# TECHNOLOGICAL CHANGE IN CONTEMPORARY PEASANT FARMING SYSTEMS OF NORTHERN CHIAPAS, MEXICO

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## *Addenda and Errata*

| | |
|---|---|
| p.7 | Pearse, 1987 was actually written at an earlier date (not known). The paper is presented in Shanin, 1987 as Chapter 10 of the Second Edition of Peasants and Peasant Societies. No date of original publication is given, though it may have been 1971, in the First Edition. |
| p.21 | The statement about *pequeños propietarios* in the northern highlands of Chiapas (2nd paragraph) could be misleading as there are a number of large ranching properties around Ocosingo and Marques de Comilla (outside the area of the study) that are designated as *pequeños propietarios*. The indigenous *pequeños propietarios* in the Cho'l and Tzeltal zones within the study were mainly founded in the 1950's, when hacienda owners in the area established these small properties as "buffers" between indigenous settlements and their own lands. According to Sanderson[1] the extent of *ejidal* land in Chiapas in 1970 was 79% of cultivated agricultural land (compared with the National average of approximately 40%) and 51-64% of total state area. |
| p.104 | Asterisk in Table 4.11 should be next to "Number of Communities", not "Forests". |
| Appendix 6 | In the calculation of labour inputs to the models womens' and childrens' labour days were counted as ½ those of men (over 16 years of age), apart from harvesting activities where all labour days were counted as equal. This does not imply that women have lower work rates for most tasks, but that they have additional jobs to complete during any working day which adsorb considerable time. |
| p253-256 | Page numbers are repeated. |

[1] Sanderson (1984) Land Reform in Mexico 1910-1980, pages 100-102, Orlando London.

# Abstract

A study of the process of technological change in contemporary Mayan agricultural systems was undertaken by an action research method that involved close collaboration with the rural development efforts of farmers in the northern highlands of Chiapas, Mexico. Firstly, the socio-economic context of technological change in Chiapas was described, with special reference to the effects of markets on agricultural development. Secondly, theta actors affecting the productivity and sustainability of the regions principal agricultural systems: maize and beans for subsistence and coffee for cash were described and measured. The use of traditional swidden methods of maize cultivation with shorter fallow periods was found to be causing a significant decline in the fertility of soils. Alternative, non-burning methods were found to be sustainable in terms of soil fertility, but required high labour inputs and were less productive during a 2-3 year transition period. Despite government programmes to promote the development of coffee plantations most farmers had adopted only *ad hoc* improvements, and coffee system productivities were found to be generally low.

Models integrating dynamic and linear programming components of the improvement problem systems in maize and coffee production were constructed using evidence from the field studies. By examining a number of hypothetical scenarios, further hypotheses about the coffee and maize systems were generated. It was inferred that the relative scarcity of farm labour, cash or land resources would affect the optimum technical decisions of farmers. In particular, it was concluded that farmers with scarce cash resources would face most difficulty (in terms of loss of effective income) in adopting non-burning maize techniques and the promoted methods of coffee plantation improvement.

On the basis of the evidence from the field studies and the modelling exercises a number of technical, project and policy recommendations were advocated. These were based upon the objective of maximising the potential competitive strengths of the peasant mode of production, including: the efficient use of marginal, dispersed and inaccessible resources and the production of a wide range of specialised agricultural and forestry products.

I declare that this thesis has been composed by myself and that it embodies the results of my own research.

Richard M. Tipper

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## Notes

The systematic nature of the study has made the frequent use of cross-referencing necessary. Cross refrenced paragraphs within the thesis are marked by their paragraph numbers, for example, (3.2.1).

The currency used throughout the thesis, except where clearly denoted, is in New Mexican Pesos ($). The New Peso was introduced at the end of 1992 and is worth 1000 Old Pesos,and roughly 0.31 US Dollars at the time of printing. During the time of the study the value of the Old Peso was 2,920 - 3,020 per 1 US Dollar.

## Glossary

| | |
|---|---|
| ARCIK | African Resource Centre for Indigenous Knowledge |
| Av | Average |
| CIKARD | Centre for Indigenous Knowledge for Argicultural Research and Development |
| CNC | Confederación Naciónal Campesina |
| CONAFRUT | Confederación Naciónal Fruticola |
| CONASUPO | Coordinación Naciónal de Subsistencia Popular |
| DIF | Desarollo Integral de la Familia |
| FERTIMEX | Fertilisantes de México |
| FAO | Food and Agriculture Organisation of the United Nations |
| ICO | International Coffee Organisation |
| INEGI | Instituto Naciónal de Estadisticas, Geografica y Informatica |
| INI | Instituto Naciónal Indigenista |
| INMECAFE | Instituto Mexicano de Café |
| NA | Not Available |
| PRI | Partido Revolucionario Institucional |
| QPRO | Quattro Pro |
| RD | Root Definition |
| REPIKA | Regional Programmes for Indigenous Knowledge for Agriculture |
| SARH | Secretaria de Agricultura y Recursos Hidraulicos |
| SSM | Soft Systems Methodology |
| SD | Standard Deviation |
| UU | Unión de Uniones y Ejidos Solidarios de Chiapas y Oaxaca |
| UC | Unión de Credito Pajal Ya Kac' Tic' |
| USDA | United States Development Agency |

# 1 Introduction

## 1.1 The Practical Background

### 1.1.1 Lessons from working in Chiapas

In 1988, after graduating in Agricultural Sciences at the University of Edinburgh, the author travelled to Mexico to work for an organisation[1] of peasant farmers in the state of Chiapas. Initial contact with the organisation had been established on brief visits to the area in 1985 and 1987. The experiences gained from working with peasants of Mayan extraction, during the years of 1988 and 1989, laid the foundation for the following study of the process of agricultural change.

The author's role within the organisation, as an adviser and trainer, was loosely defined. The Unión wished to provide a form of training for dynamic, young farmers, who would later become informal promoters of rural and agricultural development within their communities. The training objectives were to develop not only the technical skills of farmers, but also their capacity for critical analysis of agricultural and social situations, an increased organisational ability, and political awareness. These ambitious aims were to be realised through a series of courses, to be run at the site of the ex-*Finca* Cuacalhuitz[2], since re-named Kipaltik, and also known as the Universidad Campesina. From 1988 to 1990, over 40 young farmers, selected by their communities, attended courses at Kipaltik. The structure of the courses combined practical exercises (work on maize, coffee, and horticultural crops) in the mornings, with theory and discussion in the afternoons. The point of departure for the analysis of "problem situations" in agriculture was the practical experience accumulated by the group, from their communities and at Kipaltik. This approach to training was entirely new to the region and provided as many lessons for the trainers as it did for the farmers. Above all, it led the author to the realisation that most farmers, most extension agents and staff of other agencies responsible for rural development regarded the "agricultural problem" and the process of agricultural development from fundamentally

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[1] The Unión de Uniones y Grupos Solidarios de Chiapas Y Oaxaca and the associated Unión de Credito Pajal Ya Kac' Tic.

[2] *Finca* is the southern Mexican term for *Hacienda*, a large land holding or plantation. The history of the peasants' struggle to obtain the land of *Finca* Cuacalhuitz was transcribed by Rus (1990).

different viewpoints.

Farmers' views of the agricultural problem were based upon the use of household and community resources. The process of agricultural development was first a question of how more might be produced with the limited productive resources available, and second, how to increase the available pool of resources. In contrast, extension agents and other technical staff regarded the agricultural problem from the point of view of the productivity of current technology applied on peasant farms versus the potential productivity of more modern technologies. The agricultural development process was viewed as the replacement of inefficient, backward technologies with efficient, modern methods.

A second contrasting set of viewpoints concerning the role of each group within the development process was also identified. The technical staff viewed themselves (and their organisations) as the principal conveyors of new, superior technologies to the region. Farmers were seen by the technical staff as potential clients requiring persuasion and sometimes assistance (in the form of cheap inputs or credit) in order to adopt these methods. Innovative farmers were identified as those farmers who adopted the recommended methods most quickly. The farmers, however, perceived extension agents (and development institutions) as merely one more source of potentially useful information (alongside others such as family, neighbours, priests and tradesmen) and also as a source of cheap inputs and credit. Farmers viewed themselves as the makers of successive decisions about what to do on their farms in response to new opportunities (such as changes in market prices) and problems (such as shortage of land or illness in the family).

It appeared to the author that the views of each of these two groups arose from the knowledge that each had accumulated through experience. Farmers' agricultural knowledge had been gained through the experience of working and living on the land and learning from family and neighbours. It was broadly about the properties of local agro-ecosystems, the effects of (the traditional) human activities upon these systems and the constraints on these activities imposed by the limited household resources, customs and tactical considerations[3]. The agricultural knowledge of technical staff arose through academic and

3 Tactical considerations is preferred to terms such as "Strategy" which imply long term planning.

technical education, and experiences gained by professional contact with farmers and colleagues. This knowledge was about production methods, their application in certain conditions and measures of agricultural productivity.

#### 1.1.2 A Question Unanswered

Whilst it was clear that farmers and technical staff in Chiapas held different opinions about the process of agricultural development in the region there was insufficient evidence to confirm a particular viewpoint. Indeed, it became apparent that very little was actually known about any of the following:

(a) The changes in agricultural production that were occurring in the region

(b) The factors causal to this process

(c) The mechanisms of change on small farms

(d) The implications for productivity and sustainability of peasant agriculture.

In summary, the question of how change occurred in the contemporary peasant farming systems of northern Chiapas remained unanswered.

#### 1.1.3 A Problem Identified

In Chiapas, as in many areas of the Tropics subject to programmes of agricultural development, there are many obstacles to effective communication between the staff of official agencies and peasant farmers. Agencies often have limited contact with farmers, and when meetings do take place they are usually structured so that farmers are either being informed or being questioned. Meetings are often held in surroundings that emphasise the subordinate position of the peasants and any recognition of farmers' abilities to contribute to the solution of problems is usually minimal.

In the Unión, most of these obstacles had been overcome as a result of farmers placing themselves in positions of responsibility for the improvement of conditions in their communities. The input of technical assistance was at their request and on their terms. Projects for improving agricultural production were planned for each location, according to the needs expressed and the level of interest.

Within this framework, the Unión sought to make use of both farmers' knowledge and the knowledge of technical experts. However, despite this innovative approach, this planning method was still constrained by a number of obstacles.

(a) No established method for evaluating the performance of existing production systems

(b) No means of identifying the relative importance of different constraints and potential areas for improvement on production systems

(c) No means of evaluating the potential impact of changes to production systems, in either the short or long term.

These obstacles prevented the real integration of the knowledge of farmers and technical staff into the planning process. Together, they were identified as serious problem for the development of more participative methods of agricultural development.

## 1.2 Technical Change in Peasant Agriculture: Theory and Evidence

### 1.2.1 Economic Theories of Technological Change[4]

Economists have questioned the role of market forces in the development and application of new technology since Schumpeter (1911) proposed that there was no reason to believe that technical change is directly responsive to market pressures. The proof of this assertion was essentially tautological: any market mechanism involves reactions to changing prices and technical change is defined as consisting of cost-reducing improvements at constant factor prices; by definition a market response was excluded.

Induced Innovation

This position was questioned by Fellner (1951), who proposed that the direction of technical change can been accounted for in terms of rational optimising behaviour, where relative resource scarcities manifest themselves in changing relative factor price levels; so inducing both private and public research into innovations which save on the most important resource. Hayami and Ruttan (1971) developed an influential induced innovation model for agricultural development.

Market-Led Innovation

Schmookler's (1962) paper on the economic sources of inventive activity examined the evidence for market-led invention and innovation processes. Whilst strong correlation's were found between economic activity in a number of different markets and the numbers of patents, no direct causal link was established. Schmookler concluded however, that the incentive for inventive and innovative effort is like the incentive to produce any other good: it is affected by the excess of expected returns over expected costs. While the costs of invention and innovation may be reduced by scientific progress and the efforts of public institutions, the expected benefits will vary with circumstances arising from changes in the prospective market, depending upon socio-economic changes such as increases in population, urbanisation, *per* capita income, *etc.*

4 Most economic analysts use the terms "innovation" and "technological change" synonymously. Innovations are classified as either process-innovations or product innovations, and while the distinction between the two is to some extent artificial, process-innovations have received most attention from economists.

Technological Determinism

In contrast to the above models which suggest that the process of technological change can be explained in terms of economic forces. Parker (1961) argued that the possibilities of technological advance at any time are constrained by current scientific knowledge and that the intrinsic complexity of classes of natural phenomena have shaped the pattern of industrial change. In relation to agricultural development, criticisms of the failure of many complex technical packages for raising productivity raised during the "green revolution" have prompted a shift towards promoting simpler, step by step approaches (Chambers, 1983, 1989; Bunch, 1985).

