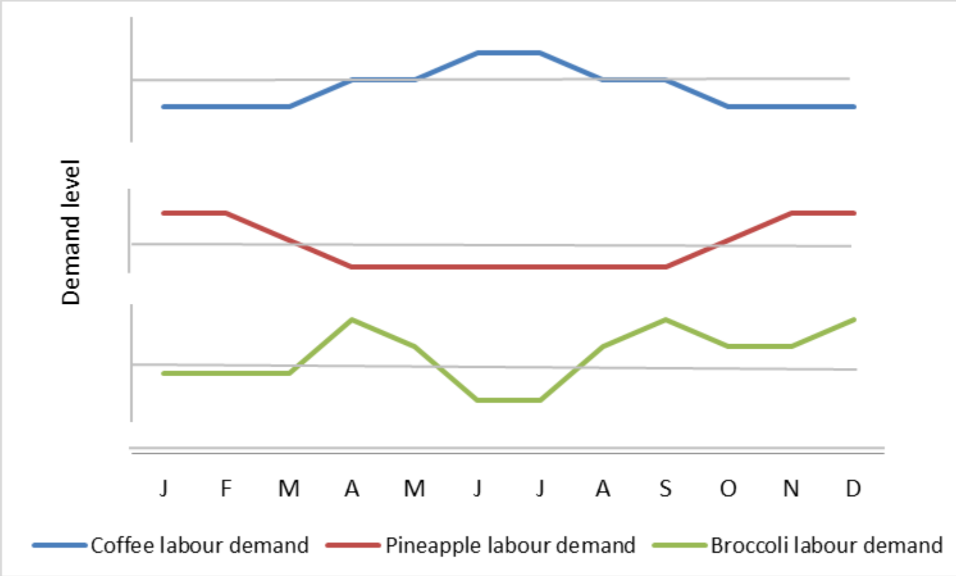


Figure 7.7. Schematic representation of the seasonal variations in labour demands for coffee, pineapple and broccoli in Sogomi and Safanga villages (Inu 2015).

Thirdly, women usually can access land for temporary food crops that does not alienate land for prolonged periods. In many areas of PNG, usufruct rights to land for gardening are flexible, thereby allowing relatives and other village lineages temporary access to gardening land. In Sogomi Village, while women were unable to access land for coffee they were able to cultivate pineapples as a cash crop, independently of their husbands. This is because like subsistence gardening, land access is short-term and part of the same framework of access rights governing access to land for subsistence food crops. This user right implies that the land can be accessed by any member of the family to plant pineapples, regardless of gender. Indeed, since mid-2000 there has been a growing trend in Sogomi Village of renting land to women for temporary food crops for market trading.

Labour supply and mobilisation

As outlined above, smallholder families pursue a wide range of subsistence, social, church and cultural activities. These livelihood activities place high demands on the time and labour of family members, which can constrain the supply of labour for coffee production. To assess labour supply and demands, time allocation surveys were conducted at the four study sites during the non-coffee season and at Asaro and Bena during the coffee season. Households were visited every second day over a 7-14 day period and interviewed about the activities of every household member from when they rose in the morning until dusk. Labour data were grouped in the following categories: coffee production, subsistence gardening, gardening for market sales, other economic activities (small business, retail enterprises, selling garden produce and waged employment), pig husbandry, domestic tasks, community activities (including church and customary activities), leisure (travelling to town, socialising, etc.), labour exchange (i.e. reciprocal labour given in social and kinship networks) and hunting, fishing and gathering from the forest.

As shown below, subsistence gardening activities were an important part of a smallholders' everyday routine (Figure 7.8a and 7.8b). Eighty per cent of women at all of the study sites reported spending most of their time in food gardening. This result is to be expected given that most women reported marketing of food crops as their primary income source (Table 7.8). In contrast, only about one-third (32%) of men at Asaro, Bena and Baira ranked food gardening as their main work activity. At Marawaka almost two-thirds of the men ranked food gardening as their main activity. Thus the majority of men, with the exception of those at Marawaka, identified coffee production as the main activity drawing on their productive time.

What is not shown in Figure 7.8b is how the amount of time allocated to gardening and coffee production varies throughout the year, especially during the coffee and non-coffee seasons. It was only at Bena and Asaro where we were able to conduct time allocation studies in both the coffee and non-coffee seasons. As expected, more time was spent on subsistence gardening and market gardening in the non-coffee season.

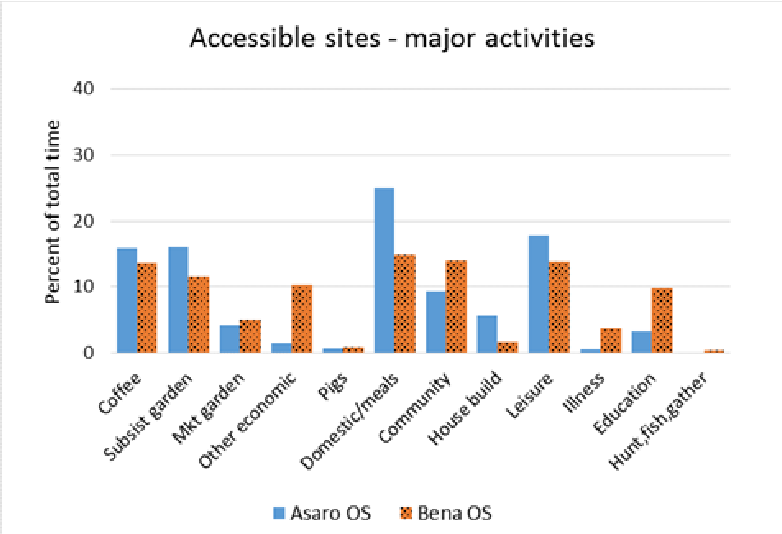


Figure 7.8a. Time allocation to major activities during the off-season at the accessible sites.

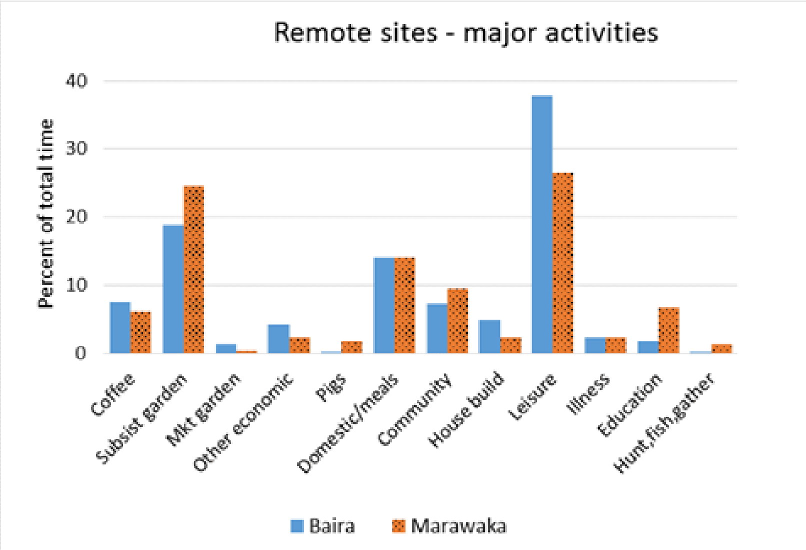


Figure 7.8b. Time allocation to major activities during the off-season at the remote sites.

Domestic tasks, as shown in Figures 7.8a and 7.8b, also took up a considerable proportion of time. Women are responsible for the bulk of these time-consuming tasks, such as collecting firewood and water and preparing meals. Most of these domestic activities were carried out by women simultaneously with caring for their young babies and children. Households also allocated a considerable amount of their time to leisure and to customary and community activities. These activities have a high premium in people's lives. They are part of a 'way of life' that is highly valued and resistant to change, and which partly accounts for the low input, low output system of production which characterises smallholder production in PNG (see below).

There are some differences between the remote and accessible sites in the amount of time allocated to certain activities. For example, there are notable difference in time spent on leisure; market gardening, subsistence and coffee production between remote and accessible sites. These differences can be largely explained by access to urban centres, cash and markets. It is not surprising that at the accessible sites more time is spent on coffee and market gardening. The greater amount of time spent on leisure at the remote sites is more difficult to explain. At Baira, 31% of leisure time was allocated to gambling, and indeed more time was spent on gambling than any other activity including subsistence gardening and coffee work: it could be argued that the need for cash for gambling was a motivating factor in allocating time to coffee production.

Labour in coffee production

At all sites the immediate family was the primary source of labour for coffee production (Figure 7.9). Within households there was also a distinct division of labour. Figure 7.10

shows the allocation of coffee tasks by gender at Asaro. This graph shows the typical pattern for all sites. Men do most of the coffee maintenance (e.g. drain maintenance, fencing and pruning) and marketing. Women make a large contribution to harvesting and post-harvest tasks. In addition, as the last bar shows, during the coffee season when labour demands are high, women play a very important role in reciprocal labour exchange where they provide harvesting labour through social and kinship networks. This labour exchange by women helps to reduce the labour shortages experienced by some households during the coffee harvesting season.

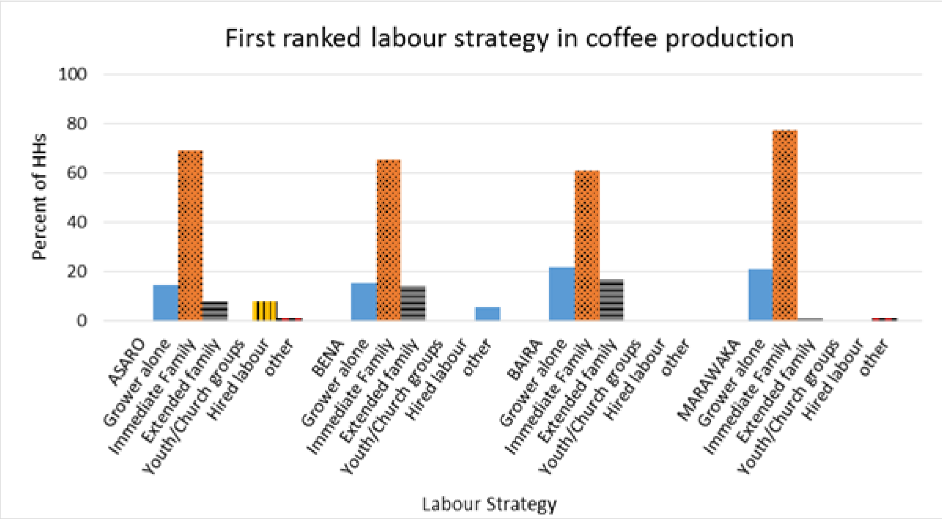


Figure 7.9. The first ranked labour strategy in coffee production as a percentage of households.

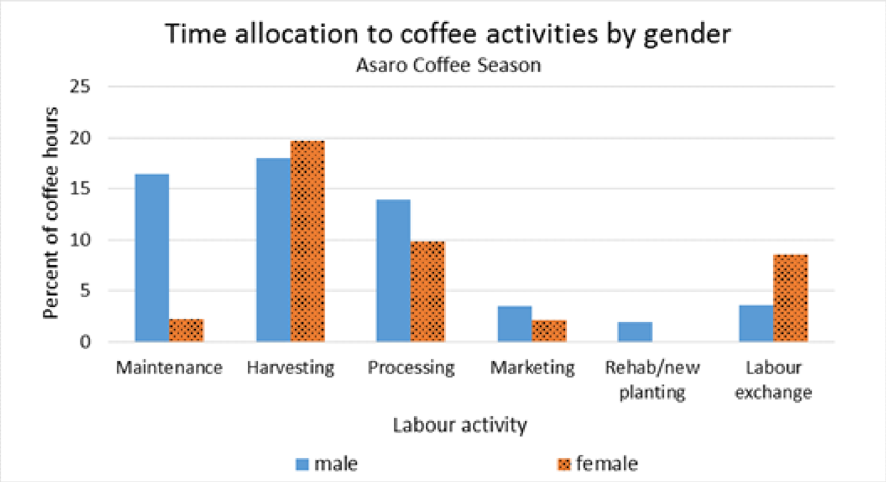


Figure 7.10. Time allocation to coffee activities at Asaro by gender.

However, generally, there was limited use of labour from the extended family or hired labour for coffee production (Figure 7.9). These issues are discussed below.

Labour constraints

The limited use of hired labour or labour from the extended family was surprising given that at all four sites, access to labour was identified in the top four constraints on coffee production (Table 7.9). Similarly, given that family size is quite large relative to areas of coffee garden, it raises the question as to why growers experience labour shortages.

Based on household interviews and survey data the labour supply constraints appear to be an outcome of several interrelated factors: namely:

1. absolute shortages of household and extended family labour;
2. the underutilisation of household labour (reluctance to provide labour);
3. competing demands on labour;
4. limited use of labour mobilisation strategies like hired labour; and
5. labour inefficiencies.

Each is discussed below.

Table 7.9. Major constraints on coffee production (Percent of HHs).

Asaro	Bena	Baira	Marawaka
Farm inputs (tools/equipment/ chemicals (66)	Labour (49)	Market access & low prices (63)	Market access & low prices (90)

Limited knowledge & skills (30)	Family/community conflict (43)	Labour (54)	Farm inputs (tools/equipment/ chemicals (42)
Environmental (24)	Poor fencing & animal damage (38)	Pests & diseases (29)	Labour (14)
Labour (19)	Pests & diseases (33)	Environmental (24)	
	Farm inputs (tools/equipment/ chemicals) (20)	Family/community (15)	
	Limited knowledge & skills (17)		
	Environmental (16)		
	Poor block management practices (15)		

Absolute household labour shortages

Household labour shortages can be either long-term or short-term and tend to be experienced by the following types of households:

- Large coffee holdings relative to household size.
- Life cycle stage of the household. Households headed by old, widowed or women, with few adult sons to assist with harvesting and maintenance experience labour shortages. Newly married families or household heads with a long-term illness, face similar problems when they have no adult children to provide labour for coffee production.
- Live in remote areas, such as Marawaka and Baira, where many young people are absent attending schools or working outside the village, either within the province or elsewhere in PNG.

For various reasons, these households are unable or reluctant to address labour shortages through hiring labour or drawing on extended kinship networks. Previously when villagers initially adopted export cash crops, labour demands were met through reciprocal exchange of labour among extended family members. Traditionally, in the non-market economy, labour was mobilised for subsistence food production to meet the labour demands of clearing new gardens and other intensive subsistence tasks. These flows of labour were embedded within extensive networks of kinship, obligations and reciprocity. These same networks of labour exchange were carried over to coffee when it was introduced. Whilst reciprocal labour exchange arrangements remain common, especially in subsistence production, villagers, especially at the accessible sites, reported a gradual contraction of the network of relatives that could be called upon for labour-intensive tasks like coffee harvesting (Curry *et al* in press). Two main interrelated factors appear to be operating. First, households are beginning to operate more independently of each other, both socially and economically, and there is now a reluctance to call on labour from the extended family for coffee production. In part, this is because most families are heavily involved in commodity production and other income-earning activities and villagers are aware that by seeking labour assistance from the extended family members they are denying them opportunities to labour for their own individual material gain. Thus, households are now much more dependent on their own labour and that of their immediate families for coffee production.

Second, with the commodification of labour in coffee production, more villagers, especially young adults are reluctant to provide unpaid labour to relatives when their labour will be used largely to deliver economic benefit to the family receiving the labour. In interviews with Sogomi and Safanga villagers many claimed that in the past relatives were once satisfied with a cooked meal at the end of a day labouring: now there is an expectation by many that when they assist relatives to work in their coffee gardens or in other cash income activities, they should be paid cash for their labour or receive some other material reward (this is a trend also seen among oil palm households in PNG: Koczberski and Curry 2016). The demise of reciprocal labour arrangements and 'free labour' has made mobilising labour for coffee production difficult. These long-term labour shortages can often lead to poorly maintained coffee holdings and consistently low production.

Underutilisation of available household labour

The underutilisation of family labour often arises from individual household circumstances and intra- and inter-household conflict that prevent labour from being deployed and adequately remunerated. At Bena the second most important constraint on coffee production identified by farmers was family conflict (Table 7.9).

Social conflicts within the family and extended family not only reduce the ability to draw on family labour, but cause much discontent among family members. Conflicts within families can result in family members working less cooperatively as they are discouraged from or resent providing labour in coffee production. Research among smallholder oil palm and cocoa households show that households that work cooperatively and harmoniously as a family, tend to have higher production (Curry and Koczberski 2004; Curry *et al* 2007). Harmonious relationships among family members help ensure their ongoing commitment to and participation in export crop production. This is particularly important in coffee production. For example, many coffee producing households did not have access to pulpers to produce parchment. Hand pulping is very labour intensive, and during periods of peak labour demands such as during flush periods, the under-utilisation of family labour was a major constraint on production.

There are a range of factors underlying the disagreements within and among households. Among the most commonly discussed during interviews with households related to conflicts over labour remuneration and income distribution from coffee. Women and young males in particular complained about what they perceived as the unfair distribution of coffee income by the male head of household. Many believed that their labour input in coffee was not adequately remunerated. This 'underpayment' creates few incentives for wives and adult sons to commit labour to coffee production and many are reluctant to do so. Others, especially women, commented on the unwise and frivolous use of the coffee income by their husbands. They felt that they, or their family as a whole, were not benefiting from the income earned from coffee production.

One response by women in villagers where alternative incomes were available and expanding, was for women to direct their labour to activities where the returns on labour were higher. As outlined above, at Bena and Asaro, where women are close to urban centres and large fresh food markets, such as at Goroka, Lae Madang and Mt Hagen, they are increasingly redirecting their labour from coffee to garden production for the expanding fresh food market. In the Bena villages of Sogomi and Safanga, this expansion in food production for local markets was facilitated and endorsed by local churches. A key factor, as highlighted earlier, why women are shifting their labour to the lucrative fresh food sector is because they can get better returns on their labour as they have greater control over the income they earn. Also, as women explained, they can have greater control over their own labour and production decisions in vegetable production. For example, married women/unmarried daughters in Sogami and Safanga villages cultivate pineapples and European vegetables as cash crops independently of their husbands/fathers. Thus, unlike household coffee production, women have more control over production decisions over the crops they grow and sell at local markets. These women are now spending less time working alongside their husbands in coffee production.