Implications of Induced Innovation

Grabowski (1979) pointed out that the induced innovation theory has important implications for the growth processes of nations such as Mexico, where the agricultural sector is characterised by a dualism of large versus small land owning farmers. Large landowners tend to be able to purchase external inputs, such as machinery and agro-chemicals, at cheaper rates than small landowners. In addition, the large landowners, relative to the small ones, are able to exert greater influence over society's research and development institutions. Thus these institutions tend to develop technologies which require the use of large amounts of external inputs. It is often unprofitable for the small farmer to make use of these technologies. Thus the distribution of income is likely to worsen. More recently, Grabowski and Sanchez (1987) reviewed technological change in Mexican agriculture between 1950-1979, and found evidence to support the hypothesis that the adoption of biochemical and mechanical innovations was constrained by the availability of inputs.

Implications of market-led innovation

Despite the potentially important implications of the market-led innovation process to the economics of the peasant household, the subject has received little attention. Where market-led innovation processes are dominant and demand for cash crop commodities are increasing then a shift in innovative effort away from subsistence crops towards marketable produce would be expected. This, in turn, could increase the commercial orientation of the farmer, leading to a stagnation of the subsistence technology.

### 1.2.3 Peasant Economies and the Market Complex

The above models of agricultural innovation require either relative factor scarcities or changing levels in the supply and demand of commodities, to be expressed through markets as changing prices. However, a fundamental feature of peasant societies is their partial and variable integration into markets with a high level of imperfections (Friedmann, 1980 pp164). Market imperfections in the developing world are also dynamic, as a result of the general drive to incorporate peasant communities into the modern urban-industrial market complex (Pearse, 1987). Furthermore, according to (Stern, 1986) markets, whether competitive or otherwise are always interlinked, in the sense that prices in one market (such as farm produce) often influence the prices in other markets (such as farm inputs). Thus, the influence of markets, whether leading or inducing technical change, is likely to depend not only upon relative resource scarcity or demand for commodities, but also upon differences in market structure, linkages and imperfections.

Rural Market Studies

Most studies of rural markets in Mexico, such as Beals' and Malinowski's investigations of the market places of Oaxaca (Beals, 1975) (Malinowski and La Fuente, 1982) have followed Mintz's (1955, 1957) example by concentrating on the trading of agricultural and craft products at the colourful markets held in villages and towns. Market places are of obvious importance, as the loci of many of the transactions that occur between peasants and the outside world. They are also important as nodes of communication and information transfer, (Good, 1970). However, these market places are only components of larger rural market systems, in which the exchange and distribution of all products and factors of production, (including labour, capital, land, transportation and agricultural inputs) takes place, both within and between communities.

A Systems Approach to Rural Markets

Proposals for a systems approach to the study of agricultural markets are comparatively recent. Fleming (1990) defines the Marketing Systems Research approach as complementary to Farming Systems

Research, to include:

(a) the mechanics of product transformation and transfer,

(b) market structure,

(c) exchange relations and market culture,

(d) the dynamics of change in the system, covering experimentation and innovation to identify and exploit the potential gains from satisfying the latent desires of consumers;

(e) the inherent uncertainty in marketing activities due to market imperfections,

(f) feedback and control mechanisms, including the transmission of price and quality;

(g) the complexity and heterogeneity of the system, and interdependence between elements in the system;

(h) interaction between actors in the system and its super-system;

(i) the purposive nature of the system (especially identifying conflicts in goals between market participants)

(j) the hierarchical market networks (vertical links within the agricultural marketing system).

Unfortunately, no actual studies of market systems using such a systematic framework were encountered by the author.

### 1.2.3 Technical Change and Markets: Evidence from Chiapas

Studies of Mayan communities in the highlands of Chiapas carried out by anthropologists of the Harvard and Stanford schools have provided some of the most detailed insights about the effects of markets on the decisions made by peasant farmers in Mexico. Cancian (1972) researched the effects of new maize marketing opportunities on the commercial behaviour of Tzotzil maize farmers in Zinacantán, Chiapas. He highlighted the effects of new market opportunities upon the harvesting and commercialisation decisions of peasant farmers, but did not consider the effects of markets upon the choice of production technology. Longitudinal studies of social and agricultural change in the neighbouring highland communities of Zinacantán and Chamula by Collier, Mountjoy and Rus, have borne out some of the important connections between the complex system of rural markets and the development of agricultural technology. In particular, Collier (1990) makes the case that the adoption of new methods of maize cultivation in Apas, a hamlet of Zinacantán, was spurred on by the development of labour and transportation markets and the availability of capital subsequent to the "oil boom" years of the '70's. Furthermore, the adoption of capital intensive production methods has led to an increase in the concentration of wealth in the hands of those who were able to invest in cash crops, such as flowers, or to rent lowland fields for further maize production. Whilst Zinacanteco farmers may have little influence on the policies of national research institutions, Collier's findings broadly support Grabowski's predicted implications of the induced innovation model.

## 1.3 The Social Process of Technological Change

### 1.3.1 Innovation in Peasant Agriculture

Chambers (1989) noted that the sources of technology used by peasant farmers are diverse. To a large extent the tools and techniques used are traditional and are received from previous generations who gradually adapted their methods, seeds and livestock to the prevailing environmental and social conditions. Traditional methods are often combined with technology derived from modern agricultural research such as new seeds or fertilisers. Modern technology may be applied as a complete "package", usually the result of an agricultural improvement programme, or application may be *ad-hoc*, according to an individual farmer's judgement and means. Innovations are diffused by both formal and informal channels of communication within, and between, households, villages, institutions, and even countries. Farmers themselves are often capable innovators, modifying, mixing and adapting both traditional and modern techniques according to their needs. Social studies of technological development in agriculture have generally shown the process of change to be more complex than suggested by any of the economic models, outlined in the previous section. Induced innovation, market led change and technological determinism all appear to be relevant in certain circumstances, but as the peasant world is increasingly incorporated into an urban - industrial market complex, new technologies in agricultural production are just one aspect of much broader changes in these societies. Culture, demography, natural environment, political organisation, and infrastructure all appear to be interrelated in the overall process of change. The following sections outline the theories and some of the relevant studies made of the diffusion and adoption of agricultural innovations.

### 1.3.2 Diffusion and Adoption of Innovations

Diffusion is the process, described by social scientists, by which an innovation is communicated through certain channels (diffusion networks), over time among members of the social system (Lionberger, 1960). It is a special type of communication in that the messages are concerned with new ideas . Communication is more effective when source and receiver are homophilous[5]. Social structure is

5 Homophily is the degree to which pairs of individuals who interact are similar in certain attributes, such as beliefs, education, social status and the like.

therefore identified as an important influence on the rate and pattern of diffusion within society. If the social structure is divided, then exchanges of information will tend to occur within groups rather than between groups, leading to the adoption of innovation by only certain sections of the society. When diffusion networks are heterophilous, opinion leaders, such as those of higher socio-economic status, education, cosmopoliteness and change agent contact play an important role in the diffusion of ideas (Rogers, 1983).

Adoption is the decision making process whereby new ideas are implemented. It is usually described in multiple stages (Table 1.1), starting with the initial awareness on the part of the farmers of a potential solution to an identified problem, and ending with the full scale adoption of the new idea.

**Table 1.1 Stages of the adoption process.**

| |
|---|
| 1. Awareness: first hear about the innovation. |
| 2. Interest: seek further information about it. |
| 3. Evaluation: weigh up the advantages and disadvantages of using it. |
| 4. Trial: test the innovation on a small scale. |
| 5. Adoption: apply the method on a large scale in preference to old methods. |
| (Proposed by van den Ban and Hawkins, 1988) |
| 1. Knowledge. |
| 2. Persuasion (forming and changing attitudes). |
| 3. Decision (adoption or rejection). |
| 4. Implementation. |
| 5. Confirmation. |
| (Proposed by Rogers, 1983) |

A number of factors influencing the likelihood of adoption of a particular technique by a particular person, in a given situation have been identified (Table 1.2). The most obvious of these factors, the relative advantage conferred by adoption, is just one of a number of different attributes of the new technology to influence adoptability. The framework for the adoption decision, the channels of communication, the nature of the social systems and the extent of promotion are other categories of factors.

**Table 1.2 Factors influencing rate of adoption of technology (adapted from Rogers, 1983).**

| |
|---|
| 1. Attributes of the new technology:<br>Relative advantage<br>Status Aspects<br>Incentives<br>Compatibility:<br>Beliefs and values<br>Needs<br>Previous methods<br>Affordability<br>Complexity<br>Trialability |
| 2. Type of adoption decisions:<br>Optional<br>Collective<br>Authority |
| 3. Communication channels |
| 4. Nature of social system |
| 5. Extent of promotion |

### 1.3.3 Studies and Implications of Diffusion and Adoption

A number of studies in the field of extension science have described the process and effects of diffusion of specific agricultural technologies within rural societies (Rogers *et al.*, 1971). Most recent studies highlight the problems that extension systems have in (a) reaching the poorest and most marginalised farmers[6], and (b) delivering technology that is of real benefit to those with the least resources[7] (Roling, 1988). The implication of this work is that extension programmes must be specially designed to target the categories most in need of assistance and the technology offered must be appropriate for the local social, ecological and economic conditions.

Particular factors that are likely to influence the rate and pattern of adoption of new technologies have been highlighted by various studies: Barrows and Roth (1990), examining evidence from Kenya, Uganda and Zimbabwe, found that security of land tenure was a critical factor in determining the

6 Ashcroft *et al.* (1973) identified categories of progressive farmers, early and late majority adopters and least progressive farmers in central Kenya. It was found that the poorest farmers were not being reached by regional extension programmes, and were therefore the last to adopt new technology. Subsequently, a specially designed programme, targeting agricultural information at these farmers, was implemented and found to be effective.

7 Cordova *et al.* (1981) showed that the very rapid adoption of modern varieties and inputs by Filipino farmers only yielded real benefits to those richer farmers who were able to irrigate their land twice a year.

"willingness to invest in new agricultural methods". Studies of agricultural technology development in Burkina Faso by Sanders *et al.* (1990) emphasised the requirement for ecological compatibility of new techniques introduced into areas, and the need for simultaneous adoption of a number of new methods to pay-off the investment in effort complicate the adoption decision process. Such observations support the arguments for technological determinism. The importance of social networks for the pattern of diffusion of zero - tillage agriculture was noted by Beck (1992). In Jamaica, conflicts of interests between development agencies and farmers were identified as important constraints on the diffusion / acceptance of new technology (Henn, 1991). Carlson and Dillman (1988) found that farmers' exisiting level of mechanical skills affected their ability to successfully implement new zero - tillage farming methods.

The effect of market factors, particularly the demand for cash crops, has been noted as a particularly important motivating force for technical change in Sudan, by Larson and Bromley (1991). This study also made the important link between national trade policies and local market influences. The role of the state in agricultural development, particularly in relation to peasant societies, is often criticised but (Porto, 1990) emphasises the need for progressive state assistance to fund non-commercial developments that will produce social benefits. The importance of formal education within the peasant sector is often neglected by agricultural developers. Eisemon (1989) discusses some of the shortcomings of current teaching practices in rural African schools and argues that schooling practices should be based on "a better understanding of how course content and language of instruction impact upon the integration of knowledge from social experience and the cognitive skills required for use of modern technology".

The Effects of Technological Change

There have been numerous studies on the impacts of technological change, from social and environmental perspectives. Within the social context studies have often focused on the implications of new technology for certain groups within peasant societies, for example: Boserup (1971) related technological attributes of peasant farming systems to the degree of women's engagement in farm work. More recent studies, such as (Morvaridi,-Behrooz, 1992) observed a disproportionate burden of labour being allocated to women as a result of increasing market orientation of peasant farms in Turkey. In a wider sense, Sorj & Wilkinson (1990) reviewed the impact of global technological advances in agricultural production upon peasant societies and concluded that agroindustrialisation was a major cause of rural poverty. Pineiro *et al.* (1981) associated technological development with a loss of the *Campesino* (peasant) nature of the production unit. Human ecology models have also been applied to study the impact of technological change upon demographic change: Albrech and Murdoch (1986) used a model derived from sociological human ecology to longitudinally examine the consequences of environmental & technological changes on farm structure & rural demographic trends in agriculturally dependent areas, of the Great Plains of India. Following a review of the literature on the costs and benefits of high yielding agricultural technology, Grabowski (1990) concluded that the overall level of benefits to small farmers was highly dependent upon social structure, particularly the mechanisms for dispersing new wealth. The environmental consequences of technological change have of course been frequently noted e.g. Larson and Bromley (1991) related the development of cash crops in Sudan to large-scale deforestation. A direct consequence of this deforestation was a permanent alteration in the international market for gum arabic.

### 1.3.4 Indigenous Innovations

In addition to the attention paid to the transfer of technologies arising from institutional research and development there has been a growth in the description of, and the value placed upon, indigenous agricultural and ecological knowledge worldwide. (Richards, 1939; Conklin, 1954; Brokensha *et al.*,1980; Richards, 1985; Chambers *et al.*, 1989). This has led to the establishment of regional networks for indigenous knowledge research in Africa and Asia (ARCIC and REPIKA) and globally CIKARD. Evidence of ecological knowledge of considerable sophistication in indigenous communities was provided by numerous anthropological fieldwork studies of indigenous agricultural practices, such as Padoch and de Jong (1987) and Rocheleau *et al.* (1987). Most efforts have been concentrated on the acquisition and description of local practices, and knowledge to be utilised as an input to current agricultural research systems. Work is currently underway to provide intelligent knowledge-based systems capable of formally representing the structure and function of local "knowledge systems" (Muetzeltfeldt, 1993). Increasingly however, local knowledge has also been recognised as an essential input to the planning process for development projects (Chambers, 1983 p75; Smith 1989 Ch.7).

A number of methods for integrating local knowledge into the project planning process have now been developed. Most techniques have been creatively adapted from ethnological methods and make use of tools such as systems diagrams of problem situations, transect mapping and ranking methods (Conway, 1989; Lightfoot *et al*, 1989). These methods have been used to define cause and effect relationships between components of agricultural systems, the spatial positions and dimensions of these components and likely effects of proposed interventions. At the agronomic level, efforts to mobilise hitherto neglected environmental information has led to the production of a software tool designed to aid agricultural planners match lesser known plants to land types on the basis of observed empirical relationships (Hackett, 1991). Hackett places emphasis on the application of these tools to enhance the working relationships between researchers, extension workers, and farmers by providing a structured, yet flexible framework for the integration of different fields of knowledge. Other techniques for integrating local and specialist knowledge to give quantitative economic estimates of the impact of alternative development proposals have yet to be developed.

## 1.4 Objectives of the Study

The principal objectives of the study were designed to address the questions and problems stated in sections 1.1.2 and 1.1.3, were defined as follows:

1. Describe the contemporary process of technological change in the agricultural systems of peasant farms in the northern highlands of Chiapas.

- Determine the principal causal economic factors of technical change.
- Determine the effect of causal factors on the principal agricultural activities (maize and coffee production).
- Determine the impact of technical change in agriculture on local livelihoods.

2. Develop and test a flexible but structured methodology for understanding and evaluating the performance and systematic behaviour of *Campesino* farms in the northern highlands of Chiapas, utilising both local and specialist knowledge. The methodology should include the development and application of computer models allowing the integration of data relating to resource constraints, local agricultural practices and new production options. These software tools should assist with the following: (a) The understanding the dynamics of the peasant farm in a *systems* sense, (b) the economic evaluation of alternative planning scenarios at a farm household level, (c) the determination of the relative importance of alternative constraints on production systems, and (d) the identification of potential leverage points for improvement within production systems.

3. Provide specific technical and management recommendations that will improve the process of appropriate technological development.

4. Test the Action Research methodology in the context of agricultural development in southern Mexico.

# 2 The Geography, Economy and Agricultural Systems of Highland Chiapas

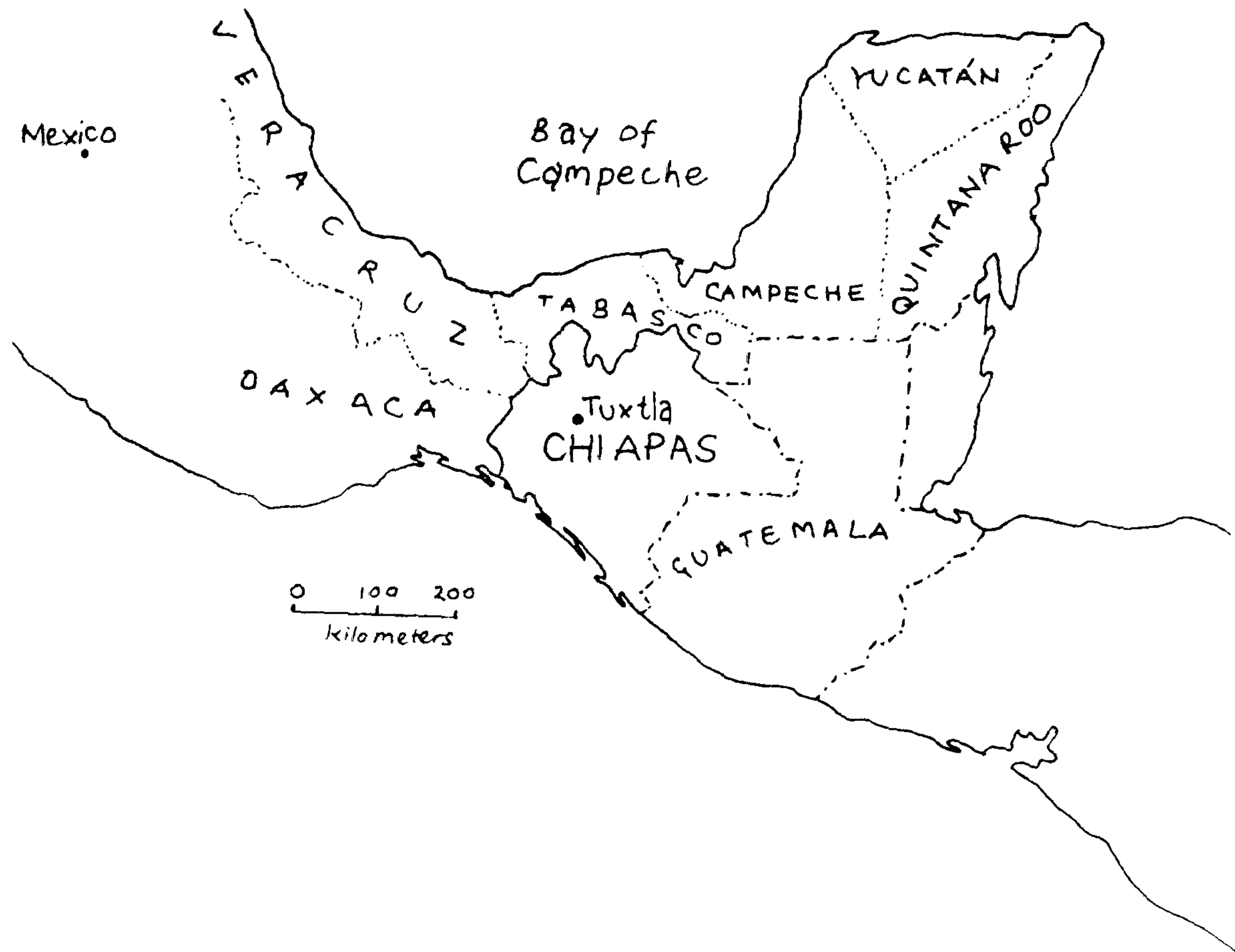
## 2.1 The Geography of Chiapas

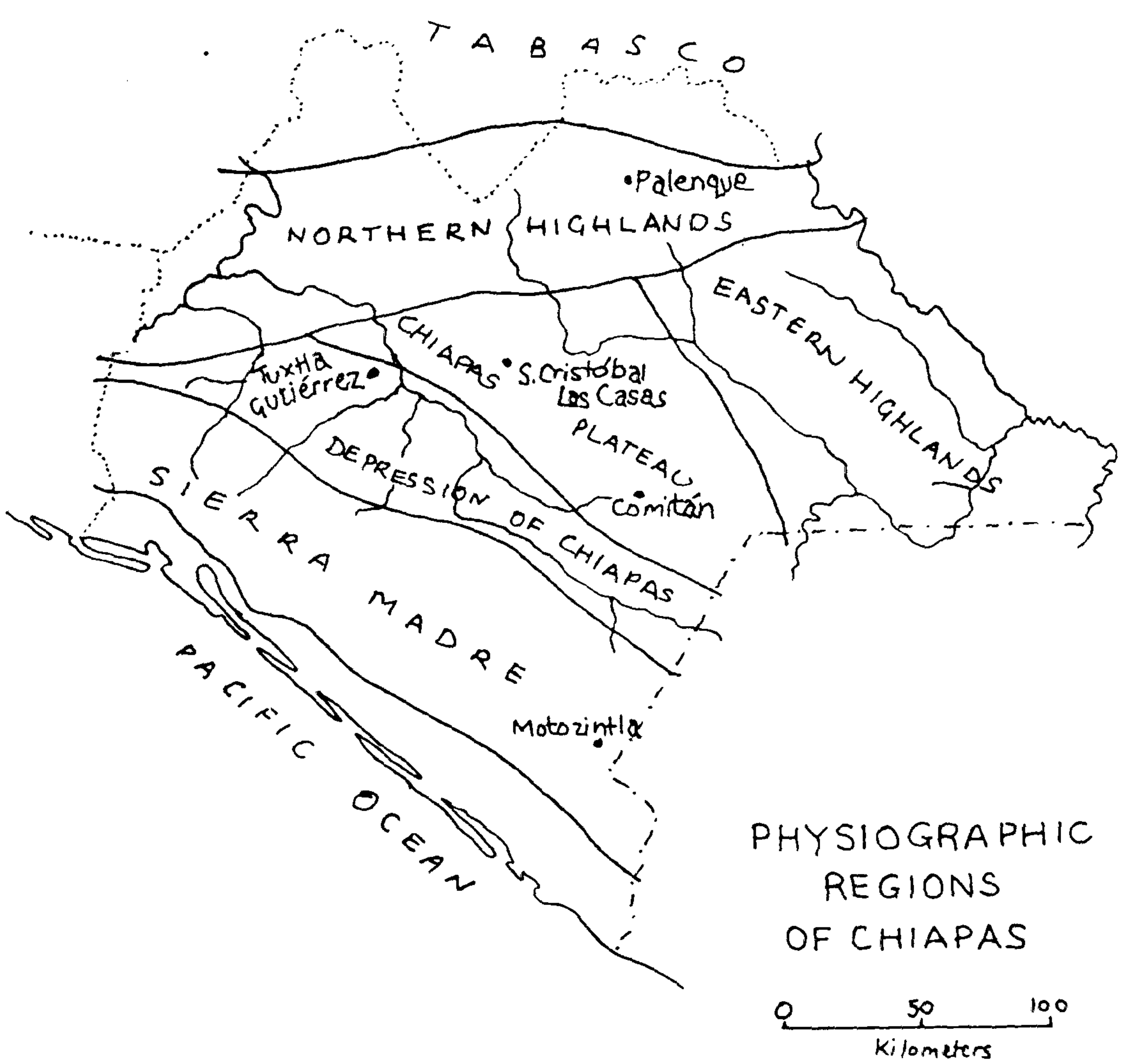
Chiapas is the southernmost state of Mexico, bordering with Guatemala (Figure i). Whilst its rural people are amongst the poorest in Mexico, the state is one of the country's richest in terms of natural resources, biodiversity and indigenous cultures. The northern highlands[1] exhibit many of these contrasts, with four different indigenous peoples practising various types of semi-subsistence agriculture on land cleared from the region's different forest types. However, the needs and aspirations of the increasing human population which has doubled in the last 20 years (INEGI,1989) mean that the pressures for more agricultural land and the depletive use of forest resources are threatening to cause major losses of both habitat diversity and management options for more sustainable development.

The Tzotzil, Cho'l and Tzeltal coffee producing zones covered by this study are located in the region of the northern highlands of Chiapas (Figure 2.i). These areas are situated north of the Central Plateau, where several of the communities in the vicinity of San Cristóbal de Las Casas have been the subject of extensive anthropological research. The Tzotzil zone (Municipios de Huitupán, Simojóvel and El Bosque) is characterised by wide valleys running south-west to north-east, between mountainous ridges, from the Pacific - Atlantic divide, as far as the river Escalon in the north. Further north, the Cho'l region lies in a broken, irregular mass of mountains, from which rivers run in all directions. The communities of these two zones are found between 600 and 2000 m above sea level and temperatures rarely exceed the range of 10 to 30 degrees Celsius. The Tzeltal zone, north-east of the Ch'ol zone is lower (400 - 900 m above sea level), less precipitous and hotter. The three zones receive abundant and frequent rainfall (1200 mm - 3500 mm per year), except in the first two or three months of the year. The region's soils are generally well drained, with "A" horizons of greater than 30 cm deep.

1 The northern highlands were delineated as one of seven distinct physiographic regions within Chiapas by Mulleried (1957).

**Figure 2.i. Chiapas in Relation to Mexico**



## 2.2 The Rural Political and Institutional System

Guillermo de la Pena (1976) described the Mexican political system as a "hierarchical patronage network", in which local and regional power is exercised through informal social networks (*redes sociales*) acting within and between formal but highly fragmented, institutions. A vast array of political intermediaries act as "gatekeepers" between local, municipal, state and federal structures. Political activity involves the distribution (or restriction of) essential state-provided goods by intermediaries using familiar, non-institutional mechanisms, such as clientelism, favouritism and violence.

The central role of the regional landowning elite and other *caciques*, such as leaders of the CNC[2] in the hierarchical patronage network in Chiapas was described by Harvey (1992). The relative weakness of the revolutionary movement in Chiapas in 1910-1917 (Benjamin, 1989), and of any subsequent multi-ethnic alliances against the *ladino* landowners, has been attributed to the exercise of paternalistic power over the local indigenous peasantry by the landowning elite. However, the fragementation of local power caused by rivalries between caciques has facilitated the centralisation of authority by the national government. De la Pena (1972) asserted that this fragmentation is intentionally sought by federal government in its drive to subordinate potential opponents in the provinces.