Competing demands on labour

At all the study sites, coffee production was one of many livelihood activities smallholder households pursued (see Figures 7.6, 7.8a and 7.8b). Operating in such a diverse coffee livelihood system, coffee smallholders face competing economic and non-economic demands on their labour. The competing demands on labour largely reflect the livelihood and socio-cultural priorities of smallholder coffee households. For example, as mentioned above, smallholders commit a large amount of labour to subsistence production, community activities, and leisure such as socialising among kin. These activities are highly valued activities as they help maintain and strengthen the indigenous economy and community. Within this livelihood system, many smallholders are not willing to commit large amounts of time and labour to coffee production, if it means taking time and labour away from other highly valued non-economic tasks. To do so would mean abandoning or curtailing a range of social, cultural and church activities that are central to the social and cultural lives of coffee smallholders, who still largely exist in a strongly traditional society still in transition to a market economy. It is for this reason, together with the reluctance to mobilise labour beyond the household, why, in an environment where there are several demands on smallholders, that very little labour is committed to coffee maintenance. Poor management levels of smallholder coffee gardens has been noted consistently in studies since the 1980s (Harding 1988; Collett 1989; Overfield 1994).

Limited use of labour mobilisation strategies

As highlighted above few households regularly employed hired labour to overcome labour shortages. It was only at Asaro where a few households (8%) ranked hired labour as their main labour strategy in coffee production (Figure 7.9). Some Asaro households used hired labour regularly during the coffee season for harvesting. At the other sites, although hired labour was used occasionally to assist with harvesting during peak labour demands, it was not a common labour strategy. At the remote site of Baira, although hired labour was not employed for coffee harvesting, 24% of households, regularly hired carriers, paid individuals or church/youth groups to carry their coffee to market (Plate 7.1). At Marawaka, no hired labour was used.

One reason given by households why they did not use hired labour was the cost and effort. Hiring labour is becoming expensive as increasingly labourers not only want to be paid cash for their work, but given a cooked meal at the end of the day which includes store foods such as rice and tinned fish. Previously a cooked meal of garden foods was accepted by labourers. By expecting store foods in their meal adds considerable time and expense to the recruitment and use of hired labour.

Other constraints on smallholder coffee production

Apart from the constraints on the supply of labour, a range of other factors contribute to low smallholder productivity and production. Smallholders ranked what they saw as the five main constraints on coffee production (Table 7.9). Constraints varied amongst sites, but those ranked highly by smallholders included labour shortages (discussed above), shortages of tools, equipment and farm inputs (labour inefficiencies), poor market access, prolonged parchment storage in poor conditions and low levels of technical knowledge of farmers regarding coffee husbandry and post-harvest processing. These factors vary from place-to-place, particularly between remote and accessible coffee growing areas.

Each factor is discussed further below. Potential extension interventions to address these constraints are discussed in Section 9.

The low level of farm inputs, tools and equipment results in the very inefficient use of labour and therefore potentially relatively low returns to labour. This is of concern in coffee growing areas that are remote from markets as well as those that have relatively good access to markets. In remote locations, high transport costs significantly reduce returns to labour while, as highlighted above, in accessible coffee growing regions, a range of alternative income sources like vegetable and pineapple production increase the opportunity cost of coffee labour.

Across all sites, household ownership of farm tools and equipment for coffee production was low, especially at Marawaka (Table 7.10). Only 14% of Marawaka households owned a hand pulper, while 2% had a pruning saw. Given the remoteness of Marawaka, families had no alternative but to produce parchment using very laborious methods (Plate 7.2). A 60 kg bag of cherry takes 30 minutes to pulp with a hand pulper (Plate 7.3) compared with 6 hours continuously using a stone (12 times as long). Very few people can use stone pulpers for 6 hours straight, so typically, coffee harvested in one day is pulped over 2-3 days thereby adversely affecting quality.

Table 7.10. Ownership of coffee equipment (percent of households surveyed).

	Percent of households			
Tool	Asaro	Bena	Baira	Marawaka
Bucket	58	49	17	13
Bush Knife	89	88	85	94
Canvas	51	77	76	27
Coffee Storage House	13	18	12	6
Grass Knife	32	54	44	51
Hand Pulper	30	45	44	14
Knapsack Sprayer	31	35	20	0
Ladder	8	17	5	5
Motor Pulper	9	7	0	1
Motorised Slasher	1	1	0	0
Pruning Saw	48	38	5	2
Scales	39	42	29	2
Pruning Secateurs	19	25	12	3
Spade Shovel	83	79	85	82
Axe	83	80	78	93
Wheelbarrow	8	4	5	0

A few families at Marawaka reported hiring pulpers during the coffee season for K10-20 per day, thereby adding to already high costs of production (mainly transport costs). Many growers at Marawaka reported under-harvesting because of the lack of pulpers. For those without hand pulpers, harvesting rates were determined by their pulping capacity which was extremely low using stones. Therefore, understandably, they tended to harvest coffee which was easily accessible and tolerated high levels of under-harvesting, especially of their more distant coffee gardens. Pulping cherry with a stone is therefore a bottleneck in the production system at Marawaka and at many other remote sites.

Plate 7.2. The use of stones in Marawaka to pulp cherry was common

Plate 7.3. Hand pulper.

Market access

Poor market access is the most significant production constraint in coffee growing areas without road access. In many districts, airstrips were unusable because they had not been maintained and airfreight charges were often so high that airfreighting was not a viable option for bringing parchment to market. In remote locations where airfreight costs are too high or airstrips unusable, farmers have no option but to carry coffee on their backs to the nearest road (Plate 7.1). The airstrip at Baira was closed for several years during the study because of poor maintenance. As a result coffee was carried out on people's backs to the nearest road: a 6-8 hour walk for a fit villager. At Baira, around 70% of households carried their coffee to market (Figure 7.11). While youth and church groups were used regularly to carry coffee, family members in the coffee season were also burdened with carting bags of parchment to market. At Marawaka over 90% of households carried their parchment to market (about 10% of households used carriers and youth groups to carry their coffee).

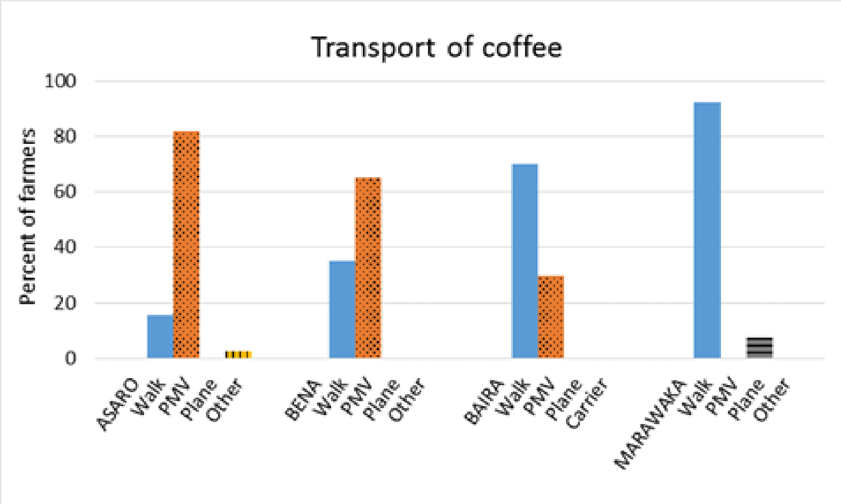


Figure 7.11. Methods used to transport coffee.

Whilst the portage of coffee on people's backs was reported by growers at all sites, the distances to cart coffee between remote and accessible sites were vast. At Bena, carrying coffee on foot to sell was less than half an hour compared with six to eight hours at Baira and around five hours at Marawaka (Table 7.11). Furthermore, in accessible locations where roads are passable, growers are much more likely to use PMVs to transport their coffee to market (Figure 7.11). When farmers in remote locations carry their coffee to the nearest road they are still confronted with long distances by road and therefore high transport charges. For example, at Baira PMV transport costs were about five times higher than for those using a PMV at an accessible site.

Carting bags of coffee to market is costly for remote growers. For example transporting coffee by foot from Baira with 20-30kg of coffee parchment will cost a grower K40 to the main highway, with another K20/60kg parchment transport fees to Kainantu (1 hr drive) and a PMV fee of K5. Total transport cost per bag is K105.00. The high costs of transport undermines smallholders' motivation to produce and invest in their coffee (Table 7.11).

Table 7.11. Coffee transport costs from remote sites

	Air freight cost (K/kg)	Carrier costs (K/kg)	Time to road (hours)	PMV cost to town (K/kg)	Total cost per bag (60 kg) (carrier & PMV)
Baira	1.50	1.60	6-8	0.33	105
Marawaka	3.35	2.00	5	0.50	150

Because of transport difficulties at remote sites, many growers stored coffee for long periods as they were often faced with long delays in getting their coffee to market. At Marawaka, for example, 100% of growers had coffee in village storage compared with less than 20% of farmers at Asaro (Figure 7.12). Moreover, 20% of Marawaka farmers had parchment coffee that had been in village storage for more than 12 months. This was in contrast to Asaro where no farmer had any coffee that had been stored in the village for greater than 6 months. Parchment quality can be adversely affected by long storage periods in sub-optimal conditions like bush material houses.

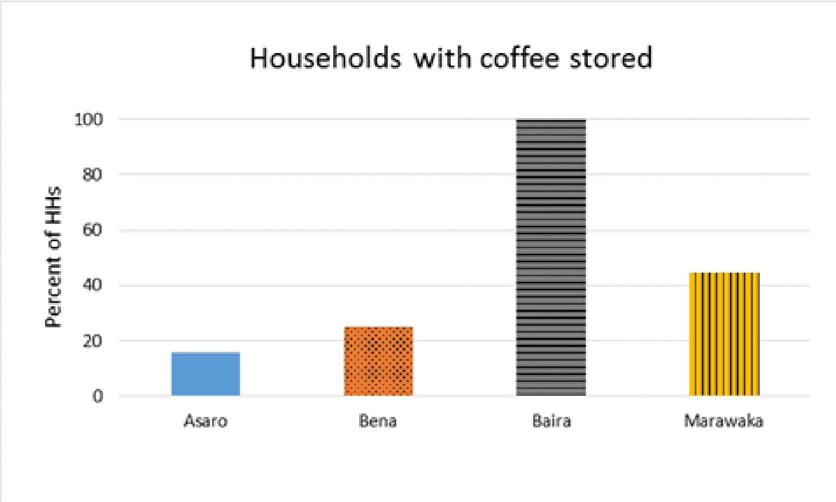


Figure 7.12. Percent of households with coffee stored.

Technical knowledge of farmers

Across all sites, growers reported receiving little no coffee extension training. This partly explains farmers' relatively low levels of technical knowledge of coffee husbandry and post-harvest processing (discussed below). Farmers were asked about the types of training or advice they had received on a range of coffee management practices. Only the Bena farmers had received any significant level of extension training which was delivered several years previously under an ACIAR-funded green scale project. At Bean, 25-30% of households had received training or advice on several aspects of coffee production including coffee garden maintenance, herbicide and pesticide use, pest and disease control, pruning, post-harvest techniques and financial management. All had considered the training or advice to be useful. However, at Asaro, 2% or fewer households had received any extension training or advice. At Baira 12% of households had received training and advice from MSS regarding certification requirements and general maintenance techniques. In Marawaka, only one household had participated in extension training and this was on certification. Overall, extension delivery was insufficient and spread too thin to have any significant impact on coffee farmers' levels of technical knowledge to which we now turn to consider.

Coffee husbandry

At each of the four study sites assessments were made of coffee farmers' levels of technical knowledge regarding coffee husbandry, post-harvest processing and marketing. Levels of knowledge were low apart from the optimal timing of pruning which most farmers knew was following the main flush period (Figure 7.13). There was no apparent difference between remote and accessible sites in this area of knowledge.

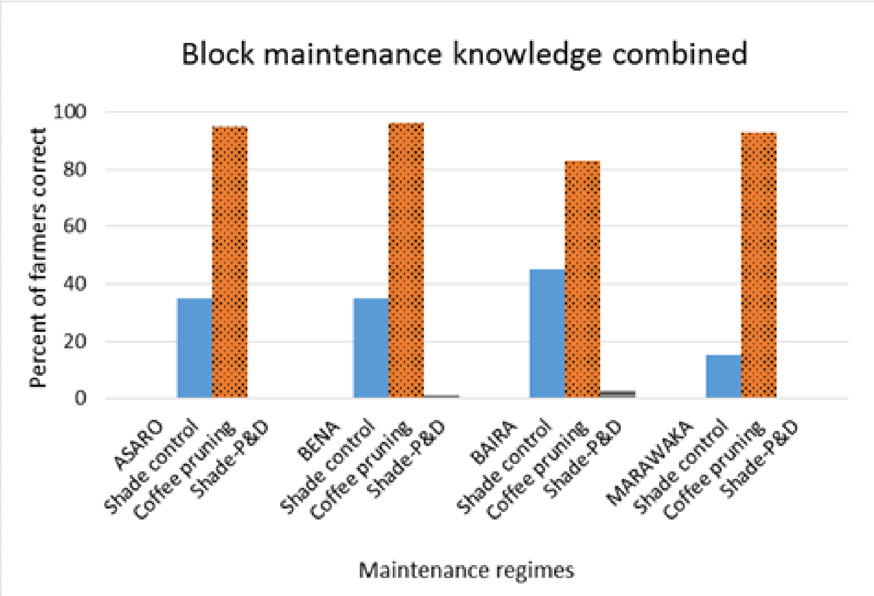


Figure 7.13. Percentage of farmers answering correctly for the three maintenance regimes.

The best time to apply shade control to maximise production is just before the main period of coffee flowering when a reduction in shade will stimulate flowering. However, at all four sites around 45% or fewer farmers knew that this was the correct time to apply shade control (Figure 7.13). The better results at Baira, where more farmers answered this question correctly, may reflect the training conducted by MSS just before the survey. At the other remote site of Marawaka, less than one-fifth of farmers knew this was the best time to prune shade trees. Many farmers at all sites thought, incorrectly, that shade control should be implemented immediately after the main flush period, at the same time that coffee trees are pruned.

While farmers knew that pests and diseases contributed to crop losses, they had very limited knowledge of coffee pests and diseases and the appropriate control methods. Field observations revealed that farmers tolerated relatively high rates of losses to pest and diseases, which is a characteristic of the low input, low output system of production of smallholders in PNG (see Curry *et al* 2007). Farmers also demonstrated a very poor understanding of the relationships between shade levels and the incidences of three common pests and diseases: green scale, pink disease and coffee leaf rust. Farmers were asked how a reduction in shade levels would affect these pest and disease infestations. Bena farmers performed better than other farmers on the question on green scale and pink disease, which was probably attributable to knowledge gained from a recent ACIAR green scale project in the area prior to the survey. At the remote sites, Baira farmers did better than Marawaka farmers and this may reflect the certification training some farmers received from MSS.

Post-harvest processing

Smallholders were also questioned about post-harvest practices and coffee quality issues. Questions covered pulping, fermentation and parchment storage. Levels of knowledge were generally low (Figure 7.14). For example, coffee cherry should be pulped the same day it is harvested otherwise quality begins to decline. Between 45% and 60% of farmers answered this question correctly at the four sites. Also, there was little difference in knowledge regarding storage time of cherry prior to pulping between the accessible and remote sites. In practice, most growers will pulp a day's harvest of cherry over a few days, especially where there is limited access to hand pulpers. Knowledge of the fermentation process was also low among farmers, and less than 30% of farmers were able to identify the characteristics of fully fermented beans. Hence, beans were often not fully fermented when sun drying commenced.

Poor processing as a result of delayed pulping and the processing of cherry harvested on different days leading to uneven fermentation rates and incorrect assessment of the completion of fermentation all detract from the quality of parchment produced. Importantly, processors were willing to pay a significant price premium for smallholder cherry, and the resultant parchment is of plantation quality.

Problems with quality also result from long and unsuitable storage of parchment. Farmers were asked to identify the maximum period of time that parchment could be stored before quality begins to decline (the recommended maximum time of storage is three months). Only between 30% and 40% of farmers at the four sites answered this question correctly. In practice, as indicated above, many farmers had coffee parchment stored for much longer than three months particularly at Bena, Baira and Marawaka.

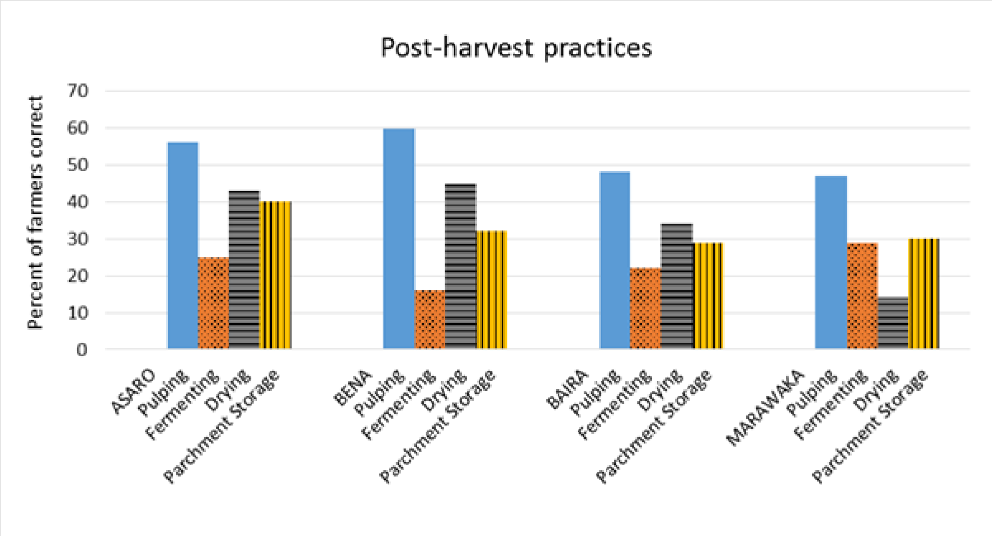


Figure 7.14. Percentage of farmers answering correctly for post-harvest practices.