Peasant movements have played an important part in the expression and control of agrarian discontent in Mexico. Until the 1970's the government affiliated CNC dominated the role of the peasants' representative in government[3]. However, the 1970's and 80's saw the emergence of a number of autonomous peasant movements, in Mexico at large and in Chiapas, in particular. The most important of the independent movements in Chiapas was the Unión de Uniones[4] (UU), formally established in 1975. In contrast to most other movements, the UU sought wider goals than land reform; these included control over commercialisation and marketing, improvements in health and education services and

2 CNC (Confederación Naciónal Campesina) is the principal rural organisation affiliated to the Ruling Partido Recolucionario Institucional (PRI).

3 Hardy, (1984) maintains that the CNC has continued to command considerable support despite its evident inability to influence agrarian policy as a result of its access to the offices and archives of the land reform department (Reforma Agraria). "Mexican agrarian reform has institutionalised the peasants' desire for a piece of land. They soon learn...that they need the CNC to represent them in their demands and to facilitate all the necessary institutional procedures.".

4 A brief history and description of the UU was made by Harvey (1992b).

development of agricultural production methods. In 1983 the UU established the first farm credit union in Chiapas and was granted permission to export coffee directly.

A large number of government institutions, both federal and state, are responsible for providing services to the rural sector. Most of these have been noted for their bureaucracy rather than their effectiveness. A list of these agencies and their main activities is provided in Appendix 1. These will only be mentioned in the course of describing any relevant activities carried out by them, in each location of the study. In general, however, the 1980's has been characterised by a reduction in State intervention resulting in the closure of several governmental agencies, such as INMECAFE and CONAFRUT. The exception was the establishment of a large federal programme in 1988, the Programa Naciónal de Solidaridad, which consists of a fund, supposedly targeted at the poorest of both the rural and urban sectors. The fund is meant to finance small and medium scale projects that have been designed with community participation. The government has appeared to have made efforts to prevent appropriation of the programme by local and regional and local *caciques*. However, opponents have argued that the programme has become more a publicity campaign to help the image of the president and his party than a serious attempt to eradicate poverty[5].

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5 Harvey (1990) noted: "The criticisms aired by the president of the consultative committee of PRONASOL, Carlos Tello, led to his removal and appointment as Mexican ambassador to the Soviet Union."

## 2.3 The Economic System of Highland Chiapas

Agriculture is the principal economic activity of the majority of the population in Chiapas. Official figures for 1980 (INEGI, 1989) showed that of an economically active population of 734,047 there were 421,561 employed in agriculture, forestry and ranching. Maize and coffee represent the most important crops in the State and in the northern highlands (Table 2.1). According to INEGI (1989) the combined area maize and coffee cultivation occupied 85% of agricultural land (not including pasture) and accounted for 75% of the total value of agricultural production from the State in 1985.

**Table 2.1 Principal Characteristics of Agricultural Production in Chiapas, 1985 (INEGI,1989 p575)**

| | Area (1000ha) | | | | | |
|---|---|---|---|---|---|---|
| | **Total** | **Irrigated** | **Rainfed** | **Yield (t/ha)** | **Prod.n (1000t)** | **Value (Mpesos)** |
| **Maize** | 678 | 26 | 652 | 2.152 | 1460 | 124,497 |
| **Coffee** | 164 | 0.1 | 163 | 0.755 | 126 | 100,164 |
| **Beans** | 76 | 0.2 | 76 | .672 | 51 | 8,232 |
| **All Crops** | 986 | 37 | 949 | - | - | 283,443 |

Peasant farming enterprises in Chiapas have many features in common with those in other parts of rural Mexico. Production and consumption are organised at a family level, in most areas of Chiapas, land is owned by the community in the legal status of the *ejido*. In the central highlands however, several of the larger Indian settlements are classed as *comunidades* (land held under traditional rights), and in the northern highlands there are a small number of *pequenos propietarios* (small private land holdings of less than 5 ha). Within communities there exist mechanisms for the exchange of capital, labour, and goods within, and between, families. Distribution and exchange of goods between the *ejidos* and nearby towns is largely controlled by local merchants. The articulation between the *ejido* and the state is via the local *Presidencia Municipal* and the *Consejo* or *Presidencia Ejidal.*

Transactions involving the exchange of factors of production and goods for consumption occur through a number of mechanisms. Exchanges between members of the same community are frequent and often informal, whilst those between farmers and outsiders, such as local merchants and agents of government institutions, are formal and often reflect the subordinate position of *campesinos* relative to those of urban origin (Wolf, 1966:13). The following section describes the main features of the markets for the main factors of production in the agricultural systems of Chiapas. Transactions within rural communities are contrasted with those between farmers and outsiders.

### 2.3.1 Labour

The History of the Labour Market in Highland Chiapas

Many highland Indians still recall the operation of the *enganche* a mechanism devised to recruit labour for the large, mainly German owned *fincas* in the Soconusco region, which had expanded rapidly after the introduction of coffee growing to Chiapas in the 1850's, and for logging companies in the Lacandón rainforest. This system worked on the basis of debt contracting.

The contractors, or *enganchadores* made wage advances to prospective labourers, who were obliged to repay the debt by working in the lowlands. The need for credit was ensured by the state which, from the 1890's levied a whole schedule of municipal charges and fees and even a head tax (*contribución por capitación*). For those who fell behind in meeting these obligations a vagrancy law was enacted, so that any man not in possession of a tax receipt was subject to immediate arrest and fine - following which he could be turned over to an *enganchador* in exchange for an even greater debt. In one community in the highlands, for which figures are available, the total burden of all these taxes by 1907 came to 10.98 pesos for each male of twelve years of age and older. Since the lowland wage at that time was .20 to .25 pesos a day this amounted in effect to more than forty days per year state obliged labour, (Rus,pp4-5, 1990).

The *enganche* system persisted in Chiapas until the mid 1940's (well after the revolution), but as the population in the highlands grew, increasing the supply of labour, and the lowland *fincas* declined, there was no longer the same need to contract labour in this way. Since the 1970's the remaining lowland fincas have depended on the even cheaper supply of migrant labour from Guatemala.

Internal Transactions

Several authors e.g. Warman (1979) have noted that labour is often bought and sold within communities at wage rates that are below regional averages. Those with little or no land often prefer to work on an occasional basis for those with more land rather than leave their homes so incurring extra costs in order to find better paid employment. Labour hiring within communities is often concentrated on particular labours such as harvesting and at particular times of the year. This may lead to substantial seasonal changes in wage rates. Labour is not always traded for cash; sometimes a family will pay in kind with food, household goods and labour often being exchanged. The lending of labour between neighbours, either at peak times or during periods of crisis, such as family sickness, is known as *mano prestado*. The organisation of communal labour is also an important feature of village life. Villagers are usually obliged to supply a certain number of *jornales* (days labour) to communal projects such as road maintenance, school building etc,. These may be fixed amounts each month or they may vary according to the level of community activity.

External Transactions

The external labour market is both a source of labour and a source of capital for the community. Men and women without land often leave the community temporarily to work either in other communities, on the remaining large commercial estates or in the towns. Young men often leave for substantial periods (and of course many never return), working on public projects such as road building or in the petroleum industry, while they wait for access to land in their village. At times of peak agricultural activity farmers may hire labour from outside the community.

### 2.3.2 Land

Internal Transactions

The legal and economic implications of the *ejidal* form of landholding has been extensively described (Simpson, 1937; DeWalt, 1979; and Wilkie, 1971). and will not be re-examined in this study. It is sufficient to mention that since the establishment of the *ejido*, following the 1910-20 Mexican revolution there has been no legal basis for the buying or selling of land within peasant communities. In practice unofficial land transactions do occur and new legislation is now being introduced to legalise such deals. However, as land transactions between community members are illegal without the approval of *ejidal* authorities it is very difficult to ascertain their true extent. Since 1992 constitutional reforms initiated by President Salinas de Gortari, which will allow the conversion of *ejidal* lands to private holdings, and their subsequent sale, albeit with certain conditions are expected to result in substantial increases in land transactions over the next ten years.

External Transactions

Whilst transactions involving outside buyers of *ejidal* land are still rare in Chiapas, both sales and rentals are said to be increasing rapidly in the Northern states of Mexico, particularly in areas susceptible to mechanized modernisation. An example is the "GAMESA deal" (Salinas, 1991) in which a multinational agribusiness has been renting large ares of *ejidal* land in Sonora, applying a technological package and even paying the farmers as labourers.

Over the past 10 years it appears that a substantial amount of land has been bought by small farmers from larger owners. This has accompanied the move by large landowners out of agriculture into more lucrative businesses such as tourism. Where peasant communities border on private properties there exists the possibility of either (a) the expansion of the *ejido* as a whole or, (b) the purchase of land by individuals or groups (such as the solicitantes) from the community.

### 2.3.3 Credit

External Sources

The only widespread source of credit for peasant farmers in Chiapas is the government, which currently distributes about 130 pesos (£26) per hectare of maize cultivated up to a maximum of 3 hectares. This *Credito de palabra*, so named because no guarantee is needed other than the farmer's signature, is lent, interest free, as part of the national solidarity programme. Only about 70% of this "credit" is ever recovered and it is regarded by many politicians as well as peasants as a form of social security or subsidy for the rural areas. Opposition parties see it as a political sweetener, or vote buying, and indeed, many of the *Presidencias municipales* that are responsible for the distribution and collection of this money, have been accused of irregularities such as the delay or non-payment of money to communities or groups known to be in opposition.

Other credits, for the improvement of cash crop or livestock production are usually obtained from the national agricultural bank - Banrural, at commercial rates of interest (currently around 35% p.a.). In order to receive this finance, producers must submit a project or cooperative proposal. Again, the process is bureaucratic and subject to delays and difficulties. There is one credit union in Chiapas which acts as an intermediary between banks and peasant farmers. The Unión de Credito Pajal Ya Kac' Tic, as it is known, has had a large impact on peasant agricultural investment in the northern highlands of Chiapas. However, despite attempts to diversify its activities into livestock and honey production the union has been heavily dependent on the coffee market, and since the collapse of the international market in 1989, its desperate financial situation has forced a curtailment of lending.

Other government institutions working in rural areas often include credits as integral parts of their programmes. INI and INMECAFE have lent to coffee producers in order to allow them to hold onto the first of the harvest until prices rise, but with rates of repayment falling well below 50% most of these schemes have been abandoned. DIF has been more successful with small credits to womens' textile cooperatives. These credits come in the form of materials or sewing machines and are repayable either in cash or finished goods.

Apart from official sources of credit there are also private money lenders in the towns, who will lend to peasant families within their confidence. Due to the high rates of interest charged (10-20% per month)[6], these sources are generally used for short term loans, of a few days or during times of difficulty.

Internal Sources of Credit

Whilst in most communities there is a strong sense of inter-family solidarity which provides financial assistance to families in need, there are also people who will lend money. Interest rates are generally high; ranging from 10 to 20% (non-compounded) per month. No guarantee is needed other than the word of the borrower.

### 2.3.4 Cash Crops

Cash crop production and export from Chiapas has been dominated by coffee for over one hundred years. The first recorded export of coffee from Mexico was in 1802, when 273 *quintales* (sacks of 57.7

6 Current annual inflation rate has declined from around 120% in 1987 to around 20% June 1991 (Heath, 1991).

kg) were shipped from Veracruz. The first coffee plantation in Chiapas was established by Jeronimo Michinelli, who in 1846, imported 1,500 plants of an old variety of coffee known as "Bourbon", from Guatemala. Large landowners in the Sierra Madre of Chiapas, an area known as the Socunusco, began to cultivate commercially and by 1862 coffee was being grown, along with tobacco near Simojóvel in the northern highlands of Chiapas. By 1862 Mexico was considered a coffee producing country, exporting around 70,000 sacks annually but it was not until a revolution in Brasil in 1886 that the country attained a strong position on the world market. By 1902, at the height of the Porfirian era, exports had exceeded 500,000 sacks per year and Mexico was the third largest producer in the World. However, the 1910 - 1920 revolutions decimated the coffee industry. Many plantations and *beneficios* were abandoned and by 1920 exports were around 200,000 sacks. A slow process of reconstruction followed in the post-revolutionary period (Salazar Peralta, 1988).

The Contemporary Coffee Market

Over most of the past century, coffee has been the most important agricultural export product from Mexico. The value of coffee exported in 1989 from Mexico was $514 million US (INEGI, 1990/91). More recently however, a combination of low coffee proces and a growth in the intensive production of fresh produce in the northern states of the country, serving the US market, has led to coffee being overtaken by tomato and fresh vegetable exports (See Table 2.2).