To summarise, the farmer technical knowledge survey revealed that:

- Generally, farmers lack the knowledge for good coffee management and processing of coffee. Less than 60% of farmers at all sites correctly answered questions relating to post-harvest processing. There were some minor differences between the knowledge levels of those at the accessible sites of Asaro and Bena and the remote sites of Baira and Marawaka, but the differences were small.
- Whilst farmers scored relatively well on pruning of coffee trees, most scored badly on other management and post-harvest questions, such as pests and diseases, shade and storage. The large knowledge gap on the effects of shade on pest and disease levels is a substantial barrier to improving production.
- There is some difference in the level of farmers' knowledge between the remote and accessible sites, but it is small. This is surprising given that accessible coffee growing areas have more opportunities to access extension information than remote sites. Although Bena had the largest proportion of households that received training or advice, their level of technical knowledge was similar to farmers at the other sites.

2. EXTENSION

In 2004, the CIC farmer extension program moved from the traditional Training and Visit (T&V) system of farmer extension to a Farmer Demand Driven Extension (FDDE) program system under the guidelines described in the newly adopted Coffee Growers Support Service Program (CGSSP). The FDDE works with farmer groups to identify farmer training needs and where possible contract service providers to supply tailored training to each farmer group. The core approach to FDDE is that CIC staff conducts farmer group profiling, carries out appraisals and training needs assessment, whilst the actual training is then contracted out to independent service providers, or, by CIC staff in the absence of independent service providers. Since 2005, 319 coffee grower groups have registered with CIC for consideration for training in the FDDE program.

To evaluate the effectiveness of the FDDE program, surveys of farmers, service providers and CIC staff, together with informal interviews, discussions and workshops with service providers, extension officers, senior CIC staff and discussions with the private sector coffee operators were conducted in 2011. The methods to evaluate the FDDE consisted of: 93 farmer questionnaires; 15 service provider questionnaires; 14 CIC staff questionnaires; a one-day workshop for CIC staff and Service Providers; and interviews with a cross-section of the coffee private sector.

The findings of the evaluation indicate that the fundamental principles of the FDDE approach were sound. Survey data indicated farmers were happy with the principles, the processes and procedures of FDDE. Farmers saw value and usefulness in the FDDE program. However, the lack of emphasis in FDDE on linking farmer groups to markets or to export companies was a major deficiency, especially given that group training and marketing have the potential to meet the growing traceability and quality demands of the expanding specialty coffee industry.

Furthermore, operationally, slow administrative and financial processes within CIC severely hampered the effectiveness of the FDDE because significant time delays in financial and administrative steps led to prolonged delays in delivering extension. This caused much dissatisfaction amongst service providers, CIC extension officers and those farmer groups affected by the delays.

Several technical issues in the FDDE program were also identified, including a need to improve the group screening process, the PRAP process and the need for more training modules and materials to be developed.

Training modules

The project identified a need for extension training materials and began to address this need by beginning to develop a suite of training modules for use with farmer groups. Although these modules were not part of the original project design, there was a high demand for such training materials from both CIC and private sector organisations. The private sector is moving towards coffee certification for their farmer groups and is obligated to ensure extension training is delivered to farmer groups as part of the certification requirements. These training materials were to be designed to accommodate the low input, low output model of smallholder production so widespread in PNG.

The training modules making up the Extension Training Package were partly developed and based on existing CIC extension materials and incorporated the key research findings from the project as well as new information from other sources. This partly developed training package will assist extension officers provide training for farmer groups by containing sets of lesson plans on a range of production, processing and marketing activities of coffee. The overarching guiding principle for the Package was a ‘whole farm system’ approach to extension training that considers environmental, social, gender and income within broader livelihood strategies including food production for home consumption and sale. It was recognised that coffee production is one of several livelihood strategies in which families are involved, so the Package considers the interactions of coffee production strategies with other livelihood strategies such as the recent rapid growth in vegetable production in coffee growing regions with good market access – what happens in one affects the other.

CIC extension would be the main provider of extension training using the extension training package to train their own farmer groups, cooperatives, other extension providers such as private sector extension service providers and NGOs. The package will be registered with the National Training Council (NTC) to allow CIC to register a CIC coffee training school. This 'training of trainers' (TOT) model would greatly extend CIC's extension capacity and reach (currently CIC has one extension officer to 60,000 growers).

The research results from the project were used to inform the development of this comprehensive extension training package. A one-day workshop and several meetings at CIC in 2016 were organised to decide on the content of the training package which is proposed to consist of 26 extension/teaching modules.

While much was achieved in developing content for these training modules, they are yet to be completed and field tested with the private sector and NGOs.

The training package will include the following:

UNIT 1: EXTENSION PRINCIPLES (modules 1-3) (Management)
Module 1 – Introduction and overview of Training Package
Module 2 – What is the role of the extension officer?
Module 3 – How to be a good extension officer

UNIT 2: KNOWING YOUR FARMERS (Modules 4-5) (Management)
Module 4 – Who are coffee smallholders?
Module 5 – What are the factors affecting smallholder production?

UNIT 3: BECOMING A COFFEE FARMER (Modules 6-8) (Coffee Technical Packages)
Module 6 – Knowing your coffee tree
Module 7 – Coffee nursery development
Module 8 – Establishing a new coffee garden:

UNIT 4: MANAGING YOUR COFFEE GARDEN (Modules 9-18) (Coffee Technical Packages – field management)
Modules 9-16 – Weed control, Pruning, Shade control, Fencing, Drainage, Pests and disease control, Safe and effective use of pesticides and herbicides
Module 17 – Soil nutrition and effective nutrient management strategies
Module 18 – Coffee rehabilitation

UNIT 5: HARVESTING AND PROCESSING YOUR COFFEE (Modules 19-21)
Module 19 – Harvesting and processing your coffee
Module 20 – Coffee grading systems and pricing (includes price premium for cherry)
Module 21 – Establishing a mini wet factory (demucilager)

UNIT 6: COFFEE MARKETING (Modules 22-23)
Module 22 – Understanding the domestic coffee market in PNG
Module 23 – Grower Group – Organisation and Management

UNIT 7: SPECIALTY COFFEE MARKETS (Modules 24-26)
Module 24 – Coffee Certification – Generic
Module 25 – Fair Trade (currently under development by CIC)
Module 26 – Financial Planning and Management

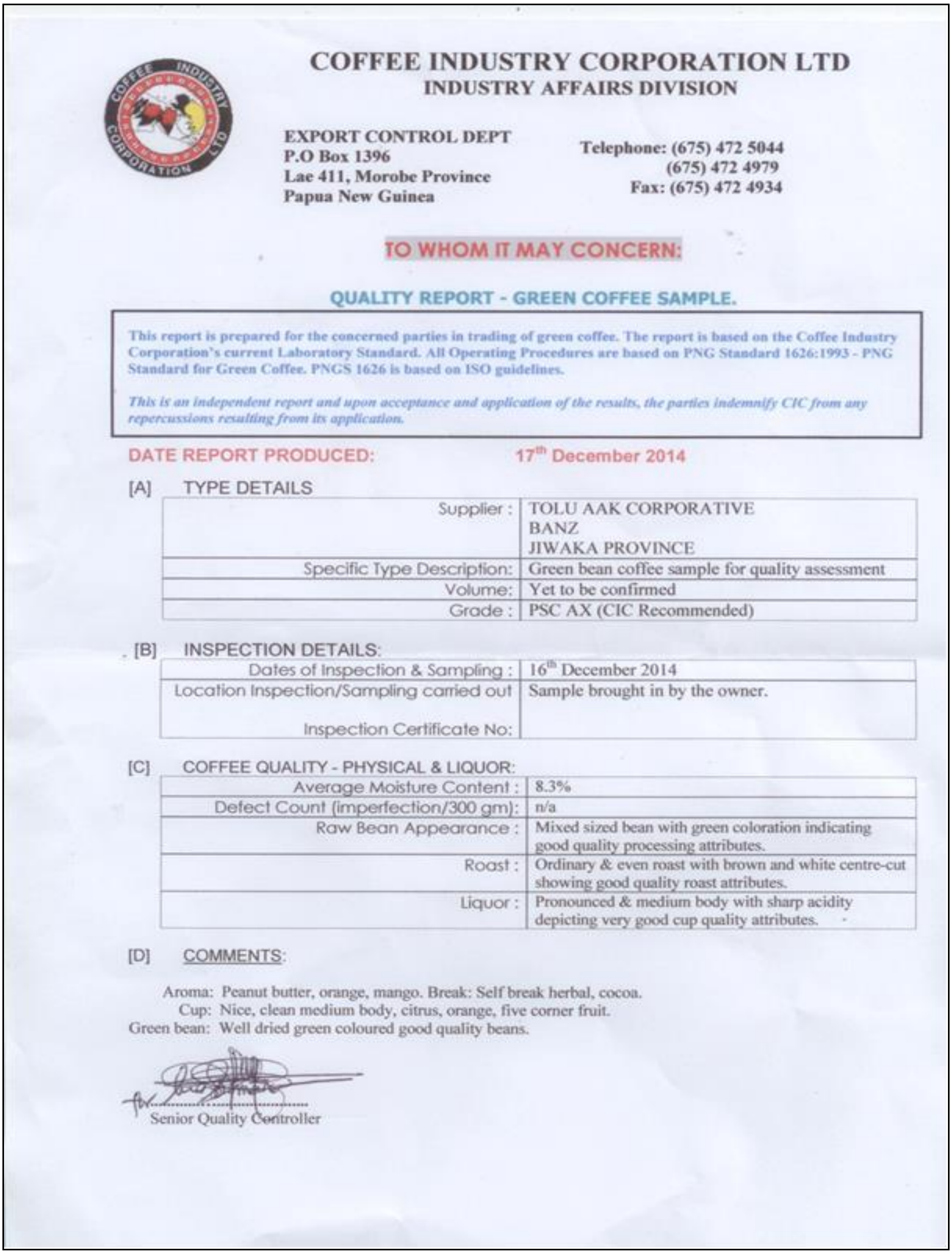
Demucilagers

Demucilagers were initially trialled under PHT/2004/017 for the purpose of water conservation. After the trial was completed there was no further work at CIC on the demucilagers, mainly because of the departure of key staff. However, the project team realised that demucilagers had the capacity to improve parchment quality and raise the efficiency of labour, two of the key constraints on coffee production and quality identified by ASEM/2008/036 (e.g. bag ferment leading to uneven fermentation). Demucilagers, if successfully integrated into PNG's socio-economic environment, have the potential to significantly improve coffee quality and labour efficiency.

Three mini wet mills were established with farmers groups supported by AAK. The ASEM/2008/036 project team undertook some preliminary evaluations of two of these mini wet mills located at Tolu Village, Banz, WHP, and at Yonki, EHP. Data were collected on parchment quality, consistency of product and returns to farmers. Farmers were also interviewed about the advantages and disadvantages of the technology. Some preliminary assessment of the potential of nutrient sinks and nutrient recycling was also undertaken.

Coffee was cup-tasted from both sites. At Yonki the parchment sample was collected not long after the processor started operating. The results were very good with the parchment rated PSC with a 10-15 t/kg P premium but there was a comment about immature coffee being processed which suggests some of the farmers were practising strip harvesting which can significantly reduce quality. At Banz, which had been operating since late 2013/early 2014, the results were excellent (Figure 7.15). These very preliminary results indicate that demucilagers can produce a consistent high-quality product suitable for exporters.

Demucilagers may improve the viability of coffee livelihoods in both remote and accessible coffee growing areas. Growers can achieve PSC quality fairly easily and it is not unreasonable to suggest they could produce even higher grades of coffee like X and A grades, commanding price premiums of between 30 and 40% (Table 7.1). Also, the labour efficiencies and improved quality of parchment would increase returns to labour in accessible sites thereby reducing the opportunity cost of labour in coffee relative to other livelihood pursuits.



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TO WHOM IT MAY CONCERN:

QUALITY REPORT - GREEN COFFEE SAMPLE.

This report is prepared for the concerned parties in trading of green coffee. The report is based on the Coffee Industry Corporation's current Laboratory Standard. All Operating Procedures are based on PNG Standard 1626:1993 - PNG Standard for Green Coffee. PNGS 1626 is based on ISO guidelines.

This is an independent report and upon acceptance and application of the results, the parties indemnify CIC from any repercussions resulting from its application.

DATE REPORT PRODUCED: 17th December 2014

[A] TYPE DETAILS

Supplier :	TOLU AAK CORPORATIVE BANZ JIWAKA PROVINCE
Specific Type Description:	Green bean coffee sample for quality assessment
Volume:	Yet to be confirmed
Grade :	PSC AX (CIC Recommended)

[B] INSPECTION DETAILS:

Dates of Inspection & Sampling :	16th December 2014
Location Inspection/Sampling carried out Inspection Certificate No:	Sample brought in by the owner.

[C] COFFEE QUALITY - PHYSICAL & LIQUOR:

Average Moisture Content :	8.3%
Defect Count (imperfection/300 gm):	n/a
Raw Bean Appearance :	Mixed sized bean with green coloration indicating good quality processing attributes.
Roast :	Ordinary & even roast with brown and white centre-cut showing good quality roast attributes.
Liquor :	Pronounced & medium body with sharp acidity depicting very good cup quality attributes.

[D] COMMENTS:

Aroma: Peanut butter, orange, mango. Break: Self break herbal, cocoa.
Cup: Nice, clean medium body, citrus, orange, five corner fruit.
Green bean: Well dried green coloured good quality beans.

Senior Quality Controller

Figure 7.15. Cupping results for Tolu AAK demucilager, Banz, Jiwaka Province.

3. Nutrient management findings

To identify the intervention points in nutrient management to improve coffee yield, a three-stage approach was taken. First, the fertility status of the soil and coffee crop was established by soil and plant chemical analysis. Second, the 'coffee garden condition' (pruning, ground cover, diseases, plant health, etc.) was determined through farmer surveys and physical garden inspections. Third, pathways of nutrients during coffee processing were identified through chemical analysis of cherry components (parchment, skin + pulp, mucilage) and the fate of those nutrients through survey questionnaires.

To address some of these issues, trials were established to study the benefit to coffee of intercropping with short-rotation, fertilised vegetables.

To gain an insight into other nutrient export pathways from the whole food-coffee garden system, various food crops were analysed for their nutrient content (both within this project and through a JAF-funded Master of Philosophy awarded to Ms Emma Kiup).

Finally, new research needs have been identified; in particular the previously unrecognised issue of B and Zn deficiencies across the whole food-coffee garden system.

Soil fertility status

Chemical analysis was conducted on the 0–10 and 10–50 cm depths of 115 soils collected from the four field sites (Tables 7.12 and 7.13). In the surface soil (0–10 cm), average values of most analyses (except P) for most sites fell within the optimal ranges suggested by Harding (1984) and Winston *et al* (2005). Average extractable phosphorus (P) was lower than the optimum range in all sites. Average exchangeable potassium (K) was below the optimum range in Asaro and Baira, and above the optimum range in Marawaka.

However, the variation of analytical values between gardens within each site was substantial. Thus the data are also presented as the percentage of gardens in each field site which had values below the optimal range (Table 7.12). For K, Asaro, Bena and Baira had a substantial proportion of gardens with values below the optimum range. For P all gardens in Asaro, Bena and Baira were below the optimum range; and 67% of gardens below the optimum in Marawaka.

Average total carbon (C) and nitrogen (N) were within the optimum range. However, Bena had a large proportion of gardens with values below the optimum range.

Average CEC, pHw (1:5 water) and pH_{CaCl2} (1:5 0.01 M $CaCl_2$) were within the optimum range with few outliers.

Average exchangeable magnesium (Mg) and calcium (Ca) were above the optimum range in all villages with only a few below the optimum range.

Average EC was better than the upper limit of salinity in all but a few gardens.

Table 7.12. Soil chemical analysis (0-10 cm depth) (values in parentheses represent the number of gardens with values lower than the optimum range; except for sodium and EC where it is the number of gardens with values greater than the optimum range).

	Total		Extractable	Exchangeable							
	Carbon	Nitrogen	Phosphorus	Potassium	Calcium	Magnesium	Sodium	pHw	pH_{CaCl2}	CEC	EC
	(%)		(mg/kg)	($cmol^+$/kg)						($cmol^+$/kg)	(dS/m)
Method[1]	6B2	7A5	9B2	15E1	15E1	15E1	15E1	4A1	4B2	15E1	3A1
Field Site											
Asaro (n=24)[2]	7.2^{a} (8)	0.51^{a} (8)	16.4^{b} (100)	0.42^{c} (71)	14.5^{b} (0)	3.8^{bc} (0)	0.20^{a} (0)	5.7^{b} (4)	5.2 (0)	12.2^{c} (0)	0.14^{a} (4)
Bena (n=33)	4.5^{d} (39)	0.34^{b} (39)	18.5^{b} (100)	0.52^{b} (67)	11.8^{c} (0)	3.6^{c} (0)	0.10^{b} (0)	5.8^{ab} (6)	5.3 (3)	10.9^{c} (0)	0.11^{b} (0)
Baira (n=23)	5.0^{c} (13)	0.39^{b} (13)	17.6^{b} (100)	0.46^{bc} (65)	20.6^{a} (4)	5.9^{a} (4)	0.10^{b} (0)	5.9^{a} (0)	5.3 (4)	18.1^{a} (0)	0.11^{b} (0)
Marawaka (n=35)	6.1^{b} (11)	0.50^{a} (6)	58.9^{a} (67)	0.98^{a} (9)	19.4^{a} (0)	4.0^{b} (0)	0.12^{b} (0)	5.7^{b} (9)	5.2 (9)	14.1^{b} (0)	0.14^{a} (3)
Mean[3]	5.7 (19)	0.43 (17)	27.8 (90)	0.60 (50)	16.6 (1)	4.3 (1)	0.13 (0)	5.7 (5)	5.2 (4)	13.8 (0)	0.13 (2)
Optimum range[4]	4.0 - 10	0.3 - 0.6	60 - 80[5]	0.5 - 0.8	5 - 10	1 - 3	0.3 - 0.7	5.3 - 6.5	4.8 - 6.0	5 - 20	< 0.2[5]
P-value[6]	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.033	0.526	<0.001	0.002

[1] According to Rayment and Lyons (2011)
[2] Number of coffee gardens sampled
[3] Mean of field site means
[4] According to Harding (1984). Values refer to the top 100 cm of soil.
[5] According to Winston *et al* (2005). Value refers to the top 15 cm of soil
[6]Values in a column followed by the same letter are not significantly different; ANOVA, means separated by LSD.

In the 10–50 cm depth, most nutrients were lower than the 0–10 cm depth but a similar pattern of results was evident except for C and N (Table 7.13). Again, all sites had very low average P and low average K with a high proportion of gardens falling below the optimum range. All four sites had many gardens with C and N below the optimum range.

Table 7.13: Soil chemical analysis (10-50 cm depth).

	Total		Extractable	Exchangeable							
	Carbon	Nitrogen	Phosphorus	Potassium	Calcium	Magnesium	Sodium	pHw	pH_{CaCl2}	CEC	EC
	(%)		(mg/kg)	($cmol^+$/kg)						($cmol^+$/kg)	(dS/m)
Method[1]	6B2	7A5	9B2	15E1	15E1	15E1	15E1	4A1	4B2	15E1	3A1
Field Site											
Asaro (n=24)[2]	4.4^{a} (50)	0.32^{a} (50)	11.3^{b} (100)	0.30^{b} (83)	9.6^{b} (8)	3.0^{bc} (0)	0.33^{a} (0)	5.7^{a} (0)	5.2^{a} (0)	8.5^{c} (2)	0.11^{a} (0)
Bena (n=33)	2.6^{c} (94)	0.20^{b} (94)	13.1^{b} (100)	0.34^{b} (85)	7.2^{b} (15)	2.5^{c} (3)	0.18^{b} (0)	5.8^{a} (6)	5.2^{a} (9)	8.7^{c} (3)	0.08^{c} (0)
Baira (n=23)	2.3^{c} (100)	0.19^{b} (100)	11.9^{b} (91)	0.30^{b} (96)	16.0^{a} (0)	5.8^{a} (0)	0.13^{c} (0)	5.7^{ab} (30)	5.0^{b} (39)	18.3^{a} (0)	0.07^{d} (0)
Marawaka (n=35)	3.5^{b} (71)	0.30^{a} (63)	28.1^{a} (94)	0.53^{a} (51)	13.7^{a} (3)	3.4^{b} (3)	0.12^{c} (0)	5.6^{b} (17)	4.9^{b} (43)	11.7^{b} (3)	0.09^{b} (0)
Mean[3]	3.2 (79)	0.25 (77)	16.1 (87)	0.37 (88)	11.6 (8)	3.7 (2)	0.19 (0)	5.7 (13)	5.1 (27)	11.8 (3)	0.09 (0)
Optimum range[4]	4.0 - 10	0.3 - 0.6	60 - 80[5]	0.5 - 0.8	5 - 10	1 - 3	0.3 - 0.7	5.3 - 6.5	4.8 - 6.0	5 - 20	< 0.2[5]
P-value[6]	<0.001	<0.001	<0.001	0.004	<0.001	<0.001	<0.001	0.043	0.001	<0.001	<0.001

[1] According to Rayment and Lyons (2011)
[2] Number of coffee gardens sampled
[3] Mean of village means
[4] According to Harding (1984). Values refer to the top 100 cm of soil.
[5] According to Winston *et al* (2005). Value refers to the top 15 cm of soil
[6] Values in a column followed by the same letter are not significantly different; ANOVA, means separated by LSD.

For both the 0–10 and 10–50 cm depths, the average ratio of Ca to K is generally much higher than the optimum (Tables 7.14 and 7.15); and many individual gardens had values higher than the optimum. Given that K is already low in the soil, this high Ca to K ratio would make K even less available. The results for the ratio of Mg to K are similar to Ca:K but not too excessive. The C to N ratio is mostly within the optimum range with only a few outside. On average, the remote site of Marawaka appears to have the most fertile soil.

In addition to the above nutrients, a subset of Bena samples (collected by Ms Kiup during her JAF project) were also analysed for extractable boron (B). In the 12 samples analysed, B ranged from 0.22 to 1.14 mg/kg soil. According to Bell (1999), the marginal concentration in soil for growth of cauliflower is 0.28 to 0.34 mg/kg soil. Almost half of the samples analysed were below the optimum level. According to Harding (1984) and Winston *et al* (2005) the optimum level of B for coffee production is 1 to 2 mg/kg soil. At this level, 11 of the 12 soils analysed are below the optimum.

Table 7.14. Ratios of key nutrients (0-10 cm depth) (values in parentheses represent the number of gardens with values higher than the optimum range; for C:N, there were no values lower than the optimum range).

	Ca:K	Mg:K	C:N
Field Site			
Asaro (n=24)[1]	41[b] (38)	11[b] (4)	14[a] (25)
Bena (n=33)	28[c] (82)	9[b] (64)	13[b] (30)
Baira (n=23)	50[a] (91)	15[a] (39)	13[b] (39)
Marawaka (n=35)	23[d] (80)	5[c] (46)	12[b] (17)
Mean[2]	34 (74)	9 (41)	13 (27)
Optimum range[3]	< 20	< 10	8 - 14
P-value[4]	<0.001	<0.001	<0.001

Table 7.15. Ratio of key nutrients (10-50 cm depth) (values in parentheses represent the number of gardens with values higher than the optimum range; for C:N, there were no values lower than the optimum range).

	Ca:K	Mg:K	C:N
Field Site			
Asaro (n=24)[1]	44[b] (79)	13[b] (42)	14[a] (13)
Bena (n=33)	37[b] (73)	13[b] (52)	13[b] (12)
Baira (n=23)	63[a] (65)	24[a] (48)	12[b] (13)
Marawaka (n=35)	32[b] (83)	8[b] (57)	12[b] (6)
Mean[2]	42 (76)	14 (50)	12 (10)
Optimum range[3]	< 20	< 10	8 - 14
P-value[4]	<0.001	<0.001	<0.001

[1] Number of coffee gardens sampled
[2] Mean of field site means
[3] According to Harding (1984). Values refer to the top 100 cm of soil.
[4] Values in a column followed by the same letter are not significantly different; ANOVA, means separated by LSD.

In general, based on averages, the soils in each field site appear reasonably fertile except for P. Asaro, Bena and Baira were somewhat similar in their average soil chemistry; with Marawaka significantly higher in P and K, and Asaro and Marawaka significantly higher in N. However, as there was substantial variability in analysis values, many of the individual gardens have quite low fertility.

Coffee nutritional status

N concentration was quite different across the four field sites, with Marawaka levels considered deficient (Table 7.16). P was either below or at the lower end of the optimum range for all sites. The K concentration in coffee leaves fell below the optimum range in Marawaka, Asaro and Bena but not for Baira. All Ca concentrations were in the optimum range. Mg differed substantially across the four sites, with Asaro above the optimum and Marawaka below. Similar to P, S was either deficient or at the low end of the optimum range.

Of the micronutrients B was below the optimum in Asaro and Bena (Table 7.17); and Zn was well below the optimum in all villages. According to Harding (1991), this puts Zn in the deficient range.

Table 7. 16. Mean concentration of macronutrients in coffee leaves.

Field site	Leaf Nutrients (% DM)						
	C	N	P	K	Ca	Mg	S
Asaro (n=24)[1]	46.0[a]	2.8[b]	0.14[b]	1.7[c]	1.1[a]	0.52[a]	0.17[a]
Bena (n=32)	45.2[c]	3.0[a]	0.16[a]	2.0[b]	0.9[b]	0.42[b]	0.17[a]
Baira (n=23)	45.3[c]	2.7[b]	0.17[a]	2.2[a]	0.9[b]	0.32[c]	0.15[b]
Marawaka (n=35)	45.6[b]	2.0[c]	0.16[a]	1.7[c]	1.1[a]	0.22[d]	0.15[b]
Mean	45.5	2.6	0.16	1.9	1.0	0.37	0.16
Optimum range[2]	-	2.6-3.5	0.16-0.20	2.1-2.6	0.8-1.5	0.26-0.40	0.16-0.25
P-value	<0.001	<0.001	0.005	<0.001	<0.001	<0.001	<0.001

[1] Number of coffee gardens sampled
[2] According to Harding (1991).

Table 7.17. Mean concentration of micronutrients in coffee leaves.

Field site	Leaf Nutrients (mg/kg DM)				
	B	Zn	Cu	Fe	Mn
Asaro (n=24)[1]	32[b]	6.3[b]	17	76[a]	68[b]
Bena (n=32)	25[c]	6.8[a]	18	64[b]	71[b]
Baira (n=23)	42[a]	6.8[a]	17	62[b]	57[b]
Marawaka (n=35)	44[a]	5.8[c]	18	59[b]	100[a]
Mean	36	6.4	17	65	74
Optimum range[2]	40-90	16-30	8-20	70-200	50-100
P-value	<0.001	<0.001	0.37	0.007	<0.001

[1] Number of coffee gardens sampled
[2] According to Harding (1991).

Interestingly, the Marawaka site seemed the most fertile from a soil N, P and K perspective, but the coffee leaves had the lowest or near lowest level of these nutrients. That B is low is no surprise. There are many cases of boron deficiency in many crops in Bena and Asaro (Plate 7.4). However, the very low levels of Zn were unexpected.


Plate 7.4. Suspected boron deficiency in cabbage at Asaro (left) and orange at Bena (right).

Coffee garden condition

Generally, the soil surface in the gardens was mostly covered by mulch (dead organic matter) or non-leguminous plants; there was very little legume cover (Table 7.18). This indicates that there is little N-fixation adding N to the coffee garden soil. Bare ground was quite often encountered, raising concern about the susceptibility of the soil to water erosion – especially on sloping gardens.

Table 7.18: Average ground cover for each field site (%).

	Bare	Mulch	Non-legume	Legume
Asaro (103)	24.4	45.2	29.2	0.4
Bena (92)	27.3	32.9	38.3	1.5
Baira (33)	17.7	34.5	45.2	3.1
Marawaka (96)	21.2	36.8	28.7	0.6
Mean (324)	23.6	38.1	33.3	1.0

A number of other parameters that indicate how well the coffee gardens are managed were also measured (Figure 7.16). Weed control was generally ‘basic’ to ‘good’ with Bena and Marawaka tending to ‘good’ condition. Bena had a wider range of conditions than the other villages; with a substantial number of gardens in the ‘very poor’ and ‘very good’ condition. Pruning was mostly of a ‘basic’ condition but with Baira having an equal number of ‘poor’ and ‘basic’ condition coffee gardens. Shade was mostly of a ‘basic’ condition except for Bena where most shade was in a ‘good’ condition. In Asaro, nutrition was mostly in a ‘basic’ condition with the other villages mostly in a ‘good’ condition.

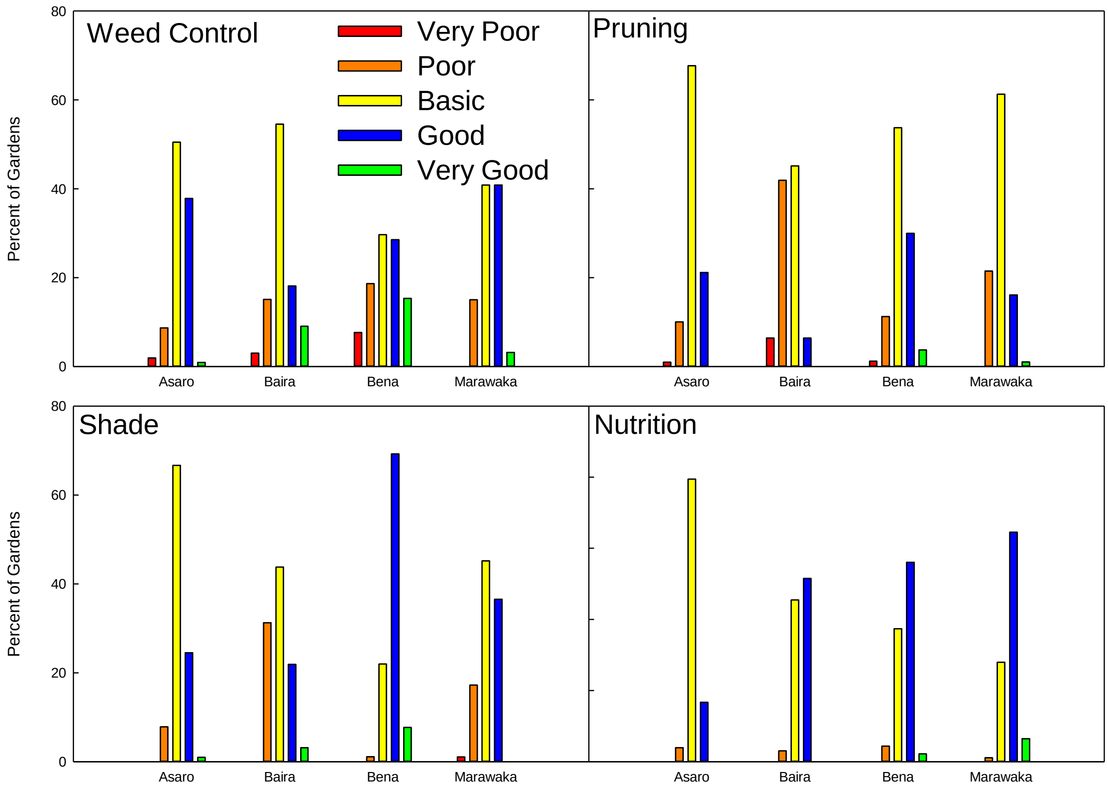

Figure 7.16. Condition of coffee garden.

These results indicate that most coffee gardens are maintained to some extent, but probably not to the extent required to maintain 'very good' condition and to obtain good and consistent yields with adequate nutrition. This implies that coffee trees will respond to the addition of nutrients, especially N and K.

Nutrient export

As with any agricultural crop, the selling of cherry or parchment coffee represents an export of nutrients. However, the processing pathway to parchment coffee provides opportunities to retain some of those nutrients. By far, the highest concentration of K is in the pulp + skin (Table 7.19). The pulp + skin also contain high concentrations of other nutrients.

Table 7.19. Macronutrient concentration in cherry parts.

Cherry Part	Cherry Nutrients (% DM)						
	C	N	P	K	Ca	Mg	S
Parchment coffee	46.2	1.82	0.15	1.40	0.12	0.18	0.11
Pulp + Skin	41.2	1.50	0.15	3.25	0.39	0.15	0.13
Mucilage[1]	43.2	1.24	0.14	1.62	0.48	0.11	0.07
Whole cherry	44.6	1.68	0.15	1.88	0.23	0.16	0.11

[1] by difference

Of the micronutrients, B has the highest concentration in the pulp + skin (Table 7.20). This has implications for pulp + skin management in an environment which is recognised to be low in B. That Zn is quite high in parchment, which is exported, has implications in Zn nutrition of the crop as zinc appears to be at deficient levels from leaf analysis.

Table 7.20. Micronutrient concentration in cherry parts.

Cherry Part	Cherry Nutrients (mg/kg)				
	B	Zn	Cu	Fe	Mn
Parchment coffee	7.3	11.0	16.3	59.5	23.4
Pulp + Skin	17.4	3.9	15.9	46.9	21.5
Whole cherry	9.5	5.6	14.6	41.1	21.2

There were some small (but significant) differences in the nutrient concentration in cherry parts between villages. The concentration of K was substantially higher in both parchment and skin + pulp in Baira (Table 7.21). Again this has implications for nutrient management within each field site.

Table 7.21: Macronutrients in cherry parts by field site.

Cherry Part	Cherry Nutrients (% DM)						
	C	N	P	K	Ca	Mg	S
Parchment coffee							
Asaro	46.3	1.81	0.14	1.38	0.13	0.19	0.11
Bena	46.1	1.92	0.15	1.43	0.12	0.18	0.11
Baira	46.3	1.83	0.16	1.48	0.10	0.17	0.11
Marawaka	46.2	1.73	0.15	1.31	0.13	0.16	0.11
Pulp + Skin							
Asaro	41.7	1.36	0.12	2.91	0.39	0.20	0.11
Bena	41.4	1.63	0.15	3.57	0.40	0.17	0.14
Baira	41.9	1.64	0.16	3.88	0.40	0.13	0.11
Marawaka	41.5	1.40	0.16	2.89	0.37	0.12	0.15
Whole cherry							
Asaro	44.5	1.58	0.12	1.71	0.24	0.18	0.10
Bena	44.6	1.83	0.15	2.01	0.23	0.18	0.12
Baira	45.0	1.73	0.15	2.03	0.19	0.15	0.10
Marawaka	44.4	1.57	0.15	1.80	0.26	0.14	0.12

As with the macronutrients, there were significant differences in the concentration of micronutrients in cherry parts, but the differences were generally larger (Table 7.22). The concentration of B in pulp + skin in Baira was double that in Bena. The high level of Zn in the exported parchment in Marawaka is of concern given that Marawaka had the lowest levels of leaf Zn.

Table 7.22. Micronutrients in cherry parts by village.

Cherry Part	Cherry Nutrients (mg/kg)				
	B	Zn	Cu	Fe	Mn
Parchment coffee					
Asaro	6.0	6.0	13.5	33.8	19.8
Bena	4.7	7.4	15.1	30.7	22.3
Baira	8.9	10.9	15.3	39.0	18.1
Marawaka	9.9	17.9	19.7	115.6	29.5
Pulp + Skin					
Asaro	14.2	4.8	15.3	55.3	16.3
Bena	12.9	2.8	14.9	56.5	23.4
Baira	23.2	4.9	19.1	48.3	15.4
Marawaka	21.5	3.8	15.7	30.4	26.2
Whole cherry					
Asaro	7.4	4.6	12.3	29.3	16.3
Bena	6.5	4.4	15.5	51.6	21.9
Baira	12.2	10.0	15.7	57.5	16.8
Marawaka	12.7	5.5	14.8	30.8	25.6

The amount of nutrient exported depends on the biomass of each component. Figure 7.17 shows the K content of each cherry part during processing. It is expressed in terms of 60 kg parchment coffee (11% moisture) as this is the unit of parchment coffee (a coffee bag) sold by smallholder coffee farmers; and thus has more relevance.