**Table 2.2 Value of Exports from Mexico 1988-1990, ('000s of US dollars)**

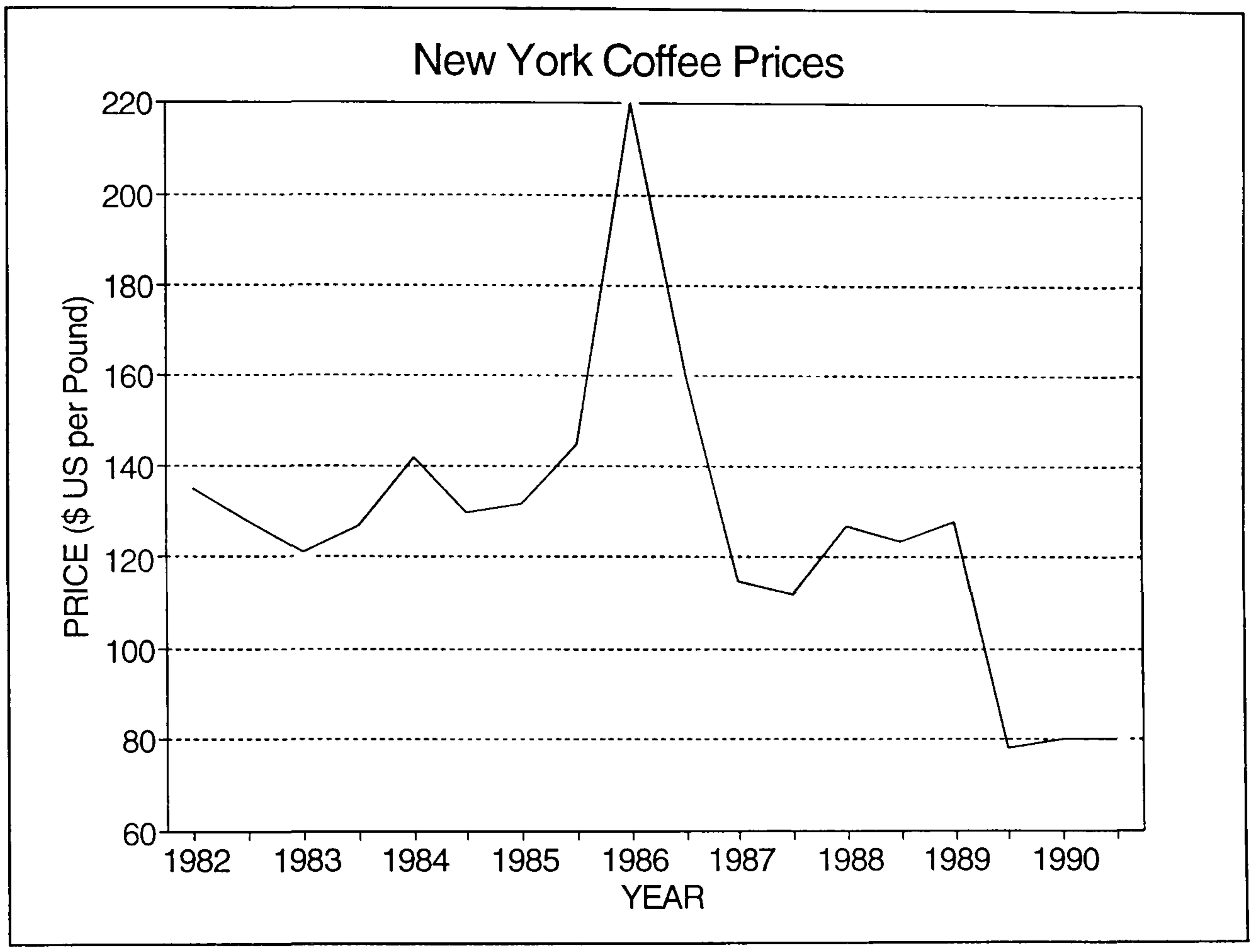
| | **1988** | **1989** | **1990** |
|---|---|---|---|
| **Agric & Forestry** | **20 565 136** | **22 842 136** | **26 950 274** |
| Coffee (green) | 434 863 | 513 506 | 332 890 |
| Tomatoes | 243 053 | 198 894 | 428 402 |
| Fresh Vegetables | 269 406 | 196 685 | 430 017 |
| Cotton | 112 584 | 112 178 | 91 833 |
| Fruits | 71 731 | 73 105 | 138 276 |
| | | | |
| **Livestock, honey, fish** | **270 923** | **292 475** | **441 736** |
| | | | |
| **Extractive Industries** | **6 543 804** | **7 896 589** | **9 537 563** |
| Oil + Nat Gas | 5 883 528 | 7 291 832 | 8 920 672 |
| | | | |
| **Manufact. Industry** | **12 287 487** | **13 091 334** | **14 966 347** |
| | | | |

Source (INEGI, 1990/91).

About 25% of Mexico's coffee is produced in Chiapas. Despite a recent collapse of prices on the international market coffee remains the most important cash crop in the state of Chiapas, accounting for around 80% of the State's agricultural exports. The structure of the national coffee market has changed considerably over the past 20 years. In the mid-seventies the government attempted to resolve, by intervention, the problem of *coyotismo*; intermediaries who controlled rural transport and commercial channels, and who were able to extract large profits as a result of monopsony. The *Instituto Méxicano de Cafe* (INMECAFE) was established in 1973 to promote the development of coffee production among small producers, by offering technical assistance, transport, processing and storage infrastructure, but above all, by commercialising the product at fair prices. INMECAFE's intervention in the Chiapas coffee market began in 1975. Unfortunately, as with many other state institutions, INMECAFE quickly became a burgeoning bureaucracy, inefficiently and at times corruptly run. Peasants complained of rigged scales and extortion by officials at coffee reception points. By the late 70's, various local unions and cooperatives were formed, to oversee the State commercialisation. In 1983, the first concessions allowing cooperatives to export coffee were granted. Despite their inexperience these local organizations usually able to offer 10% above the INMECAFE price. By 1987 INMECAFE accounted for only 20% of the commercialisation in Chiapas and in 1991 the Institute was dissolved.

In 1989 the market received a great shock with the sudden fall in the world coffee price (Figure 2.ii). Many local merchants and cooperatives were driven out of business and many farmers were unable to repay loans that they had secured to improve their coffee production. Since 1990 a new regional market structure has emerged, with 2 or 3 large companies (based in Veracruz and Puebla, such as Tomari) exerting a strong grip on the Chiapanecan coffee market. These companies are large enough to own de-caffeinating plants, which in the current situation give the merchants an additional 15% margin (Torres, pers.comm. 1991). If these merchants require coffee from the Chiapanecan market, as occurred last year, following frosts in Puebla and Veracruz, they are able to outbid even the local cooperatives. This increased integration of the national market has added to the volatility of prices this was demonstrated during the 1990/91 harvest. The season began with prices of *pergamine* at low levels (around 2 pesos / kg) in November, but these quickly rose to above 3.8 pesos / kg by late January.

**Figure 2.ii.**


New York Coffee Prices
PRICE ($ US per Pound)
220
200
180
160
140
120
100
80
60
1982
1983
1984
1985
1986
1987
1988
1989
1990
YEAR

Other Cash Crop Markets

There have been various efforts to diversify sources of cash income from agriculture in Chiapas. These included government programmes and a number of projects by local organizations as well as the initiatives of individual farmers. On the whole, government programmes, such as the highland potato project, described in (4.1.7), have failed because insufficient attention was paid to the marketing of products. Current government crop diversificaton programmes include *chicle* and pepper along the frontier region. Local projects have had some successes: notably, honey production from the Lacandón rainforest, plums and pears in the Altos and cattle in the Simojóvel area. A number of individual efforts have also been observed involving a variety of crops: strawberries, avocados, bananas, honey and mangos. In most cases these alternatives represent only minor additions to total family income (but possibly at times of year when cash is scarce). Furthermore, the amounts offered onto local markets are not enough to have a major impact on price. The shortcoming of most local initiatives is that they lack the resources necessary to ensure quality, quantity, packaging and transport needed to commercialise products in Mexico City or to export.

### 2.3.5 Corn Markets

Each year, every farmer must judge whether the corn harvest will be sufficient to cover the family's need for food and for seed for the following season. If there is surplus then he will need to consider the alternative ways of transporting and marketing his crop. Despite the official regulation of the price of maize since 1970, and the large scale intervention of the state in marketing and distribution of basics, there remains a large number of marketing options for peasant farmers. Cancian (1972) studied the options faced by Zinacanteco corn farmers; these included: selling in the San Cristóbal market; to middle-men in San Cristóbal; to the Government reception centre; to private lowland buyers; or to local Zinacanteco speculators. Most farmers sold to two or three different outlets each year. Farmers from different hamlets in Zinacantán tended to favour different outlets. Often farmers will sell the first part of their crop to local speculators at a lower price in order to raise capital for the harvesting and transport costs of the remainder. The location of the farmer's fields are therefore an important consideration.

Sale of Corn Futures

Many farmers who run out of cash before the harvest is in will sell a part of their crop to someone who agrees to take future delivery. Besides family emergencies that produce a sudden need for cash, *fiestas* are major occasions for such sales.

Corn Supply

Despite government efforts to distribute low priced basic goods to rural areas through CONASUPO, maize supplies are not always reliable. Thus, even if cash crop alternatives appear to be more financially attractive, farmers are unlikely to abandon maize cultivation.

### 2.3.6 Transportation Market

Given the general isolation of indigenous communities from most external markets, the transportation market plays a central role in the rural economy. In most highland communities of Chiapas the transportation, in the form of "pick-ups" or three tonne trucks, is owned by local *ladino* merchants from the municipal centre. However, the strength of *ladino* transport oligopolies is variable; many larger communities now include either private or cooperative vehicle owners.

### 2.3.7 Agricultural Inputs Markets

Many highland communities situated above 1500 metres altitude are now dependent on the use of artificial fertilisers to ensure an adequate harvest (due to the intensity of land use and the frequency of burning). This contrasts with less densly populated areas at slightly lower altitude, where fertiliser use by farmers is still mainly sporadic. FERTIMEX, a state run monopoly was established to ensure regular supplies of cheap fertiliser to small farmers. However, the corporation was notoriously inefficient, and these supplies were often bought up by intermediaries upon reaching regional depots, to be sold at higher prices in the villages. The fertiliser market is currently changing as FERTIMEX is in the process of being privatised. It remains to be seen whether this will improve efficiency. In 1991 the Governor of the State of Chiapas, Gonzalez Patrocinio bought a large stake in the newly privatised company. Other agricultural inputs such as herbicides, pesticides and veterinary medicines are already supplied by the private sector, and are sold over the counter at the numerous *veterinarias* to be found in all market towns.

### 2.3.8 Artisan Craft markets

Over the past 10 years tourism has grown considerably in Mexico and Chiapas. The traditional woven garments, and pottery produced by local craftswomen (and only a few men) are now sold in large quantities in San Cristobal, Mexico City and are even exported. This market provides important income that goes directly to women at times when money is scarce (Rus, 1990). One problen is that production is in excess of demand for most of the year (tourist season peaks are Christmas, Easter and Summer), hence the pitifully low prices of beautiful goods that require many hours of work. The growth of "Third World Craft Boutiques" in the U.S. and Europe means that, on a world-wide scale Mexican artisans are now competing with crafts from Guatemala, South America and even Asia.

## 2.4 The Agricultural Systems of Highland Chiapas

The following sections describe the development of the two principal components of the peasant farming systems in the northern highlands of Chiapas. Firstly, the annual cultivation of maize and beans for subsistence, and secondly, the perennial cultivation of coffee for cash income. All the individual farms surveyed in the following study managed some combination of these two methods with the limited productive resources available.

### 2.4.1 Subsistence Agriculture: The *Milpa* System

Maize and beans are the staple foods of the Indians of Central America and of peasants in many parts of Latin America. The Mayans have cultivated these crops together for some 4500 years in a variety of systems ranging from low intensity swidden agriculture as described by Conklin (1961), to intensive, multi-cropped cultivation on raised beds (Turner, 1974). The generic Mayan term for the maize field is *milpa*. For the Maya the cultivation of the *milpa* has religious as well as economic significance: maize, like humans, is believed to have an "inner soul" which is found in the ear and in the "heart" of each kernel just as it is found in the "heart" of a person (Vogt, 1970 p48).

The Tzeltals, Mayan Indians of the Central and Northern highlands of Chiapas, Mexico, cultivate maize in a traditional *milpa* system similar to that used by other highland Mayan groups in Chiapas and Guatemala. Several accounts of this system have been published since Weathers, (1946) account of the agriculture of highland Tzotzils. Probably the most detailed description of the swidden *milpa* is given by Tax (1972).

<u>The Costs of Intensifying a Traditional System.</u>

The long term effects on the fertility of soils caused by reductions in the length of fallow periods in swidden agriculture were explained by Nye and Greenland (1960): most of the nitrogen contained in the surface litter is volatilised by burning, thus continual cultivation leads to a depletion of this important element. Furthermore, the exposure of bare soil following burning can allow severe erosion to take place. Burning for several years in succession can also affect the composition of the soil's seed bank, encouraging the proliferation of hardy runner grasses. Many of these effects are now apparent in the highlands of Chiapas; Short, (1991) has estimated that average yields in some communities have fallen from 1,500 - 2000 kg/ha to 700 - 900 kg/ha over the past 10 years, despite increased use of fertilisers. Collier (1990) states that fertilisers are now indispensable on many Zinacanteco lands. The ministry of agriculture (SARH) now recognises that many farmers in Chiapas are using non-sustainable methods. However, there has been no proper study to determine the scale or parameters of the problem. Neither has the possible cost to the state, in terms of reduced future productivity, been estimated.

### Sustainable Alternatives

In 1979, an agronomist with the Presbyterian Church mission in Oxchuc, a large Tzeltal community in the Central highlands, began to promote non-burning *milpa* production (Short, 1991). During the 1980's other institutions, including the Unión de Credito and SARH began to promote various non-burning cultivation techniques in the area. Most of these programmes were rather discontinuous and disorganised. Nevertheless, some farmers successfully adopted or adapted these practices for their own use and achieved substantial long term benefits. Two case studies of successful examples of adoption of non-burning are given in Appendix 8. The benefits of adoption included: (1) improvement in soil fertility and moisture retentive capacity; (2) complete control of erosion; (3) reduction of weeds, especially runner grasses after three years without burning. However, the adoption of the new method did present problems in the short-term: (1) increase in the work required to clear and prepare land for planting; (2) increase in the weed growth in the first two years; (3) low yields in the first two years, possibly due to weed competition or immobilisation of nutrients.

### Current Knowledge About *Milpa* Systems in N. Chiapas

Despite the importance of the *milpa* system as the principal means of subsistence for the majority of the rural population in Chiapas, there is no published study of the current state of *milpa* technology employed by the indigenous peasant farmers. Whilst new methods such as non-burning cultivation are clearly gaining ground in the region, there has been no investigation of the rate or pattern of adoption, or of the impact of new technology on short and long term productivity.

### 2.4.2 Cash Crop Agriculture: The Coffee System

Coffee Cultivation in Chiapas

There are two major coffee producing areas in Chiapas: the Soconusco, a strip of fertile land rising from the Pacific coast towards the Sierra Madre, and the Northern highlands. There is a great contrast between the types of producers and the methods of production employed in these two areas. The Soconusco is dominated by large landowners, with plantations of several hundred hectares, generally intensively farmed, using hired Guatemalan labour and with large capital investments in processing, storage and transport. On the other hand, the producers of the northern highlands are nearly all peasant farmers of three indigenous Mayan groups: Tzotzils, Tzeltals and Cho'ls, most of whom have only been freed from indentured labour on German owned *fincas* in the past 30 years. Despite some technological advances in the past 15 years their production systems can still be described as generally "rustic", compared with the modern, capital intensive methods practiced in the Soconusco.

Coffee and Agrarian Change in the Northern Highlands

The development of coffee production systems in the northern highlands has been a rather erratic process. The Mexican *haciendas* established in colonial times reached their peak during the Porfirian regime (see 2.3.4) but in the revolutionary years that followed, when the state saw more than half its male population lost to war and disease,(Brading, 1980 and Knight 1987) coffee production and agriculture in general collapsed. In Chiapas it was the *ladino* landowners (*latifundistas*) who won the (1910 - 1920) revolution (Rus, 1990). Despite sporadic interventions by Federal governments in the '30s and '50s most large holdings remained intact. However, this situation did not prevent many local indigenous peasants from pressuring landowners with the threat of invasion or sabotage. In the northern highlands in particular, the growing population of Cho'ls was further swelled by Tzotzil and Tzeltal migrants form the Central Plateau. In the context of mounting agrarian pressure the landowners of the northern highlands were loath to invest in agriculture whilst relatively secure and higher returns were to be found in the rapidly industrialising cities or overseas.

The transition of the northern highlands plantation agriculture from *ladino* to indigenous peasant ownership has occurred in a piecemeal fashion since the 1930's. Each indigenous community has a different story to tell (Unión Tierra Tzotzil, 1990). Some villages moved into unoccupied, uncultivated territory, some were founded as a result of indentured labourers taking over the plantations that they worked on, some were allocated land by the government's *Reforma Agraria* and a few bought land from owners who decided to cut their losses and vacate the countryside. In some areas of the northern highlands a few *haciendas* remain, though only one, the *finca* Morelia, has retained more than 1000 ha. Disputes, both between and within communities, over land ownership remain frequent and outbreaks of violence are not uncommon. It is therefore not surprising that until the 1970's (and in some places even today) the question of land ownership rather than production and productivity has been the principal preoccupation of farmers and government alike.

The Coffee System

Coffee (*Caffea arabica var.*) is a perennial shrub that originates from Northeast Africa and Madagascar. In its natural habitat coffee is an understory plant of 3-4 metres height, found in upland forests with seasonal rainfall. It is well adapted to the climate and soils of the northern highlands of Chiapas, where it is normally grown under medium to heavy shade. This is provided either by remnant forest species or artificially grown shade trees, mainly the Chalum (*Inga spp.*). Coffee annually produces a burst of snow white gyneacious flowers at the end of the dry season (May - June). Once fruit is set it matures for 6-7 months before turning red as it ripens at harvest time December - February). Most of the cultivation methods employed by the peasant farmers of the region are derived from techniques introduced by the colonial coffee growers. These involve control of the shade trees and the vegetative growth of the coffee by pruning, weeding by machete, and plantation maintenance (re-planting of old stock and sanitary pruning of diseased wood). More recent techniques such as the application of mineral fertilisers and fungicides are also employed. (A more detailed description of the coffee systems of Chiapas, and their development, is provided in Appendix 4.

Recent Technological Developments and State Intervention

In 1976, the Mexican government in the form of INMECAFE, initiated a programme for the intensification of coffee production in several areas of Mexico including the northern highlands of Chiapas: "El Programa Naciónal Contra la Roya". *La Roya* (coffee rust disease - *H. vastatrix*) had spread from South America into Southern Guatemala and was expected to arrive in Chiapas by the early '80s. It was thought that this defoliating disease would make coffee production at less than intensive levels uneconomic: there were no resistant varieties at that time, and in order to cover the costs of purchase and application of fungicides, farmers would have to expect a substantial level of production.

INMECAFE developed "technological packages" of inputs at its experimental station in the Soconusco. These consisted of a new variety; Garnica (a high yielding dwarf), fertiliser and herbicide inputs, and recommendations for pruning, shade control and the renovation of old coffee plantations. The potential benefits of the new system were calculated on the basis of the results from trials at the experimental station. The technical package was then promoted by technicians and extension agents who made visits to communities and arranged for the delivery of inputs at subsidised prices.

No study was ever made of the results of these efforts in terms of rates of adoption of the new package (or of components of the package) and of the costs and benefits to farmers arising from adoption. However, there was general dissatisfaction with the results of the technical programme. Much of this dissatisfaction centred on the poor performance of INMECAFE's Garnica variety which gained a poor reputation by reverting to its parental types.

In the 1980's INMECAFE turned its efforts away from technical assistance towards commercialisation. The government realised that small coffee growers often received only a fraction of the value of their product due to the oligopsony of intermediaries. The technical programme continued but sporadically. It was argued that farmers could not be expected to adopt modern technology if they were not paid proper prices. Government intervention in the national coffee market was only partially successful (see 2.3.4) and in 1991 INMECAFE was dissolved by government decree.

A few cooperatives and unions have established their own technical programmes (Unión de Uniones Quiptik, 1988). Initially, in the early '80s, they depended on the technical leadership of INMECAFE. With subsequent experience they have also gathered ideas from a variety of sources including commercial growers in Puebla, the Soconusco and Central America. The activities of farmers organisations appears to have accelerated the diffusion of technical knowledge around the northern highlands.

Current Knowledge About Coffee Systems in N. Chiapas

Despite the obvious importance of coffee production both as a component of the economy of Chiapas and of the farm households in the region there has been no published study of the techniques employed on these small farms. Similarly, the inputs of labour, land and capital relative to the outputs obtained from these systems are hitherto undocumented. Furthermore, the adoption of new coffee growing technology, or the impact of these methods on the small-scale farming systems of the region, have not been investigated.

# 3 The Methods Used

## 3.1 The Systems Approach

The study of agricultural production from a systems perspective was spearheaded by Spedding (1976 - 1985), as editor of the journal *Agricultural Systems*, and Dillon (1976), who drew heavily on the contributions of Ackoff (1973) to systems research. Numerous studies have since been undertaken along these lines. Mathematical modelling techniques have frequently been used to analyse or simulate agricultural systems (for example: Soybean system modelling - Wilkerson *et al.* 1983; Jones *et al.* 1988; and Nagarajan *et al.* 1993. Models of Leptospirosis in Dairy herds - Bennett, 1993. Irrigation Planning Models - Millan & Berbel, 1994), and have been important in the development of agricultural systems studies. In fact, some agricultural systems simulation pre-dates Spedding's 1976 work. (Anderson & Dent, 1972; and McGregor 1971). Not surprisingly, there has been an emphasis on the development of models that will provide decision-support for farmers or farm policy makers. However, as most agricultural systems models are based upon the current state of scientific knowledge about the biological components (e.g. crop physiology) of the systems, and as scientific knowledge about many of these biological components becomes increasingly detailed, the models are necessarily complex. To cope with complexity, models are therefore generally used to analyse specific components - such as pest plant interactions, or plant growth, or particular aspects of farm operations (Glen, 1987). Most farm planning models aim to provide specific "optimum" solutions to defined technical problems, albeit taking into account some stochastic elements such as soil moisture variability. In application to the improvement of farming methods (and particularly in developing countries) such modelling approaches tend to produce rather prescriptive "Top Down" messages - for example Thornton and Hoogenboom (1990) proposed that a large-scale model combining crop growth, edaphic, climatological and social components could provide recommendations to Guatemalan peasant farmers in their choice of seed type and planting date. Fewer models have been based upon empirical knowledge (an exception is Hackett (1991) who used a model to integrate empirical knowledge about lesser-known species of crops to predict growth), and less effort has been made to use models as a way of testing knowledge about a system or integrating information from different sources (such as "local" and "expert"). The importance of this aspect of modelling was highlighted by Kent *et al.* (1991) and Johnson (1987) when describing their experience of developing the USDA Forest Service FORPLAN, a large-scale linear programming system used to support national forest land management planning. FORPLAN was used extensively to help interdisciplinary planning teams to develop forest-wide plans as dictated by the National Forest Management Act of 1976. Johnson stated that:

> "FORPLAN is one tool in an internal cleansing.. of the professional beliefs and tenets that have guided the national forest management from its inception. It is part of the attempt to prevent professional groups within the forest, especially foresters from imposing their objectives for management of the forest on the rest of humanity".

The use of models to explore, rather than optimise, complex systems has been more in evidence in the field of ecology. Robertson *et al.* (1991), and Muetzelfeldt, (1986 & 1991) emphasise the important role of models in integrating, comparing and evaluating knowledge about ecological systems from different sources.

The use of modelling techniques to integrate, compare and explore sets of knowledge requires the modeller to have a framework on which to base the systems analysis: boundaries, system structure, units of measurement, meaning of words used to describe events, objects and processes, should be defined and justified. Soft Systems Methodology (SSM), developed by Checkland (1984) and further elaborated in Checkland (1988, 1990 and 1991) provides such a framework.

Checkland (1991) describes SSM as an iterative process, involving structured thought at a number of abstract (meta) levels, beginning with the concept (derived from the perceived world) of the system as a *holon*. The core system attributes[1] (ideas) are those of emergence, hierarchy, communication and control. The concept of the holon, at the most abstract level, leads on to the ideas of holonic processes,