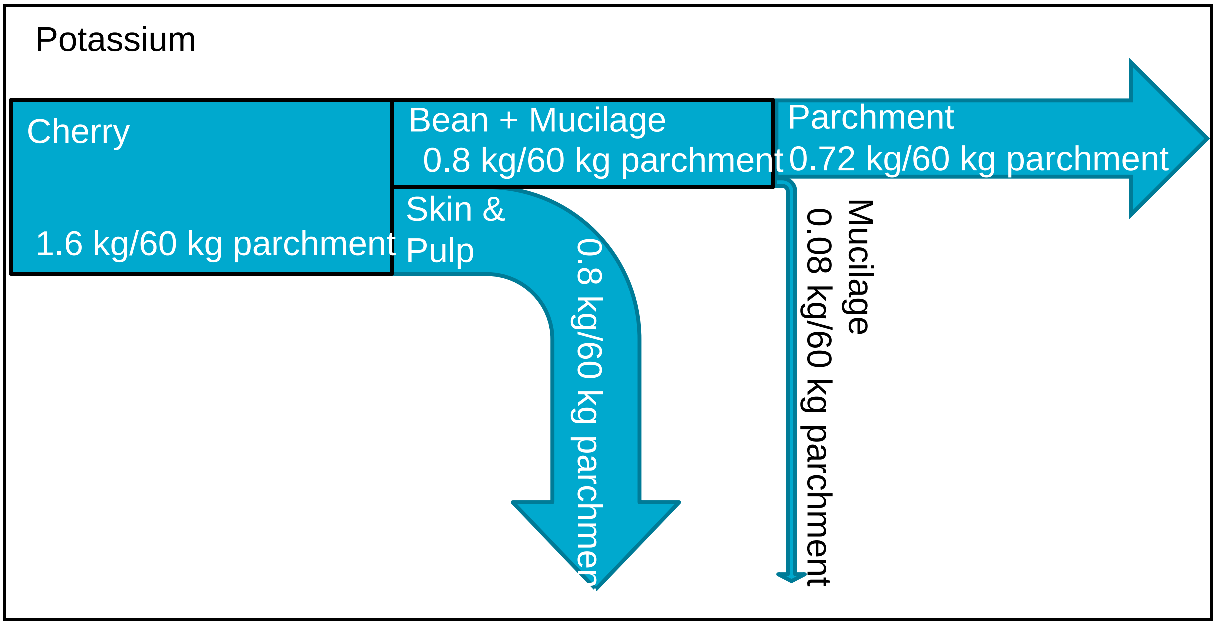

Figure 7.17. K content of cherry parts during processing to 60 kg parchment coffee.

The amount of cherry required to produce 60 kg parchment coffee (~300 kg fresh cherry) contains 1.6 kg K. During the first stage of processing cherry (pulping), half of that (0.8 kg

K) is retained in the pulp with the other half in the bean + mucilage component. Further processing (fermenting) will release a small additional amount (0.8 kg K) via the mucilage, with the remainder (0.72 kg K) in the parchment coffee. While nothing can be done about the loss of K from the coffee garden in the parchment coffee, the K in the pulp + skin, and to a smaller extent, the mucilage waste water, can be re-used. For example, it could be placed back in the coffee garden or used on vegetables.

A similar pattern is evident for N and organic C except that the proportion in the pulp + skin is lower (Figure7.18).

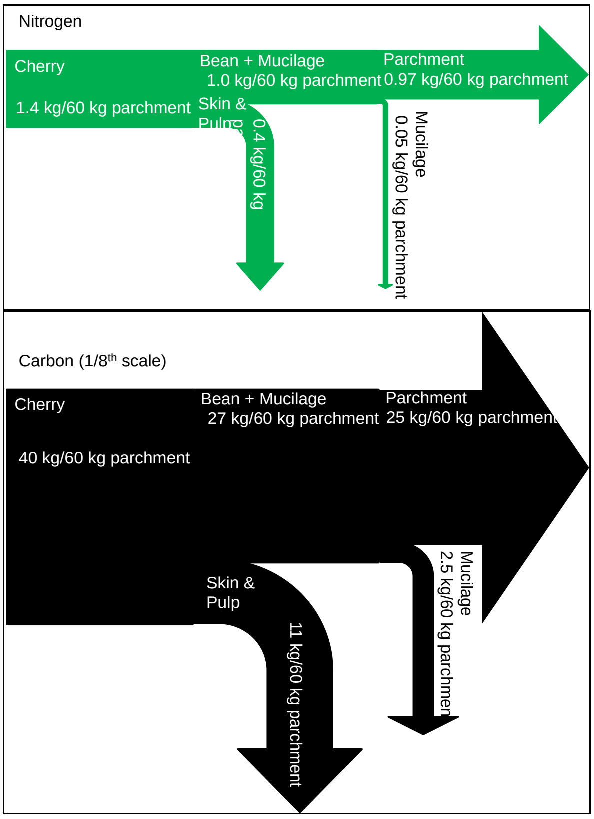

Figure 7.18. N and C content of cherry parts during processing to 60 kg parchment coffee.

Because of the high concentration of nutrients in the pulp, it has considerable 'fertiliser' value. The price (in 2015) of fertilisers and the corresponding values of individual nutrients are shown in Table 7.23.

Table 7.23. Price (2015) of fertiliser in Goroka and corresponding values of nutrients in each fertiliser.

Fertiliser	Nutrient %				Cost Fertiliser (Kina)		Cost (per kg Nutrient) (Kina)		
	N	P	K	kg =	5	per kg	N	P	K
Urea	46				26.00	5.20	11.30		
NPK (12:12:17)	12	5	14		24.00	4.80	40.00	91.61	34.03
NPK (10:25:12)	10	11	10		26.00	5.20	52.00	47.64	52.22
TSP		18			25.00	5.00		27.78	
MOP			50		23.00	4.60			9.20

Assuming that all of the nutrients in the pulp + skin are (eventually) available for uptake by plants the value of the fertiliser it could replace (in vegetable production) is considerable (Table 7.24). For example, the pulp + skin generated during processing 60 kg of parchment coffee could replace PGK16.29 worth of urea + MOP + TSP; or PGK 41.78 worth of NPK (10:25:10).

Table 7.24. Value (2015) of pulp + skin in terms of fertiliser replacement.

Pulp (per 60 kg parch.)	Export (kg)					
N	0.38					
P	0.04					
K	0.80					
Cost to replace (PGK)	N	P	K		Fertiliser costs	PGK
Urea	4.30				Urea + MOP+TSP	16.29
NPK (12:12:17)	15.20	3.66	27.22		NPK (12:12:17)	27.22
NPK (10:25:10)	19.76	1.91	41.78		NPK (10:25:10)	41.78
TSP		1.11				
MOP			10.88			

In the remote sites, Baira and Marawaka, fertiliser is not used. So expressing the value of pulp in terms of fertiliser equivalents is meaningless. Instead we have expressed it in terms of additional productivity. According to the PNG Coffee Handbook (1992), 50 kg N/ha, 2 kg P/ha, and 40 kg K/ha will increase green bean productivity by 500 kg/ha. Fertiliser equivalent in pulp + skin from processing 60 kg of parchment coffee would satisfy 76 m^2, 200 m^2, and 200 m^2 of coffee garden for N, P, and K respectively to produce that extra 500 kg/ha. Taking the minimum (76 m^2), this would equate with an additional 3.8 kg green bean or 4.2 kg parchment coffee (assuming 10% weight loss on processing parchment coffee to green bean). At PGK 6.87 per kg Y1 grade parchment coffee (Table 7.25), this puts the value of the skin + pulp from processing 60 kg parchment coffee at PGK 28.85 worth of extra yield. If we take the larger area (200 m^2), this puts the value at PGK 75.57 worth of extra yield.

In the accessible field sites near processers, there are opportunities to sell cherry rather than parchment to capture the 33% price premium. This of course has implications on even greater export of nutrients which are not being replaced. Even within a field site (e.g. Asaro) whole cherry is sometimes sold to another farmer who has a pulper. This means that there is a transfer of nutrients within the village to the advantage of the buyer. If the pulp is used well, this can have benefits in extra food production.

Table 7.25. Nutrient requirement to increase green bean yield by 500 kg/ha; and area of coffee garden that could be satisfied by the equivalent fertiliser value of pulp + skin from processing 60 kg of parchment coffee.

Yield increase of 500kg/ha GB needs				Pulp nutrients (60kg parchment)	
Fertiliser	kg/ha	Nutrient	kg/ha	kg	m^2
N	50	N	50	0.38	76
P_2O_5	5	P	2	0.04	200
K_20	50	K	40	0.80	200

However, a survey of coffee growers shows that most do not utilise the skin + pulp efficiently for either food gardens or coffee gardens, except at Marawaka (Figure 7.19; Plate 7.5). Most of the farmers in Baira and Bena leave the pulp + skin at the pulper (Plate 7.3), while in Asaro most pulp goes into the river. Both of these management options result in a waste of valuable nutrients.

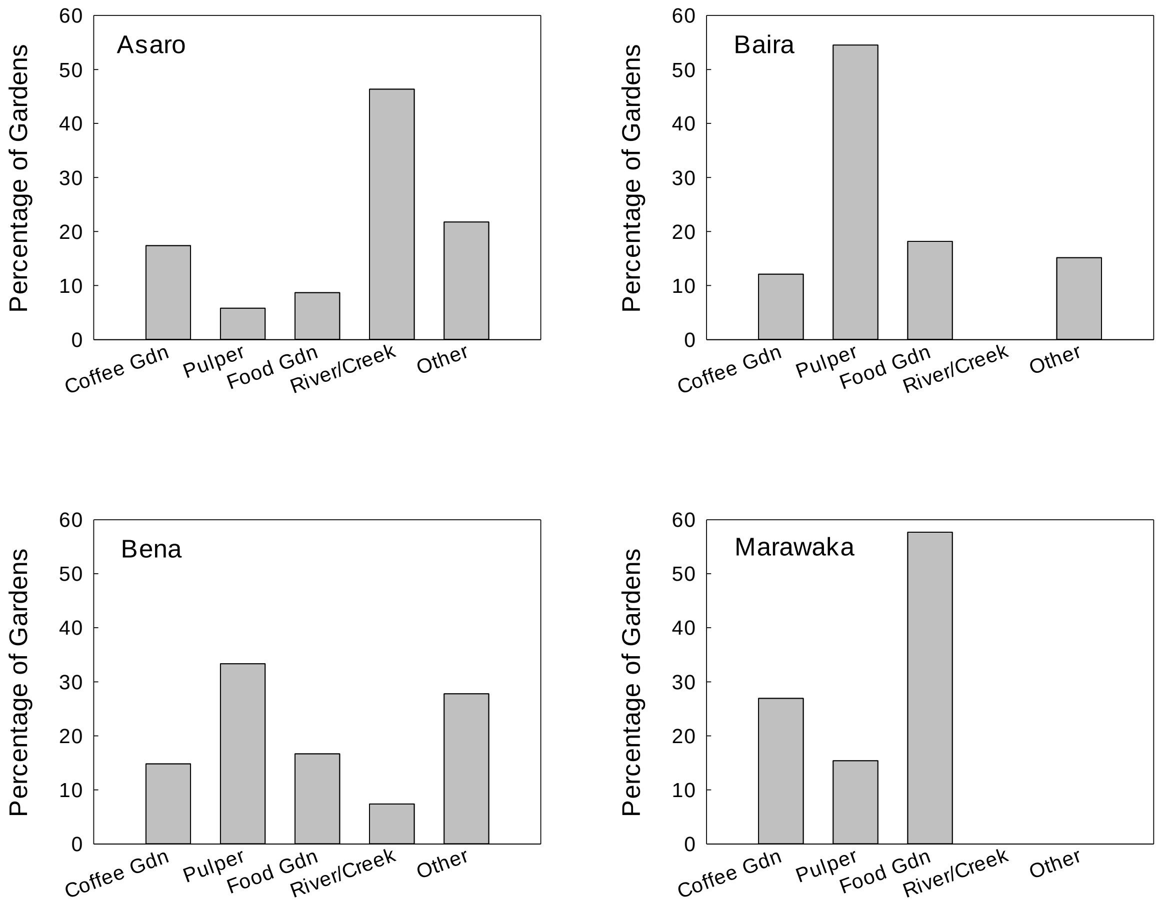

Figure 7.19. Fate of pulp + skin in each field site.

Plate 7.5. Effective recycling of pulp.

If a follow-on proposal is successful, this aspect of pulp value will be emphasised in the development and roll-out of training manuals.

As part of her project-related JAF, Ms Emma Kiup has been tracking the fate of nutrients from food gardens associated with coffee gardens. She found that even when coffee farmers use fertiliser on their vegetables they are still in negative balance. The export of N, P and K in the marketable part of broccoli is 8.7, 1.1, and 11.2 g/m^2 respectively. The amount of N, P, and K added in fertiliser is 4.4, 4.8, and 4.4 g/m^2, respectively. This represents a balance of soil N, P, and K of -4.3, +3.7, -6.8 g/m^2, respectively. For cauliflower the N, P, and K balance is -15.2, +4.3, and -21.4 g/m^2; and for bulb onion it is -4.7, +0.9, and -8.4 g/m^2.

Generally, poor use is made of food crop residues; they are often left in a pile near the house or removed at the market place. For example, cauliflower leaves contain 78, 72, and 70% of the N, P, and K in the whole plant top respectively. Simply leaving the leaves in the food garden will reverse the negative N balance (+0.9 g/m^2) and reduce the negative K balance to about one tenth (-2.6 g/m2).

Intercropping

While intercropping was practised in some coffee gardens, these were usually of an *ad hoc* nature, often filling gaps where coffee trees had died, or to take advantage of additional light near roads and pathways through coffee gardens (Plate 7.6).

Plate 7.6. Informally intercropped cabbages.

Trials were established in Bena and Asaro to test the concept that intercropped and fertilised vegetables would be advantageous to the coffee (Plate 7.7).

Plate 7.7. Intercropped cabbages under a low-density, low-shade coffee garden.

We demonstrated a response in coffee to intercropping with fertilised vegetables (Figure 7.20). We have only vegetative data because this trial was initiated late in the project and coffee harvest data were not available as it was not the coffee flush period. However, it was clear that intercropping with fertilised cabbages improved the vegetative parameters of adjacent coffee trees.

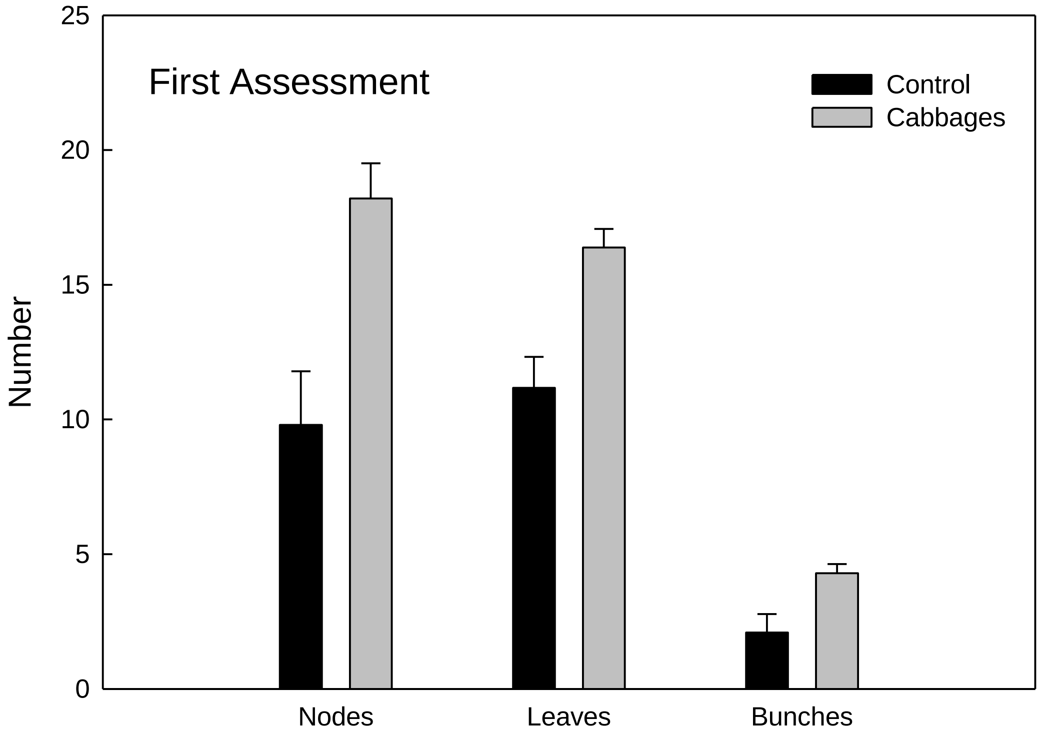

Figure 7.20. Effect of intercropping with cabbages on number of stem nodes, leaves and bunches. Error bars are the standard error of the mean.

Intercropping of coffee with cabbages was rapidly adopted by farmers. Figure 7.21 is a timeline of the effective uptake by one farmer in Bena district. Blue represents the project's input and green the farmer's input in each subsequent crop. Clearly, by the third crop, the farmer had fully adopted this technology, including the financial costs.