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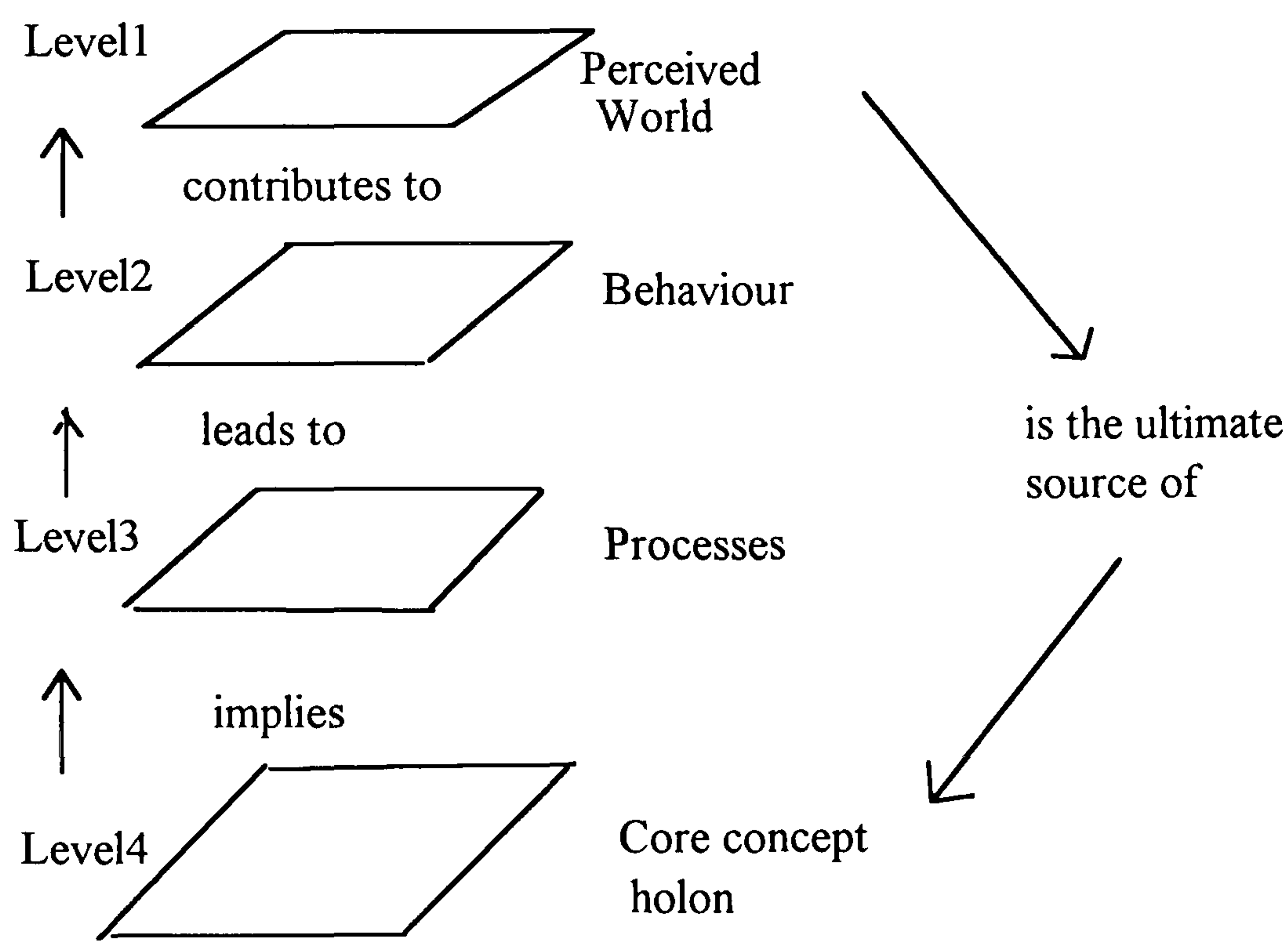
[1]Checkland defines these ideas as follows: emergence (the existence of properites meaningful only at the level of a whole), hierarchy (a layered structure in which wholes may contain sub-wholes), communication and control (processes enabling adaptive action to be taken in response to environmental shocks).

such as feed forward and feedback, at the next meta level. These processes are implied by, but are less basic than emergence, hierarchy, communication and control. The processes conceptualised as taking place in a holon will themselves lead, at the next meta level, to the behaviour of the holon as an entity. This might include such phenomena as growth, decay, equifinality or goal-seeking behaviour. Such behaviour, at the next meta level will help to constitute our images of the perceived world. This explanation of the epistemology of SSM is summarised in Figure 3.i. Applications of SSM have mainly concerned the analysis of social systems, and complex "real world" problems, involving qualitative relationships that defy conventional mathematical modelling.

**Figure 3.i The epistemology of Soft Systems Methodology** (From Checkland,1991)




However, the methodology used in this study differed significantly from the conventional application of SSM by employing quantitative modelling techniques (in place of purely qualitative techniques of Rich Pictures, the CATWOE mnemonic, and Root Definition Models) to explore the behaviour of the peasant farming systems at Checkland's 2nd meta level (see Fig.3.i). The application of quantitative (hard) modelling techniques within the SSM domain was foreseen by Checkland (1984, p16), but was not elaborated:

> "..it is if course the case that the activity system conceptualised may require for its internal functioning models of other kinds- linear programming models, depot location models, or models of operations built using the 'systems dynamics' language."

More recently, Strain (1990) pointed out that the SSM used by Checkland contained little provision for making concrete and quasi-experimental realisations of the conceptual models, and suggested that techniques such as simulation modelling might enhance the relevance of SSM in areas where social systems interact with mechanical systems. In the case of the peasant farm, the *holon* includes social systems interacting with technical and biological systems. Theoretically, any hard system model type could be utilised within the soft system framework. In practice however, it is desirable to use simple model structures that illustrate the main features of the holon under consideration, because transparency can be retained and problems due to variable data quality can be more easily handled. To explore complex ecological systems Muetzelfeldt (1991) has chosen to use relatively simple compartment-flow type models in preference to more traditional integration techniques. These emphasise the significance of the structure of ideas about a system, rather than merely the inputs, conditions and outputs of the modelled system. In the context of the decision-making peasant farmer, it was decided to use a linear programming (LP) approach. LP can readily reflect key the features of the peasant farm *holon*, as viewed by the researcher in the field (See section 3.4.1). The human activity system (*holon*) consisted primarily of: (i) a motivated decision maker (in the sense that the farmer has to make the "best" use of what is available), (ii) limited resources for production, and (iii) finite alternative ways of combining (using) those resources to provide food and income. At the most basic level, a simple 2D or 3D LP "solver" made from graph paper, a box and string can be utilised to explore these systems, to teach the fundamentals of systems thinking, and encourage its application in this field. (The actual modelling techniques applied in this study are described in sections 3.4.2 - 3.4.7). Spedding (1976) appears to have anticipated this approach in his preface to the 1st Volume of the journal *Agricultural Systems*, when he stated:

> "Mathematical model-building offers new dimensions in aids to decision-making and comprehension by harnessing the power of computers to deal with the complexity of large

systems. However, model-building in its widest sense will also help in assisting the human mind to comprehend these complex systems but it is important to recognise that it is only assistance that is being rendered. Ultimately, we depend upon the mind grasping the essentials of the systems that are to be operated, improved or chosen, and we are concerned to develop a methodology that will help in conception as well as in the detailed clothing of the initial framework."

### 3.1.1The Soft Systems Framework

Table 3.1 sets out the various stages of the study: fieldwork, data analysis and modelling, through which the soft systems methodology was applied. The details of the methods used in each stage are described in the following sections.

**Table 3.1 Methodological Stages of the Study**

| Phases of the Study | Stages within the SSM Iterations |
|---|---|
| 1. Initial contact with the systems through work experience in the area (1987-1988) | Initial perceptions of the nature of peasant farming systems, and the associated environmental, political and economic systems. |
| 2. Review of literature and theoretical models of peasant farming systems (1988 - 1989) | Revision of initial perceptions and posing of questions in the light of theoretical models. |
| 3. Ist Fieldwork Period within Study (1989):<br>(i) Close contact with, and observation of a small number of farmers.<br>(ii) Discussions and semi-structured interviews with farmers' leaders, extension agents and technical experts.<br>(iii) Collection of data and information on the key parameters of production systems.<br>(iv) Working with farmers on cooperative reforestation projects. | Study of system processes, and system participants |
| 4. Data Analysis and Systems Thinking (1990-1991):<br>(i) Determination of trends and relationships.<br>(ii) Definition of systematic representations of agricultural problem situations. | Meta- modelling of system processes at levels 2 and 3 of Checkland's epistemology (Fig. 3.i) (prototype models) |
| 5. 2nd Fieldwork Period within Study (1991):<br>(i) Farm surveys and questionnaires | Relation of system processes to system behaviour (as above, levels 2 and 3) |
| 6. Systems Analysis (1992-1993):<br>(i) Development of models of the above problem systems.<br>(ii) Exploration of the problem system by flexible use of models. | Meta-modelling of system behaviour (level 2) |

## 3.2 Fieldwork

### 3.2.1 The Action Research Approach

The methodological approach of the fieldwork study was action research based. The author became involved, in an advisory capacity, with the technical development programme of a peasant organisation the Unión de Credito Pajal Ya Kac' Tic (1.1.1). During the course of the fieldwork the author was also responsible for several training courses for extension agents and the operational requirements for a programme of re-afforestation.

Action Research

Foster (1972) attributed the origin of action research to Kurt Lewin's view (Lewin, 1967) of the limitations of studying complex real social events in a laboratory. Lewin highlighted the artificiality of isolating single behavioural elements from an integrated system. Lewin's Field Theory regarded any observed behaviour (by a subject) as the outcome of a large number of factors, including the interaction between the subject and the observer. The involvement of the researcher in the "action" processes is therefore fundamental to Foster's formal definition of action research.

> "A type of applied social research differing from other varieties in the immediacy of the researcher's involvement in the action process and the intention of the parties, although with different roles, to be involved in the change process of the system itself. It aims to contribute both to the practical concerns of people in an immediate problematic situation and to the goals of social science by joint collaboration within a mutually acceptable framework."

In action research the roles of subject and researcher can sometimes be switched (Clark, 1972). The researcher may become an actor and the subjects become observers, in a mutual examination of the system and the possibilities for change. An obvious implication of this approach to research is the limited scope for pre-planning methods and outputs of the investigation; these will depend upon the paths that open up as the investigation into the particular "human activity system" proceeds. The application of action research, guided by systems concepts, was pioneered by Checkland and Jenkins at

Lancaster University in the 1960's and 1970's (Checkland and Jenkins, 1974).

Action Researching in Rural Mexico

A major factor in the collection of data from small farms in indigenous areas is the difficulty of access to communities; both physically (time to travel especially in rainy seasons) and socially; farmers tend to be suspicious of outsiders and therefore reluctant to divulge information, the use of which is unlikely to benefit them personally. The author's introduction to the communities studied was provided by the Unión de Credito Pajal Ya Kac' Tic. By working with the Unión on several projects, such as training courses[2] and a re-afforestation programme the author was not only provided with a pretext for visiting these communities but was also seen to be working for the farmers. He was therefore able to talk with them in some confidence. Data arising from the execution and monitoring of the above projects was also available to the author. The author also took time to stay with a limited number of farm families to observe and participate in agricultural tasks. It was found that the most effective means of obtaining detailed insights into the economics of peasant production was to work alongside farmers on their own land (Richards, 1985). Nine months in 1988 and several days of each month in 1990 were spent working in *milpa* and coffee plantations in the communities of San Miguel and Alvaro Obregon in the Tzotzil zone and Rio Grande in the Cho'l zone. Points raised in informal discussions with individual farmers while working during the day were verified and elaborated with groups of farmers in the evenings. These interactions with farmers and the farmers' organisation allowed the author to employ a number of investigative techniques. These methods were integrated in to the general project cycle within the union's overall programme (Table 3.2) and involved contact with individual farmers, community leaders, groups of farmers and technical advisers.

1. Training courses provided excellent forums for the exchange of information about production systems. Courses for young farmers in elementary soil and plant science were run in a tutorial style at various times during the study period (1.1.1).

**Table 3.2 Investigative Field Techniques Employed and Context in Action Research.**

| Techniques | Context in Action Research Cycle |
|---|---|
| Direct observation of farming practices and extended conversations about peasant life and work | Working alongside farmers (to define the nature of problem situations faced by farmers) |
| Semi-structured interviews and discussions with individuals and groups. Hand drawn land-use maps and transects | Visits to communities (to determine the extent of problems and examine possible improvements; mobilise interest) |
| Detailed discussions about problem parameters and possible improvements | Training courses (to develop improvements to the problem situation and define further information requirements)<br><br>Contact with innovative farmers (to review local methods for coping with problem situations) |
| Formal questionnaires and quantitative surveys (see Appendix 8) | Official union surveys (to determine quantitative parameters of problem situations and monitor improvements) |

A particularly important group of informants was a small number of exceptionally resourceful and innovative farmers[3], with whom the author established contact during the course of fieldwork. These farmers contributed many ideas to the development of the systematic concepts of the "production problem situations" used in the modelling sections of the study (Chapters 6 & 7). They also provided baseline data for model parameters.

Whilst the author was provided with excellent access to informants and data, his involvement in the projects did also act as a constraint on the time available for conventional investigative activities. Collaboration with the union also influenced the communities that were included in the study. All the communities, apart from San Juan Chamula and Zinacantán had inhabitants who were active participants in the union. As the union wished to include as many communities as possible in its surveys (10 villages were included in *milpa* survey and 39 in the coffee survey) it was only possible to collect detailed data from two or three farmers in each community, given the constraints on time and manpower. Furthermore, by working in this mode the author recognises that his view of the overall rural situation and interpretation of events must have been strongly influenced by those with whom he worked.

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[3] Profiles of three selected innovative farmers are given in Appendix 8.

The fieldwork was organised into three related study areas; (1) the economic and social context of technical change, (2) land use at village level, (3) subsistence production (*milpa*), and (4) coffee production. The field methods used for each study area are described in sections 3.2.2 to 3.2.5.

### 3.2.2 The Field Study of the Economic and Social Context

The study of economic and social determinants of technological change in Chiapas was based on case studies of four locations. (1) San Juan Chamula and Zinacantán, (2) San Miguel, (3) Coquija and (4) Yaluma. These case locations were chosen to represent some of the diverse social, cultural and economic conditions that are to be found in the region. Information was collected during visits to these communities, from 1989 to 1991. Some of the results were obtained by direct observation, others from conversations with farmers, community leaders, traders and officials.