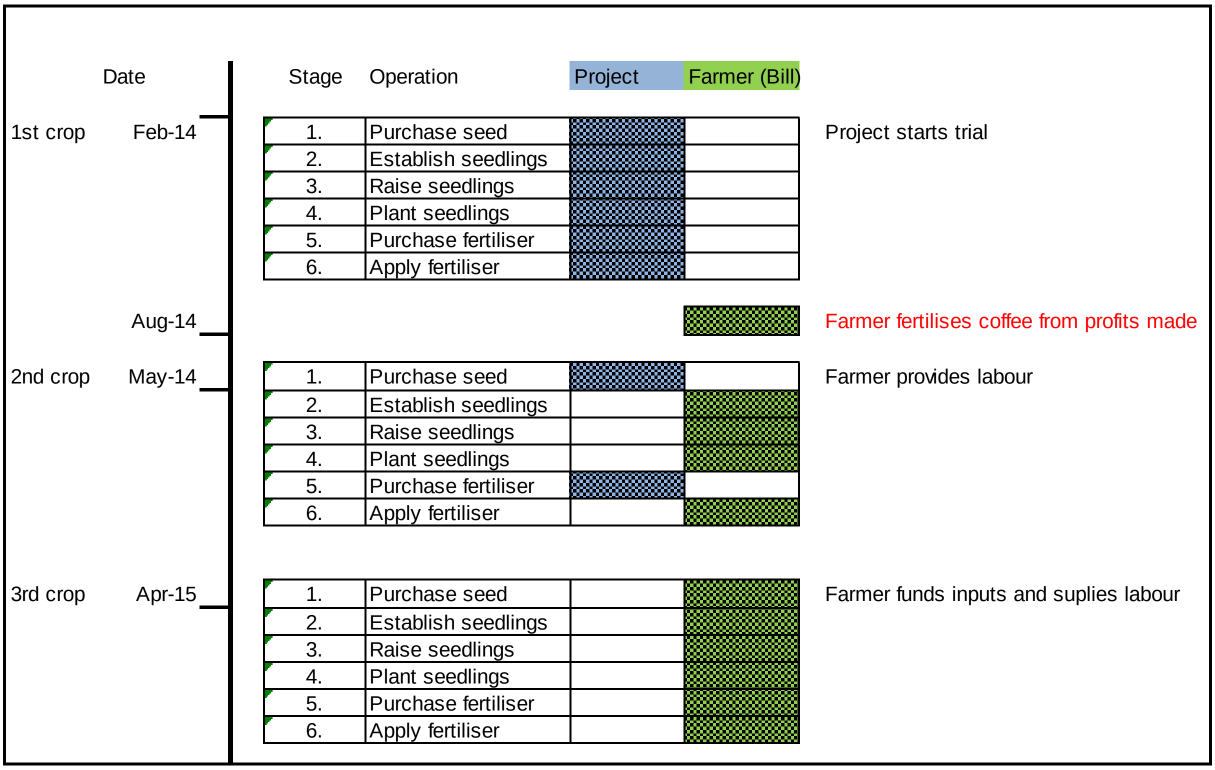

Figure 7.21. Demonstration of rapid adoption of intercropping technology by a Bena farmer's family.

Intercropping coffee gardens with food crops (whether fertilised or not) conveys a number of advantages to a food-coffee gardening family:

- Weeding of food crops will also benefit coffee
- Coffee and shade trees will be pruned to allow more light to reach food crops
- Fertiliser applied to food crops will also benefit the coffee
- The roots of food crops remaining after harvest will add to the soil organic matter and improve soil fertility
- Women will become more involved in coffee garden maintenance through their work on food crops
- More regular visits to coffee gardens to tend food crops will alert the family to coffee tree maintenance issues like pests and diseases
- Food production will be intensified leading to more efficient use of land

Food crops

A number of food crops were also analysed for their nutrient concentration to gauge how much nutrient is exported from food gardens. In most crops, the concentration of K is higher than that of N (Table 7.26). This is particularly relevant in terms of long-term sustainability of these farming systems as K levels in the soil are low and the Ca:K ratios are high, thus limiting the availability of K to growing food plants. This emphasises the importance of nutrient conserving management practices such as effectively utilising pulp + skin from processing parchment coffee. Some crops, such as Highlands pitpit (*Setaria palmaefolia*) have high concentrations of all nutrients and thus represent a major export of nutrients from garden beds.

Table 7.26: Macronutrient concentration of common food crops.

Crop	Crop Nutrients (% DM)						
	C	N	P	K	Ca	Mg	S
Banana	40.2	0.95	0.11	2.63	0.25	0.20	0.06
Bean	40.5	2.90	0.28	1.81	0.32	0.22	0.13
Broccoli	35.4	2.78	0.39	3.83	0.95	0.30	
Bulb Onion	40.0	1.52	0.26	1.68	0.45	0.13	0.29
Cabbage	37.4	1.72	0.31	2.70	0.52	0.19	
Carrot	39.4	0.98	0.25	2.71	0.33	0.14	0.10
Cassava	39.8	0.44	0.09	0.83	0.14	0.12	0.04
Cauliflower	38.7	2.47	0.21	3.11	1.17	0.23	
Corn	42.5	1.10	0.20	0.81	0.06	0.12	0.08
Ginger	39.1	1.38	0.17	3.11	0.35	0.44	0.14
Guava	43.9	0.83	0.11	1.44	0.11	0.06	0.10
Highlands pitpit	37.4	2.67	0.35	6.09	0.18	0.22	0.20
Irish Potato	39.5	1.40	0.21	2.50	0.03	0.14	0.17
Marita	50.1	1.04	0.13	1.89	0.87	0.19	0.11
Orange	41.7	0.67	0.14	0.97	0.42	0.11	0.04
Papaya	39.3	1.40	0.17	2.20	0.25	0.17	0.17
Peanut	51.2	2.80	0.21	1.00	0.14	0.17	0.14
Pineapple	40.0	0.41	0.05	0.84	0.12	0.12	0.04
Pumpkin	40.5	1.73	0.32	2.44	0.11	0.17	0.13
Pumpkin leaves	38.1	3.90	0.26	2.60	2.50	0.69	0.24
Rice	40.5	1.35	0.19	0.31	0.02	0.08	0.12
Singapore taro	39.2	1.21	0.17	1.86	0.14	0.14	0.07
Spring Onion	40.6	1.82	0.25	2.38	0.53	0.17	0.21
Sugarcane	37.8	0.29	0.13	0.97	0.48	0.12	0.11
Sweet potato	39.9	0.64	0.12	1.20	0.14	0.09	0.06
Taro	39.6	0.65	0.16	1.38	0.15	0.11	0.05
Tomato	42.5	2.49	0.43	4.90	0.17	0.23	0.17
Yam	39.9	1.26	0.21	1.62	0.05	0.06	0.06

Of the micronutrients, Fe is particularly high in the food crops which contain green leaves (broccoli, cabbage, etc.) and usually this is accompanied by high levels of Zn (Table 7.27). This reinforces the importance of these crops in human diets as the staples (e.g. sweet potato) are generally quite low in these nutrients. Surprisingly, ginger is particularly high in all micronutrients except B.

Table 7.27. Micronutrient concentration of common food crops.

Crop	Crop Nutrients (mg/kg DM)				
	B	Zn	Cu	Fe	Mn
Banana	10.5	30.7	4.0	66	35.9
Bean	14.1	27.2	6.7	87	19.3
Broccoli	11.3	35.5	12.5	273	78.1
Bulb Onion	21.2	25.6	4.5	112	22.6
Cabbage	6.9	22.2	6.4	290	28.9
Carrot	25.9	45.2	7.7	160	18.6
Cassava	4.2	17.4	2.4	139	15.7
Cauliflower	10.6	29.0	3.7	380	51.2
Corn	2.9	31.7	3.9	127	18.8
Ginger	6.7	89.6	16.2	1791	245.6
Guava	8.0	10.8	7.5	27	7.9
Highlands pitpit	7.5	43.2	7.1	223	59.6
Irish Potato	7.0	15.1	8.3	65	8.4
Marita	10.8	21.4	9.4	85	65.0
Orange	14.3	3.4	2.5	55	4.9
Papaya	10.7	9.6	2.3	53	6.9
Peanut	12.7	23.0	13.2	787	20.5
Pineapple	7.8	15.8	8.9	399	201.9
Pumpkin	12.1	19.8	7.4	76	9.2
Pumpkin leaves	28.4	25.9	10.9	550	64.1
Rice	1.4	20.9	5.8	59	13.8
Singapore taro	6.3	47.1	7.8	158	97.9
Spring Onion	12.8	50.0	6.0	358	32.9
Sugarcane	1.5	27.7	3.8	112	19.2
Sweet potato	5.6	8.9	5.5	123	19.3
Taro	3.8	54.6	9.3	242	26.4
Tomato	15.5	20.8	12.7	194	18.7
Yam	3.9	9.7	7.0	182	4.3

Boron deficiency

During the project, project staff identified boron (B) deficiency in vegetable crops. B deficiency is largely unrecognised, although it has devastating consequences. Because it is unrecognised it does not make it on to the list of country priorities for many of these regions. This is an area in which ACIAR should invest. It is devastating because B deficiency prevents the pollen tube from growing though the stigma, thus preventing fertilisation of the ovum and effective fruit production. However, it is simple and cheap to solve with the application of B. Indeed Dr Webb, has identified (and solved) B deficiency in coconuts in Misimas Orientale (Philippines) and has identified suspected B deficiency in banana during his involvement in ACIAR project SMCN/2009/031 (Plate 7.8).

Plate 7.8. Rolled-up leaves - suspected B deficiency in banana leaves.

B deficiency can also make brassicas more susceptible to ‘club root’ (*Plasmodiophora brassicae*) (Plate 7.9). This broccoli plant was collected during Ms Kiup’s fieldwork in Bena. While adding B after the disease is established will not cure it, good B nutrition can prevent its occurrence in the first place.

Plate 7.9. Club root in broccoli.

The key findings of the nutrient management component of the project can be summarised as follows. Many of the coffee (and food) gardens are low in essential plant nutrients, especially N, P and K, and this is reflected in leaf nutrient concentrations. Also, leaf nutrients analysis reveals deficiencies in both Zn and B.

The pulp + skin produced during processing to parchment coffee contains high levels of nutrients, especially N and K. Effective use of this waste material is usually quite poor and could be better managed to maintain nutrient levels in coffee (and food) gardens. Intercropping with fertilised vegetables is also an effective means of delivering nutrients to coffee trees in easily accessible sites. This is particularly important in areas where there is evidence of population pressure. Intercropping can also contribute to income diversification, particularly women's income.

Section 7 Summary

The backdrop to declining smallholder productivity and coffee quality is a marked deterioration in road infrastructure, reduced extension capacity and the demise of the plantation sector which had previously provided centralised processing and many other services to their surrounding growers (Sengere 2017). These factors, together with poor knowledge of coffee husbandry and processing, have resulted in lower quality parchment from the smallholder sector and therefore discounted prices for farmers. Farmers receive a discounted price of approximately one-third on Grade X parchment (Table 7.1) and this is excluding further price premiums that could be achieved with certification. Farmers are therefore earning coffee incomes significantly below potential levels.

Moreover, evidence from this project suggests that soils in some coffee and food garden areas are under stress and are low in essential plant nutrients, especially N, P and K. Leaf nutrient analysis also reveals deficiencies in both Zn and B. Despite these nutrient deficiencies, farmers are losing significant quantities of potentially reusable nutrients through inefficient reuse of nutrients (especially N and K) contained in pulp and skin produced during processing to parchment coffee. Effective use of this waste material is typically poor and could be better managed to maintain nutrient levels in coffee (and food) gardens. Similarly, in areas experiencing land pressures and where nutrient depletion risks are greater, intercropping with fertilised vegetables proved also to be an effective way to deliver nutrients to coffee trees in easily accessible sites.

This raises two important points where socio-economics interacts directly with nutrient management:

1. Because of the recognised value of pulp as a nutrient source, selling cherry rather than parchment will contribute further to nutrient losses from the food-garden system. However, this will only be important to those farmer families who use pulp effectively. It will make no difference (in terms of nutrient retention) to those farmers who leave the pulp at the pulping station or flush it down a river. Indeed, in the latter case, cherry sales may prevent the environmental consequences of pulp being discharged into rivers.

2. Intercropping is a win-win situation and provides the following benefits:
    - Weeding that is essential for food production will benefit the coffee.
    - Proper pruning of coffee will be encouraged in order to maximise light penetration to the food crops.
    - If the food crop is fertilised, the residual fertiliser will benefit the coffee
    - If non-root crops are grown (root crops are not recommended for intercropping because of the soil disturbance during harvesting) the roots remaining after harvest will add to the soil organic matter and improve soil fertility.
    - Integration of food crops with coffee will also integrate the activities of men and women. There is evidence that women are moving away from investing labour in coffee production to pursue alternative and more secure income streams in food production (Inu 2015). Integrating food production with coffee production will provide more gardening land for women that will strengthen livelihoods generated from coffee and food crops.
    - A physical and regular presence in the coffee garden will alert the family to maintenance issues with coffee (pruning, pests and diseases) as well as encourage more regular harvesting of coffee.

- It will intensify food production (and thus income) without requiring additional land area. This is particularly important in areas where land pressures are rising.

Reliable access to markets has an enormous positive influence on smallholders' economic well-being and coffee farming practices. Farmers at remote locations have significant livelihood constraints and a narrower and less financially rewarding range of income options than are available in accessible locations like Bena and Asaro. Poor market access means they are unable to produce fresh food produce for the lucrative and growing urban markets. They also have limited access to extension information and other services, all of which contribute to raising quality of life.

Remote locations, therefore, have a much heavier reliance on coffee for cash income. Coffee is the primary source of income for school fees, bride prices and other large expenses. Because they have few alternative income sources that provide an equivalent or higher income than coffee, coffee farmers in remote locations would be more likely to act on extension advice and invest more labour in coffee garden maintenance than growers in accessible sites where a broader range of livelihood options compete directly for coffee labour. Farmers in Bena and Asaro, for example, were earning relatively high incomes from the sale of vegetables and pineapples and had less time to invest in their coffee gardens. Therefore, extension strategies targeted at remote areas should emphasise coffee garden maintenance and correct processing techniques to enhance parchment quality.

Labour shortages are a major concern in both accessible and remote coffee growing areas. This is despite what might be viewed as relatively small levels of production per household or adult equivalent. Labour shortages were not just absolute – though that is certainly a factor for some households – but are what could be called functional labour shortages, that is, there is labour available but socio-economic factors are preventing the deployment of labour in coffee, especially women's labour, for a range of reasons, including perceived inequities in the distribution of coffee income and perceptions of better or more certain returns to labour invested in other livelihood pursuits. Payment certainty is therefore a significant factor in improving the supply of labour in coffee production.

Another important factor constraining the labour supply is lifestyle or 'way of life' which leaves little time for coffee production and which constitutes a suite of activities including leisure pursuits, church and community activities which are highly valued by smallholder communities. This partly explains why smallholders are reluctant to move from a low input, low output system of production to a high input, high output, modern system of production requiring greater inputs of labour. The difficulty for those seeking to increase coffee production and productivity through higher labour inputs or through expensive inputs like inorganic fertiliser, is that this 'way of life' is highly valued and remains an important path to status and prestige in rural PNG society. It also provides a moral framework for community standards of acceptable behaviour (Curry et al. 2017). This makes it highly resistant to change.

Labour mobilisation strategies such as the use of hired labour are not commonly used to address labour shortages in cash crop production in PNG. They remain the exception, partly because labour invested in crop production builds ownership claims to crops, and this is a difficult area to address through extension. Moreover, as pointed out above, payment uncertainty for labour is a major disincentive to hired labourers.

Our research suggests that one way to improve smallholder productivity and coffee quality is to develop strategies to improve labour efficiency and to encourage smallholder practices that are more likely to guarantee a fair rate of remuneration of coffee labour, especially women's labour. Improvements in labour efficiency make coffee more viable in remote areas where transport costs are so high and where processing standards are poor and where parchment quality is adversely affected by long-term storage. Potential strategies to improve the efficiency of labour are presented in Section 9.

Demucilagers may improve the viability of coffee livelihoods in both remote and accessible coffee growing areas. Growers can achieve PSC levels of quality fairly easily and it is not unreasonable to suggest they could produce even higher grades of coffee like X and A grades, commanding price premiums of between 30 and 40% (Table 7.1). Also, the labour efficiencies and improved quality of parchment would increase returns to labour in accessible sites thereby reducing the opportunity cost of labour in coffee relative to other livelihood pursuits. Coffee would therefore become a more attractive livelihood pursuit in accessible locations.

8 Impacts

8.1 Scientific impacts – now and in 5 years

This project has filled a gap in the knowledge and understanding of the socio-economic and nutrient management practices that affect smallholder coffee production. Some of the higher-level structural constraints on smallholder production had been identified in earlier research (Section 3). However, little was known on how socio-economic factors and nutrient management strategies influence the productivity of growers and their uptake of extension, or what motivates or constrains smallholders to invest time and labour in coffee production. Likewise no recent data were available on the nutrient status of smallholder coffee gardens, and nor was there an understanding of the pathways of nutrient movement into, through, and out of smallholder coffee gardens. This project has produced new and valuable knowledge in these areas which has now been used in the drafting of extension training manuals. These manuals seek to improve extension intervention strategies to increase smallholder income and promote management practices that maintain or improve the nutrient capital of coffee and food gardens.

Some of the key findings and new knowledge produced by the project that are now available to influence the design of future research and more suitable smallholder extension interventions include :

- Coffee production is but one of a range of livelihood strategies smallholders undertake which place demands on growers' time and labour.
- Smallholders practise a low-input, low-output system of coffee production.
- Household labour. Labour shortages are among the top constraints on smallholder coffee production.
- In villages with good market access (near major urban centres), coffee production is now competing with the growing and lucrative production of fresh vegetables for land, labour and capital investment. In some areas coffee is being replaced with fresh food production for urban markets.
- In remote coffee growing areas without road access, there is little incentive or motivation to improve production when structural and infrastructural constraints are so high. Very high transport costs and very low labour efficiencies, particularly in processing, leave coffee farming barely viable.
- The value of pulp as a nutrient source and thus points in the coffee farming system that are most vulnerable to nutrient loss.
- The generally low level of available nutrients in the soil for coffee growth.
- The low status of N, P, K and boron, and the deficient status of Zn in coffee trees.
- Intercropping coffee with short rotation fertilised vegetable crops can be beneficial to the coffee crop.

Ideas and concepts developed during this project have stimulated interest within CIC to explore new research questions and interventions around socio-economics and nutrient management. For example, the research on nutrient distribution in coffee cherry components (and in other crops), as well as the concept of intercropping have influenced the development of a Master of Philosophy research project at James Cook University (Emma Kiup). The findings of the nutrient management component of the project is also influencing the scientific thinking of project staff and collaborators associated with other

ACIAR and DFAT projects in PNG, Philippines, Indonesia, Fiji, Tonga, Samoa, Kiribati and Tuvalu). For example:

- In the Philippines (SMCN/2009/031), project collaborators from local Government authorities now appreciate the vulnerability of the soil resource to permanent loss of nutrients (erosion and product export), especially in low-input (no fertiliser addition) systems. Likewise, boron deficiency was diagnosed in this project and in the Philippines project (SMCN/2009/031). This was subsequently solved and the Philippines team is actively looking at solving boron deficiency in other crops. These messages are being relayed to farmers and farmer groups.
- In Indonesia (DFAT, ARISA project), local project staff are now thinking about nutrient flows in the cassava farming system. Although they do not use fertiliser on cassava ("it does not need it"), they now realise they are getting nutrient inputs through other (at the time not appreciated) means. Stubble and cob remains from fertilised maize are fed to cattle; cattle manure (problematic for cattle farmers with penned animals) is applied to the cassava field before planting. The Indonesian project staff are also now analysing data on the effect of intercropping fertilised crops on cassava nutrition and productivity.
- In the new South Pacific project proposal (SMCN/2016/111) one of the objectives is "To quantify nutrient cycling in island agricultural and taro production systems and undertake field trials to highlight the importance of budgeting for soil fertility management and increasing yield" because of the involvement of a project member in ASEM/2008/036.
- Promising preliminary results from the work on intercropping and demucilagers is being developed into a new ACIAR project proposal.
- It is clear that the nutrient management component of the project is already having scientific impacts in other related projects and it is expected that this will continue.

There is also now greater awareness within CIC of the potential of socio-economic research to assist with more targeted extension interventions that take into account the diverse social, economic, cultural and geographical contexts in which smallholder production takes place, as well as the intra-household constraints on smallholder coffee production. For example, in January 2017, CIC management began discussions on the establishment of a socio-economics section within CIC. It is expected the new section will be established this year and that CIC will have a growing programme of socio-economic research over the next five years.

8.2 Capacity impacts – now and in 5 years

Many of the socio-economic and soil nutrient research techniques employed in this project were new for our PNG partners. Most CIC researchers had not undertaken face-to-face qualitative interviews with farming households, nor run focus group discussions or made biomass or ground cover estimations. Most also had limited experience with database management. Thus there was an ongoing element of training and capacity building as team members learnt these new skills. Indeed, reviewers' of this project stated "*The Australian project team must be commended for showing exemplary mentoring acumen as a number of officers have now progressed into further studies, which would not have been possible in the absence of the project. Much on-the-job capacity building was clear to the reviewers, and was supported by the following specific training activities:* …"

In May 2010, Debbie Kapal received Crawford funding to attend the Oil Palm Inception meeting (SMCN/2009/013) to meet and establish connections with other soil scientists in PNG.

In 2011 CIC and NARI research team members received training in several areas. Mike Webb and George Curry conducted a one-day training session in the use of databases (MS Access and MS Excel). Mike Webb also conducted training in techniques of biomass and ground cover estimation.

In July 2011 Ms Inu completed an ACIAR research impacts workshop in the Philippines.

In December 2011, Gina Koczberski and George Curry conducted a three-day research training workshop on “Social Science Research Techniques” for junior research staff from CIC, NARI, CCIL and PNGOPRA. The workshop was hosted by PNGOPRA and partly funded by the Crawford Fund.

In 2013, CIC researchers attended a three-day training workshop on “Social science methods for smallholder agricultural research: writing up qualitative and quantitative research for publication”. The workshop was conducted by Gina Koczberski and George Curry and was for project staff from CIC, NARI, CCIL and PNGOPRA. The workshop was hosted by CIC-Goroka and partly funded by the Crawford Fund.

Five CIC staff completed or are currently completing postgraduate research studies in Australia. All studies are related to the project. Researchers include:

1. Susan May Inu. She was awarded a John Allwright Fellowship and enrolled in a Master of Philosophy (by research) at Curtin University. Her thesis title is: “The influence of socio-economic factors on farm investment decisions and labour mobilisation in smallholder coffee production in Eastern Highlands Province, Papua New Guinea”. Ms Inu graduated in 2016. A poster developed from her Master of Science research was awarded ‘best poster’ award at the Inaugural 2015 Tropical Agriculture Conference, Brisbane Australia (240 posters were assessed).
2. Reuben Sengere. He was awarded a Curtin University PhD scholarship. His thesis title is: “The rise, fall and revival of the Papua New Guinea Coffee Industry”. Mr Sengere’s thesis was passed this year and he will be graduating in September 2017.
3. Emma Kiup. She was awarded a John Allwright Fellowship and enrolled in a Master of Philosophy (by research) at James Cook University and CSIRO. Her thesis title is: “Maximizing nutrient use and soil fertility by managing nutrient stocks and movement in smallholder coffee and food garden systems”. Ms Kiup is in the final stages of her thesis write-up.
4. Jonah Aranka. He was awarded a John Allwright Fellowship and enrolled in a Master of Science degree at the University of Queensland. His thesis topic is: “Rapid molecular characterisation of Coffee Berry Borer”.
5. Matilda Hamago. She was awarded a John Allwright Fellowship and enrolled in a Master of Philosophy (by research) at Curtin University. Her thesis title is: “The role and impact of female extension officers on the participation of women in export crop production in Papua New Guinea”.

In 2014 Ms Matilda Hamago from CIC was awarded a John Dillon Fellowship. She visited several institutes in Australia in February-March 2014, including a visit to Curtin University for a week. Her trip was very successful and attracted positive media coverage for ACIAR, CIC and female farmers in PNG (for example, see http://www.abc.net.au/news/2014-03-04/australia-aid/5296060).

Few CIC and NARI staff have had previous experience presenting research findings in public fora. This project provided informal training on presentation skills. During the project junior staff members had opportunities to develop their research presentation skills. In addition to in-house presentations during which they received feedback on their seminars, presenters had opportunities for more formal presentations at the following fora:

- Workshop on "Extension methodologies for smallholder producers of cocoa and other plantation crops in the Pacific". CCIL, Kerevat, ENB, 6-8 November 2012.
- ACIAR workshop on "Socio-economic agricultural research in Papua New Guinea: Comparative Workshop". NARI, Bubia, Lae, 5–6 June 2013.
- ACIAR project mid-term review. 2013.
- ACIAR end of project review (September 2015).
- June 2015. James Cook University pre-candidature seminar (Ms Kiup).
- May 2016. James Cook University mid-term review seminar (Ms Kiup).
- January 2017. James Cook University pre-submission seminar (Ms Kiup).
- Curry and Koczberski organised Panel 7: Adaptation, Resilience & Changing Land and Marine-based Livelihood Systems in the Pacific. The 6th Biennial Conference of the Australian Association for Pacific Studies. Tides of Transformation. Pacific Pasts, Pacific Futures, James Cook University, Cairns, 1-3 April 2016 (Ms Inu and Mr Sengere).

8.3 Community impacts – now and in 5 years

During village fieldtrips, villagers received extension training as a token of the team's appreciation of their cooperation in the research. Training was provided by CIC staff, Jenny Bekio and Matilda Hamago, and involved a half-day training session at each field site. Villagers received training on pruning, block maintenance and pest and disease control. Training helped foster a collaborative approach to the research with the community benefiting from the presence of researchers and extension officers residing in their village.

It is anticipated the community impacts will begin to be experienced with the roll out of the extension training package which was partly developed in this project.

Improved relationships and links between CIC and exporters. Throughout the project there were several informal meetings with private sector representatives to keep them informed of project activities. Most meetings have been with CARE-International, Monpi Sustainable Services which is a partner in the research, and John Leahy of PNG Coffee Exports. Strengthening the links between CIC and the private sector raises the probability that the research findings will be adopted by private sector stakeholders and be of benefit to growers.

At the Bena field site in particular, a strong community group under the leadership of Pastor Albert Ukaia was able to capitalise on other opportunities that became available through networks established through the project and students researching there. For example, FPDA selected this community for a successful bulb onion project and CIC later established a solar powered coffee pulper for this community, enhancing greatly the productive capacity of this community.

Also, early investigations of the potential of demucilagers for improved parchment quality and greater labour efficiency were promoted with the private sector. PNG Coffee Exports through John Leahy acquired three demucilagers to trial with AAK farmer groups, two of which were monitored by the project. These demucilagers were having a positive impact on their communities.

8.3.1 Economic impacts

The main economic impacts of the project are yet to be realised. However, it is anticipated that within five years, communities will benefit economically through six main outcomes of the project. These are:

- The comprehensive extension training package.
- Cherry sales to enable farmers in accessible sites to capture the significant price premium for cherry.
- The adoption of demucilagers to increase labour efficiency and parchment quality in both remote and accessible locations.
- Intercropping of coffee with food crops in areas experiencing land pressure.
- Efficient recycling of nutrients to offset fertiliser use in accessible villages.
- Efficient recycling of nutrients to increase coffee or food crop productivity in remote villages. Use of unproductive land and increase in coffee productivity through intercropping coffee with fertilised vegetables.

The draft package of training manuals to assist private sector and government extension officers to train farmer groups contains sets of lesson plans on a range of production, processing and marketing activities of coffee (see Section 7). The package adopts a 'whole farm system' approach to extension training that considers environmental, social, gender and income within broader livelihood strategies that include food production for home consumption and sale. CIC would be the main provider of extension training using the package, which will be registered with the National Training Council (NTC) to allow CIC to train private sector extension officers in their use. The extension training package will lead to improved coffee garden maintenance, coffee quality and higher prices. This will be achieved through the adoption of better coffee husbandry including pest and disease management and nutrient recycling, coffee processing methods, improved knowledge of marketing including certification and the adoption of new technologies to improve labour efficiency.

Feedback from the industry is that the research is highly relevant to their needs and will be adopted quickly, especially by processors/exporters seeking certification of their farmer groups. The private sector is moving towards coffee certification for their farmer groups and is obligated to ensure extension training is delivered to farmer groups as part of the certification requirements. The industry is keen to make use of the extension training materials that are geared to the low input system of production that characterises the PNG smallholder sector. Industry partners are also keen on training materials that differentiate smallholder farmers because they are increasingly aware that farmer needs vary spatially and socially (e.g. remote and accessible growers; low input and high input farmers; male and female farmers; less educated and more educated farmers, farming communities facing land pressure and those with adequate land, etc.).

The promotion of cherry buying in accessible locations is likely to lead to significant income gains for farmers with greatly enhanced returns to their labour through higher prices received (33% price premium directly) and reduced labour in processing cherry to parchment (pulping, fermenting and drying). In addition, the freeing-up of labour from processing will enable smallholders in highly accessible locations to engage in other high income livelihood activities such as vegetable and pineapple production for urban markets. It would also provide more time for block maintenance and sanitation when Coffee Berry Borer arrives in PNG.

Demucilagers will improve returns to farmers in both remote and accessible locations. In accessible sites where cherry sales are not an option, demucilagers will significantly add to parchment quality and dramatically reduce labour in processing. Like the release of labour from processing with cherry sales, demucilagers will allow smallholders in accessible locations to engage in other high income livelihood activities such as vegetable and pineapple production for urban markets. The freeing-up of labour together with price premiums from cherry sales and demucilagers will also provide more time and incentives for investment of labour in coffee garden maintenance, particularly in preparation for the imminent arrival of Coffee Berry Borer (CBB). In remote locations, demucilagers will improve parchment quality and dramatically reduce labour inputs in processing thus significantly increasing returns to labour. Improvements in parchment quality to PSC (easily attainable) would generate a 9% increase in price on Y1 grade (Table 7.1).

Effective use of waste materials such as coffee pulp and kitchen waste can reduce the financial burden of purchasing mineral fertilisers for use on vegetables in accessible villages or to retain nutrients in food or coffee gardens in remote villages. It also improves soil fertility as it increases soil organic matter and soil pH (as demonstrated in Ms Kiup's thesis) and thus nutrient retention capability of the soil which, in turn, improves soil productivity.

Intercropping with short rotation fertilised vegetables improves coffee health which will lead to increased coffee productivity and also utilise previous unused land for vegetable growth thus increasing income for women.

8.3.2 Social impacts

The prospect of this project having beneficial social impact on the communities where the research was conducted relate to three main project findings. First, the project has highlighted the enormous challenges and difficulties encountered by coffee farmers living in remote areas compared with those in accessible locations. Remote farmers have very limited access to CIC extension training, markets and infrastructure. These findings have raised awareness within CIC of the need to better target extension to remote areas where there is a strong reliance on coffee as a source of household income and where services are poor. This awareness raises the opportunity for more suitable and targeted interventions that improve the well-being and livelihoods of remote coffee farmers, who to date, have been largely overlooked in extension efforts.

Second, the project has identified the gender inequalities in coffee production. As demonstrated, whilst women are central to coffee production they typically have little control over the distribution of the coffee income and often have limited access to coffee income. The relatively low returns on their labour partly explains why many women in accessible sites are shifting their labour from coffee to vegetable production where they have greater control over the income they earn. By highlighting the gender inequalities in coffee production and the gradual shift of women's labour out of coffee production, the project has highlighted the need for the industry to develop suitable interventions that assist with improving women's income in coffee production.

Third, because vegetables are regarded as a woman's crop, increasing the land available for vegetable growing through intercropping will increase women's income as well as benefit the coffee crop.

8.3.3 Environmental impacts

It is too early for environmental impacts, but it is anticipated that some of the nutrient management findings will lead to more efficient recycling of nutrients, particularly with coffee pulp. In some villages pulping is done near streams because of the requirement for water. Survey results indicate that in such situations the pulp goes directly into the stream. When the value of pulp as a fertiliser is realised, this environmentally degrading practice will stop. If demucilagers become widely adopted it is likely that research findings will help ameliorate pollution problems arising from the concentration of coffee pulp at these processing sites.

8.4 Communication and dissemination activities

Key communication and dissemination activities completed during the project included the following:

- The project paid for a satellite internet connection for CIC-Aiyura which has transformed communications from the station. The satellite was installed by PPAP with ACIAR funding.
- Research findings from the project have been presented at two workshops for extension methodologies for smallholder producers of cocoa and other plantation crops in the Pacific.
- Reports have appeared in NARI's newsletter and in PNG's national press.
- The World Bank-funded PPAP project which started in 2011 was kept informed of the research findings through regular meetings with their staff during fieldtrips. There has been collaboration in workshops with PPAP staff and other stakeholders on the content of training materials being developed under the project and on the revision of the "Coffee handbook" which will be released shortly by PPAP.

Seminars/Conference Papers

2011

Curry, G.N. and Koczberski, G. (2011). Socio-economic factors influencing smallholder oil palm production in PNG: implications for socio-economic research in coffee. Presented at CIC, Aiyura, Eastern Highlands Province, 21 March, 2011.

Curry, G.N. and Koczberski, G. (2011). Engaging with the market: the social embeddedness of commodity crop production in Papua New Guinea. Presented to the Department of Anthropology and the Department of Geography, University of Durham, UK, 22 October, 2011.

2013

Webb, M.J., Togonave, P.P., Apis, B.S., Kiup, E., Pakatul, J., and Kemei, J. (2013). Potential potassium, nitrogen, and carbon loss pathways in coffee processing by smallholders in Papua New Guinea. Presented at the XIV International Plant Nutrition Colloquium, 19-22 August, Istanbul, Turkey.

Hamago, M. (2013). Is Conventional extension effective in controlling Coffee Green Scale? Presented at the "PC/2012/051 Extension methodologies for smallholder producers of cocoa and other plantation crops in the Pacific. Second Workshop Evaluating Technology Transfer Approaches, 11-13 June, CCIL, Kerevat, PNG.

Hamago, M. (2013). Evaluation of the effectiveness of the CIC-Farmer Demand Driven Extension Approach. Presented at PC/2012/051 Extension methodologies for smallholder producers of cocoa and other plantation crops in the Pacific. Second Workshop Evaluating Technology Transfer Approaches, 11-13 June, CCIL, Kerevat, PNG.

Inu, S.M. (2013). Coffee Farmers Technical Knowledge and Extension. Presented at PC/2012/051 Extension methodologies for smallholder producers of cocoa and other plantation crops in the Pacific. Second Workshop Evaluating Technology Transfer Approaches, 11-13 June, CCIL, Kerevat, PNG.

Aranka, J. N. Togonave, P. and team (2013). The value of village-based fieldwork for understanding socio-economic factors affecting smallholder productivity: the example of coffee. Presented at the ACIAR Comparative Research Workshop on Socio-economic agricultural research in Papua New Guinea. National Agricultural Research Institute, 5-6 June, Lae, PNG.

Alepa, R., Apis, B., Aranka, J., Bafeo, M., Baro, A., Bekio, J., Bore, W., Curry, G.N., Hamago, M., Inu, S.M., Kapal, D., Kiup, E., Koczberski, G., Paisawa, M., Pakatul, J., Togonave, P. and Webb, M. (2013). Improving livelihoods of smallholder families through increased productivity of coffee-based farming systems in the highlands of Papua New Guinea. Presented at the ACIAR Comparative Research Workshop on Socio-economic agricultural research in Papua New Guinea. National Agricultural Research Institute, 5-6 June, Lae, PNG.

2014

Webb, M.J. (2014). A length of rope, a $17 set of kitchen scales, and some hot rocks: appropriate technology research. Presented to the CSIRO Land and Water management committee/science executive in July 2013 and to ACIAR in May 2014. The topics were each about ACIAR projects with the "hot rocks" being about this project.

Susan May Inu presented a paper on her Masters research at the annual conference of the Institute of Australian Geographers, 30 June – 2nd July, Melbourne.

2015

Webb, M.J. (2015). Ideal nutrient management systems for tropical crops – limiting nutrient losses. Presented at the Argus FMB NPK Fertilizers 2015 conference, 3-4 June, Bangkok, Thailand.

2016

Webb, M.J., Koczberski, G., Curry, G.N. and Nelson, P. (2016). Socio-economic factors influencing fertilizer use among smallholder farmers. Presented at the Argus FMB NPK Fertilizers 2016 conference, 9-10 March, New Delhi, India.

9 Conclusions and recommendations

9.1 Conclusions

The context for falling smallholder productivity and parchment quality has been a marked deterioration in road infrastructure, declining extension capacity and the demise of the plantation sector. As the plantation sector declined, the services delivered to surrounding smallholders such as extension, planting material and centralised processing also declined and government extension was unable to fill this gap. The result has been reduced smallholder productivity and declining quality of parchment coffee delivered to exporters. In addition, poor coffee husbandry and cherry processing practices, partly attributable to a knowledge gap amongst smallholders, result in low productivity and poor quality parchment and therefore low prices paid to farmers.

The research also highlighted major differences between various groups of smallholders – between remote and accessible sites and between men and women. Some general principles to emerge from the research are that accessible sites experience higher levels of land pressure leading to more intensive use of land which has consequences for nutrient capital. Households in accessible sites also tend to have larger and a wider range of incomes, have smaller families and are more attuned to the modern market economy than households in remote regions. They are very different and therefore require different extension strategies.

There are also significant population pressures and land shortages in some locations near town. Land pressure for coffee was reflected in a trend towards permanent cultivation of food crops, the addition of synthetic fertilisers to maximise production in the absence or reduction of fallow periods and the conversion of coffee gardens to food production. Some coffee and food gardens are deficient in essential plant nutrients, especially N, P and K, and leaf nutrient analysis revealed deficiencies in Zn and B. There was much wastage of nutrients, particularly potassium, from the inefficient use of nutrients from cherry pulping. Very promising results were obtained from intercropping of coffee with food crops and recycling nutrients to develop sustainable production systems for both coffee and food through efficient use of land and nutrients. Intercropping was of particular benefit to women by enhancing food security and cash incomes.

Labour shortages were a major concern in both accessible and remote coffee growing areas. While there is potential family labour available, socio-economic factors prevent the deployment of labour in coffee, especially women's labour, for a range of reasons, including perceived inequities in the distribution of coffee income and perceptions of better or more certain returns to labour invested in other livelihood pursuits. Payment certainty is therefore a critical factor affecting labour supply.

Smallholders are reluctant to switch from a low input, low output system of production to a high input, high output, modern system of production requiring greater labour inputs. This is partly because smallholders pursue a lifestyle or 'way of life' involving leisure pursuits, and church and community activities that leave little time for coffee production. This 'way of life' remains an important path to status and prestige and provides a moral framework for community standards of acceptable behaviour. It is therefore highly resistant to change.

To conclude, the key findings relating to smallholder production were: 1) a low level of technical knowledge amongst farmers of coffee husbandry and processing; 2) poor quality smallholder coffee and consequently lower prices received for smallholder coffee; 3) low smallholder productivity; 4) under-utilisation of household and hired labour; 5) low awareness amongst farmers of the 32% price premium for selling cherry rather than parchment to processors (only an option in relatively accessible locations); 6) nutrient deficiencies in some coffee growing areas despite considerable potential for the efficient recycling of nutrients to minimise costs to farmers; 7) low levels of knowledge amongst farmers of the positive benefits for coffee (and income) of intercropping with intensively managed, short rotation vegetable crops; and 8) a demand amongst extension providers and farmer groups for extension materials that are tailored to the low input system of production practised by the vast majority of smallholder coffee farmers.

9.2 Recommendations

It is recommended that a new project be developed to build on the preliminary work carried out in this project. There are four aspects to this future research: the extension training package, the evaluation of demucilagers, the further investigation of intercropping of coffee with food crops in land-short areas; and the evaluation and promotion of cherry sales. Each is briefly discussed further below.

Extension package

It is recommended that the extension package partly developed in this project be completed, field tested, evaluated, refined and rolled out. It should incorporate the best of existing CIC extension materials (previously funded by ACIAR) and also draw on the research findings of this project and include new concepts such as intercropping, demucilagers, certification and the price premium for cherry over parchment.

Demucilagers

In addition, it is recommended the project evaluate the use of demucilagers to improve parchment coffee quality for farmer groups. Pulp and waste water management from demucilagers should also be investigated to identify strategies to recycle water and nutrients efficiently, thereby reducing negative on and offsite impacts. This could potentially achieve further price premiums by ensuring demucilagers are fully compliant with the certification criteria of the main certification organisations.

Intercropping

The project demonstrated very promising results from intercropping of coffee with fertilised short-rotation vegetable crops and recycling nutrients to develop sustainable production systems for both coffee and food through efficient use of land and nutrients. Intercropping appears to be of particular benefit to women by enhancing food security and cash incomes.

This research needs to be followed up. It is recommended that formal intercropping of coffee with short term vegetable crops be investigated to assess potential income gains for women as well as improved nutrition and yield of coffee. It should also assess the impact of intercropping on the supply of land to enhance food security.

Cherry sales

The promotion of cherry sales to farmers in accessible sites would free-up labour for other livelihood activities such as vegetable production for markets in urban centres, as well as provide more time for coffee garden management, which will become urgent when Coffee Berry Borer arrives in the highlands. However, the social and economic benefits of direct cherry sales to processors need to be assessed in terms of the distribution of household income between men and women. If economic benefits accrue to women from the switch to cherry sales to processors, then this should be promoted through the training package to farmer groups able to capitalise on this opportunity.

10 References

10.1 References cited in report

Api, F., Murray-Prior, R., Aroga, L., and Batt, P. (2009). *Establishing Partnerships between Private Sector and Government to Deliver Extension and Training to Smallholder Farmers in the PNG Coffee Industry.* Paper presented at the V International Symposium on Horticultural Research, Training and Extension.

Bailey, J.S., Ramakrishna, A., and Kirchhof, G. (2009). An evaluation of nutritional constraints on sweet potato (*Ipomoea batatas*) production in the central highlands of Papua New Guinea, *Plant and Soil*, 316(1-2): 87-105.

Batt, R. and Murray-Prior, P.J. (2007). Emerging possibilities and constraints to PNG smallholder coffee producers entering the speciality coffee market. Australian Centre for International Agricultural Research, Australian Government, Canberra.

Batt, R. and Murray-Prior, P.J. (2009). Assessing and extending schemes to enhance the profitability of the PNG coffee industry via price premiums for quality. Project Final Report for ASEM/2004/042.

Bell, R.W. (1999). Boron, in Peverill K.I., Sparrow L.A., and Reuter D.J. (eds), *Soil Analysis: An Interpretation Manual*, CSIRO Collingwood.

Bourke, R.M. and Harwood, T. (eds). (2009). *Food and Agriculture in Papua New Guinea*. Land Management Group, Department of Human Geography, Research School of Pacific and Asian Studies, Australian National University, Canberra.

Boyle, M.H., Racine, Y., Georgiadis, K., Snelling, D., Hong, S., Omariba, W., Hurley P and Rao-Melacini, P. (2006). The influence of economic development level, household wealth and maternal education on child health in the developing world, *Social Science and Medicine* 63(8): 2242–2254.

Charmetant, P. (1994). Selection within dwarf and segregating leaf rust resistant material, Aiyura, Block E6, 1990-1994. Coffee Research report No. 28.

CIC. (2007). Coffee harvesting and processing notes: a guide for coffee extension workers and farmers of the coffee industry in PNG. Aiyura, Eastern Highland Province, Papua New Guinea.

CIC. (2008b). Research and grower services division 2005 annual report. Aiyura, Eastern Highland Province, Papua New Guinea.

Coffee Research Institute (1992). “The Papua New Guinea Coffee Handbook” Registration No. 871, ISBN 9980-85-934-2, Coffee Industry Corporation, Goroka, Papua New Guinea.

Collett, G.N. (1989). Smallholder coffee yields – estimates from the Benabena, Eastern Highlands Province, Papua New Guinea. Working Paper No. 14, ACIAR Project 8734, Designing Monitoring Systems for Smallholder Agriculture in Papua New Guinea, Department of Human Geography, Australian National University, Canberra.

Collett, G. N. (1992). *Coffee, capitalism and constraints to agrarian transition: A case study of smallholder coffee production in the Highlands of Papua New Guinea* (Unpublished Master’s thesis). Flinders University, South Australia.

Collett, G. N. (2008). Socio-economic and institutional factors influencing smallholder coffee production in PNG. Review of published literature, project evaluations and reports and summary of discussions with researchers and selected industry representatives. PPAP World Bank Project.

Collett, G.N. (2009). Report Working Paper No. 3 Coffee Sub Sector. Draft report prepared by PNG Department of Agriculture and Livestock, URS Australia Pty Limited, Adelaide.

Curry, G.N. and Koczberski, G. (2004). *Mobilising Smallholder Labour in Oil Palm Production: Results of the Mobile Card Trial, Hoskins, West New Britain, Papua New Guinea*. Department of Social Sciences, Curtin University of Technology.

Curry, G.N., Inu, S.N. and Koczberski, G. (2017 in press). Reorienting livelihoods and moralities in rural PNG: the case of fresh food produce. *Oceania*. Special Issue on Morality and Markets in Papua New Guinea.

Curry, G.N., Dumu, E. and Koczberski. G. (2016). Bridging the digital divide: Everyday use of mobile phones among market sellers in Papua New Guinea. In M.E. Robertson (ed.) *Communicating, Networking, Interacting. The International Year of Global Understanding - IYGU*. Springer, pp.39-52.

Curry, G.N., Koczberski, G., Omuru, E. and Nailina. R.S. (2007). *Farming or Foraging? Household Labour and Livelihood Strategies amongst Smallholder Cocoa Growers in Papua New Guinea*. Perth, Black Swan Press.

Driscoll, R., Srzednicki, G., Shaw, W. and Maika, N. (2010). Assessment and improvement of quality management during postharvest processing and storage of coffee in Papua New Guinea. Project Final Report for ASEM/2004/017.

Fleming, E. and Anthony, G. (1993). *Strategies and policies to encourage development of the coffee industry in Papua New Guinea: A review of options*. Port Moresby, PNG.

Floyd, C.N., D'Souza, E.J. and Lefroy, R.D.B. (1987). Composting and crop production on volcanic ash soils in the Southern Highlands of Papua New Guinea. Technical Report 87/6. Department of Primary Industry, Konedobu, NCD.

Gannicott, K.G. and Avalos, B. (1994). Pacific 2010: Women's education and economic development in Melanesia. Canberra: National Library of Australia.

Gibson, J. and Rozelle, S. (2004). Is it better to be a boy? A disaggregated outlay equivalent analysis of gender bias in Papua New Guinea, *The Journal of Development Studies*, 40(4): 115–136.

Giovannucci, D. and Hunt J. (2009). Papua New Guinea Strategic Assessment of the Coffee Sector. Retrieved from: http://www.euacpcommodities.eu/files/1PACD01PNGCoffeeFinalReportENGLISH.pdf.

Hanson, L.W, Allen, B.J, Bourke, R.M. and McCarthy, T.J. (2001). *Papua New Guinea Rural Development Handbook.* Canberra: Australian National University.

Harding, P.E. (1984). A Preliminary Report on the Arabica Coffee Soils of Papua New Guinea: Coffee research report No. 1, Papua New Guinea Coffee Research Institute, Kainantu, Papua New Guinea.

Harding, P. E. (1988). Rehabilitating smallholder coffee gardens in Papua New Guinea: The effects on yields during the first year following rehabilitation. *PNG Coffee*, *7*(1), 79-90.

Harding P.E. (1991). Foliar nutrient level studies in smallholder coffee gardens in the Kainantu area of Papua New Guinea. Coffee research Report No. 6. PNG Coffee Research Institute, Aiyura, Papua New Guinea.

Harding, P.E. and Hombunaka, P.H. (1998) A review of coffee nutrition research in Papua New Guinea. Papua New Guinea Journal of Agriculture, Forestry and Fisheries.41(1):44-64.

Hartemink, A.E. and Bourke, R.M. (2000). Nutrient deficiencies of agricultural crops in Papua New Guinea, *Outlook on Agriculture*, 29(2): 97-108.

Inu, S.M. (2015). *The influence of socio-economic factors in farm investment decisions and labour mobilisation in smallholder coffee production in Eastern Highlands Province, Papua New Guinea*. Masters Thesis, Curtin University, Western Australia.

Johnson, P.L. (1988). Women and development: A highland New Guinea example. *Human Ecology* 16(2): 105–121.

Kare, P. and Sermel, R. (2013). Providing relevant and quality learning: An aim of universal basic education, in A. Kukari (ed.), *Universalizing basic education in Papua New Guinea: Experiences, lessons learnt, and interventions for achieving the goal of universal basic education*, pp. 83–94, The National Research Institute, Port Moresby.

Koczberski, G. (2007). Loose Fruit Mamas: creating incentives for smallholder women in oil palm production in Papua New Guinea. *World Development* 35(7): 1172-1185.

Koczberski, G. and Curry, G.N. (2008). *Smallholder Mobile Card Trial, Bialla Oil Palm Project, West New Britain Province, Papua New Guinea*. Research Unit for the Study of Societies in Change, Curtin University of Technology.

Koczberski G. and Curry G. N. (2016). Changing generational values and new masculinities amongst smallholder export cash crop producers in Papua New Guinea. *The Asia Pacific Journal of Anthropology* 17(3–4): 268–286.

Koczberski, G., Curry, G.N. and Gibson, K. (2001). *Improving Productivity of the Smallholder Oil Palm Sector in Papua New Guinea*. Research School of Pacific and Asian Studies, Australian National University. Retrieved from:

Munnull, J.P. and Densley, D.R. (1978). Coffee, in Densley, D.R. (ed), Agriculture in the Economy: A Series of Review Papers. Volume 2, Department of Primary Industry, Konedobu, pp. 1-42.

Murphy, S., Shaw, R. and Brook, A. (2008). Sustainable management of coffee green scales in Papua New Guinea. Seminar presented at Coffee R&D Workshop, ACIAR House, 26-27 November, 2008.

Murray-Prior, R., Batt, P. J., Dambui, C. and Kufinale, K. (2008). Improving quality in coffee chains in Papua New Guinea. *Acta Horticulturae, 794*: 247-256.

Overfield, D. (1994). The smallholder coffee system: production costs, grower returns, and economic sustainability. Coffee Discussion Paper No. 15.Coffee Industry Corporation Ltd, Goroka.

Overfield, D. (1998). An investigation of the household economy: Coffee production and gender relations in Papua New Guinea. *Journal of Development Studies* 34(5): 52–70.

Quirke, D., Harding, M. and Warner, B. (2007). Papua New Guinea coffee and cocoa policy linkages. Project PLIA/2005/148, Australian Centre for International Agricultural Research, Canberra.

Rayment, G.E. and Lyons D.J. (2011). Soil chemical methods – Australasia, CSIRO Collingwood.

Rowe, M.L., Thapa, B.K., Levine, R., Levine, S. and Tuladhar, S.K. (2005). How does schooling influence maternal health practices? Evidence from Nepal, *Comparative Education Review* 49(4): 512–533.

Ryan, S., Koczberski, G. Curry, G.N. and Germis, E. (2017). Intra-household constraints on educational attainment in rural households in Papua New Guinea. Asia Pacific Viewpoint. doi: 10.1111/apv.12143.

Sengere, R.W. (2017). *The rise, fall and revival of the Papua New Guinea Coffee Industry*. PhD thesis, Curtin University, Perth.

Sexton, L. (1986). *Mothers of money, daughters of coffee: the Wok Meri movement.* UMI Research Press, Ann Arbor, Michigan.

Strathern, A. (1982). The division of labour and processes of social change in Mount Hagen. *American Ethnologist* 9(2): 307–319.

UNDP (2014). National Human Development Report. Papua New Guinea. From Wealth to Wellbeing: Translating Resource Revenue into Sustainable Human Development. United Nations Development Programme, Port Moresby and Massey University, Auckland. Retrieved 14 November 2015, from website: http://www.pg.undp.org/content/dam/papua_new_guinea/docs/Publications/FINAL%20PNG%20NHDR_low%20res.compressed.pdf

UniQuest (2013). *P110959: Productive Partnerships in Agriculture Project. Baseline Survey Final Report.* Goroka, PNG.

Winston E., Op de Laak, J, Marsh, T., Lempke, H., Aung, O., Nyunt, T., and Chapman, K. (2005). *Arabica coffee manual for Myanmar*, FAO Regional Office for Asia and the Pacific, Bangkok; Food and Agriculture Organization of the United Nations. Bangkok. http://www.fao.org/docrep/008/ae938e/ae938e00.htm

10.2 List of publications produced by project

Apis, B., Aranka, J., Asiota, B., Bafeo, M., Bekio, J., Bore, W., Curry, G.N., Hamago, M.R., Inu, S.M., Kiup, E., Koczberski, G., Lummani, J., Nailina, R., Natera, K., Peter, E., Pundu, J., Togonave, P. and Webb, M. (2013). The use of activity diaries for understanding the daily lives of farmers and their livelihood choices. In: G. Hickey (ed.), *Socio-economic Agricultural Research in Papua New Guinea*. ACIAR Proceedings 141, pps.36-47. Australian Centre for International Agricultural Research, Canberra.

Curry, G.N., Inu, S.N. and Koczberski, G. (2017 in press). Reorienting livelihoods and moralities in rural PNG: the case of fresh food produce. *Oceania*. Special Issue on Morality and Markets in Papua New Guinea.

Curry, G.N. and Koczberski, G. (2013). Development Implications of the Engagement with Capitalism: Improving the Social Returns of Development. In: McCormack, F. and Barclay, K. (eds) *Research in Economic Anthropology, Engaging with Capitalism: Cases from Oceania*. Emerald Group Publishing Limited. pp 335-352.