### 3.2.3 Field Study of Land Use at Village Level

Hand drawn maps and transects showing the use of land, soil conditions and particular agricultural problems within the 39 communities studied were produced. The procedure for constructing the maps and transects was as follows:

(1) A guided tour of the community lands with one or two farmers to point out the boundaries and explain the division of land between villagers. This was usually carried out in the mornings.

(2) Production of initial sketches of the community boundaries, particular features and the topographic transect.

(3) Compilation of additional information, such as land use and soil types, onto the maps in the context of a gathering of a small group of farmers after work in the afternoon or in the early evening.

An example of a map and transect are provided in Appendix 3.

### 3.2.4 The Field Study of *Milpa* Production[4]

Interviews and questionnaires (see Appendix 7) were conducted with 27 farmers in 10 villages from May to August 1990. This supplemented information gathered by working alongside selected farmers in the region periodically, from 1989 to 1991. Data collected in the field was then used to analyse the process of technical change in Tzeltal *milpa* agriculture from extensive swidden (slash and burn) to non-burning, continuous cultivation.

The survey was carried out in cooperation with a local group of farmers interested in promoting non-burning techniques of maize production. Data collection was greatly assisted by two native Tzeltal representatives of the Unión who were well known to the villagers. This allowed us to conduct many of the interviews in Tzeltal; as a result, farmers were keen to participate and talk openly about their *milpa*s.

<u>Selection of Sample Farmers</u>

The selection of farmers to be interviewed was made by villagers at each location, who were asked to select 3 individuals representative of the village. Whilst recognising that this means of interviewee selection might not be statistically ideal (see 3.2.6 Representativeness) it was considered both desirable and necessary to obtain the sanction and involvement of the communities in the analysis of local problems. Since the distribution of land within these communities was quite even, the emergence of social stratification was not thought to be a major influence. The sample included 6 new entries into farming; mostly young men who received either an allocation of *ejidal* land or inherited land during the period 1984-89.

The communities included in the study were all in the municipality of Chilón, Chiapas. They are named in the table below (Table 3.3), along with the sample numbers for each farm visited.

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4 The results from this field study are presented in section (4.3).

**Table 3.3 Communities and Corresponding Farm Sample Numbers**

| Community | Sample Number | Community | Sample Number |
|---|---|---|---|
| Chich | 1,2,3 | Jolcacuala | 15,16, |
| Tiaquil | 4,5,6 | Tianchibil | 17,18 |
| Alan Cantajal | 7,8,9 | Alan Cacuala | 19,20,21 |
| Pactium | 10,11,12 | Mango Limonal | 22,23,24 |
| Chapullil | 13,14 | Guadalupe Paxilja | 25,26,27 |

Data Collected in the Survey

The following data and information was collected in the survey questionnaire (see Appendix 7):

·Length of rotations mainly used 1984-86.

·Length of rotations, if different, 1987-89

·Fertiliser use 1984-86.

·Fertiliser use, if different, 1987-89.

·Adoption of non-burning cultivation 84-89.

·Use of herbicides 1984-86.

·Use of herbicides, if differeent, 1987-89.

·Calendar of labours, with man-days required for each task.

·Yields obtained from 1987-1989.

·Time saved by herbicide use.

·Farmers' general experiences with non-burning cultivation.

·Farmers' opinions of sources of information on innovations.

·Opinions of main constraints on production improvement.

Farmers were also asked more general questions arising from their reponses to the questionnaire; such as, why did they think that yields had changed or why did they favour certain techniques.

Evaluation of Sources of Information about Innovations

Farmers were asked how they had heard about innovations such as fertilisers, herbicides and non-burning cultivation and what convinced them to use them. They were also asked about which of the various sources of information about new methods were most believable: neighbours, extension agents, radio broadcasts, vendors, and others.

Obstacles to Future Productivity Improvement

In an open question farmers were asked to explain what were the main obstacles to the improvement of their *milpa* production.

### 3.2.5 Field Methods Used in the Study of Coffee Production[5]

Data was collected in the field between from February to October 1991 by group interviews and structured questionnaires with farmers (see Appendix 7). This supplemented information gathered by working alongside selected farmers in the region periodically, from 1989 to 1991. A total of 108 farms were covered, representing 39 communities in the Cho'l, Tzeltal and Tzotzil zones of the northern highlands of Chiapas were covered in the survey. (Appendix 2 contains a list of communities and the corresponding names of farmers interviewed). Unfortunately, as a result of time constraints the coverage of the Tzeltal and Tzotzil areas (9 and 8 villages respectively) was less extensive than the Cho'l area (22 villages). The method of selecting interviewees was the same as in the *milpa* study (3.2.4). As with the *milpa* study, the collection of data was greatly assisted by indigenous fieldworkers provided by the Unión. The study sought both qualitative, descriptive information and quantitative data about the coffee production system:

Descriptive Information

The following descriptive information was derived from observations and discussions with farmers and visits to a number of communities:

(1) Description of plantation types found on peasant farms in the northern highlands of Chiapas (Appendix 4).

(2) Description of the agricultural tasks in coffee cultivation systems of the northern highlands of Chiapas (Appendix 5).

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5 The results from this field study are presented in section (4.4).

Survey Data Collected

The following data was collected from each household covered by the survey (see Appendix 7):

Plantation characteristics:

- Size of plantation
- Shade type and level
- Varieties of coffee, age profile and interplant spacings
- Condition of coffee bushes (sanitary, vegetative growth)
- Weed control
- Level of fertilisation
- Degree of renovation and re-planting

Labour and cash inputs

- Labour inputs to weeding, pruning, shade control, fertilisation and sanitary measures, and harvesting
- Post-harvest inputs to wet processing and drying

Cash inputs to fertilisation and transport

Outputs

- Yields and farm-household production for the years 1987-89

Information about the inputs required for plantation improvement was also requested from farmers who had experience of implementing more intensive methods.

### 3.2.6 Some Methodological Problems Encountered in the Field

Errors of Measurement

Incorrect estimates and measurements by farmers were a potential source of errors in the field data. Few farmers posses scales for measuring production or equipment for surveying plantation areas. However, the author was impressed by the skill of peasants at estimating of amounts (*e.g.* the number of seeds in a heap, weights and areas - they often play estimation games). Furthermore, produce is weighed at the point of sale and farmers are often excellent at memorising these figures; an important attribute considering that many are unable to read or write.

Deliberate Errors

Some farmers may not wish to reveal true figures: they may feel threatened or ashamed of declaring low performance or feel worried that other villagers will be suspicious of high performance. (They may suspected of witchcraft or some other trickery). Farmers may simply be uninterested or unwilling to cooperate in the investigation. (This is not particularly surprising as there is rarely any motivation or short term benefit to be gained from cooperation) With some experience it is possible to detect these problems. One extreme example, of a group of villagers who obviously did not wish to cooperate with the investigation occurred when the author was informed that they had all harvested exactly the same amount of maize from their *milpas*.

Representativeness

It is very difficult to prove that the farmers questioned were representative of the zones studied. As a result of the author's relationship with the villagers and the limited time available for the study it was not possible take a completely random selection of farmers. Instead, at village meetings, the assembled group nominated two or three representative[6] farmers. This method of selection may have led to the under-representation of the extremes of richer and poorer farmers. Furthermore, the assembled farmers were all those who were in some way motivated to participate in communal projects, they were also nearly all male, over the age of 17 and therefore not necessarily representative of the whole community. (Whilst women were not represented in the survey, it is the men who are the principal decision-makers in matters relating to the principal subsistence and cash crops). The communities chosen for the study covered a large area and appear to be geographically representational of the zones, as defined. However, the communities were all in some way connected to the Unión de Uniones or the Unión de Credito Pajal Ya Kak' Tic. As the Unión has delivered various technical and financial inputs over the past ten years and the farmers in these communities have some experience of successful cooperative activity it might

[6] Groups were asked to pick individual farmers who were "typical" of and the general conditions, and problems within the community.

be expected that there would be some differences between the communities studied and others in the same geographical regions.

### 3.2.7 Unmeasured sources of variation in field studies

Site Differences

It was not possible to measure micro-climatic, edaphic or biological differences between farms. In the broken terrain of the Cho'l and Tzotzil zones these are likely to be important sources of variation to input : output ratios of production systems. Some important factors in coffee production that vary from site to site are (a) potential frost damage, which is related to the altitude and aspect of a given site (b) disease damage is also related to altitude (damage is worse at lower altitudes), climate (mist and light drizzle favour spread) sources of infection and the direction of prevailing winds.

Quality of Work

Labour applied to coffee stands was measured quantitatively (man-days). Differences in the skill or thoroughness in the tasks undertaken was not measured. Clearly the skill with which task such as pruning, shade control, replanting technique and fertilisation are undertaken have major effects upon the yield of individual coffee plants.

Sub-Plot Differences (Micro-Management)

The study did not take account of management of sub-plots within farmers' plantations. While some farmers carry out labours uniformly across their plantations others modify small patches of land, perhaps by planting a different variety at a different spacing, or possibly by interplanting with bananas or some other fruiting shade tree. Sub-plot management may be an important feature of overall farm performance. Some notable cases of sub-plot management were noted (Appendix 8). This subject should be considered an area for future investigation.

## 3.3 Analytical Methods

### 3.3.1 Analysis of Technical Change in *Milpa* Agriculture

Evaluation of Rotations

The determination of the length of rotations in *milpa* cultivation was not as straightforward as anticipated. The length of rotations (R) was calculated as follows:

R= *Total amount of land available for cultivation / Hectares cultivated each year*

Then, cross-checking that;

R= *Number of fallow years per cultivated year for each area*

Unfortunately, there are a number of difficulties in the calculation of the length of rotations used by a farmer at any particular time. Firstly, the length of time that any given plot of land is left fallow is not usually planned in advance and secondly, not all land is cultivated with the same frequency. Instead farmers tend to selected areas of land for cultivation using several criteria: (1) the types of weeds growing are indicative of the fertility of the fallow and whether it is ready to be cultivated; (2) the greater the distance of the plot of land from the homestead, the less frequently it will be used and farmers will also tend to use more inputs on nearby plots; (3) the steeper the slope of the land, the longer it will be left fallow.

Rotation length may decrease for several reasons: (a) decrease in the total land allocation to *milpa*, (b) increase in area of land sown each year, (c) shorter fallow periods, or (d) longer cropping periods. Each of these may change from year to year due to variations in family food requirements, the amount of labour invested in self sufficiency and the amount of land and labour given over to cash cropping (coffee production).

For these reasons three simple ranges were chosen: (1) long rotations, where less than 1/5 of the land available to *milpa* is under cultivation each year (>5 fallow years to each cultivated year); (2) medium rotations, (thought to be a transition phase) where more than 1/5 but less than 1/2 of the available land is cultivated each year (1-4 fallow years to each cultivated year); and (3) short rotation or continuous cultivation, where more than 1/2 the land is under cultivation each year (<1 fallow year to each cultivated year).

After describing their current rotation method farmers were asked whether, and in what way this was different prior to 1985.

Evaluation of Fertiliser Use

A similarly simple scale for fertiliser use was used owing to the variation, from year to year of fertiliser supplies and available capital. Three ranges were specified: Non users; Occasional users; and Regular users.

Evaluation of Non-Burning Adoption

It was fairly easy to determine whether burning or non-burning was the predominant cultivation technique used. However, we found that the two methods were not necessarily mutually exclusive. During questioning it became apparent that some farmers had tried non-burning techniques on small plots of land (usually prior to more general adoption). Also, some of the farmers committed to non-burning occasionally used fire to help clear particularly overgrown areas.

Analysis of Technical Practices

Farmers were grouped into eighteen categories, according to the length of rotations, the amount of fertiliser used between 1987-1989 and whether they used burning or non-burning cultivation (Table 3.4).

**Table 3.4 Possible Categories of Farmers According to Rotation, Fertiliser Use and Cultivation Criteria.**

| **Rotation** | **Fertiliser use** | | |
|---|---|---|---|
| | None | Occasional | Always |
| Short | B or [NB] | B or [NB] | B or [NB] |
| Medium | B or [NB] | B or [NB] | B or [NB] |
| Long | B or [NB] | B or [NB] | B or [NB] |

B= Burning cultivation, NB= Non Burning Cultivation.

Analysis of the Results of Change

To estimate the effects of technical change upon agricultural productivity in the area (a) the average yields of maize from 1987-89 and (b) the average changes in productivity during this period were calculated for each category. Farmers' estimates of seasonal labour requirements, were also grouped according to the above categories.

### 3.3.2 Analysis of Technical Change in Coffee Production

Description of Agricultural Labours

The inputs of labour to the coffee system, were divided into the following categories:

1. Production labour: All the labour applied to production prior to harvesting, and therefore, representing an annual investment. Production labour can be divided into (a) annual cultivation labours that have a direct effect on the following harvests (as coffee is a perennial crop cultivation tasks such as fertilisation and weeding often have a greater effect on the second years' harvest than the first); and (b) plantation improvement labours, which represents a longer term investment as the replacement of old trees takes about 4 years until yields show an improvement.

2. Harvesting and Processing Labours: These represent the realisation of the production labours; for the amount of labour required to harvest the crop will depend on the amount of labour that was invested in production.

Characterisation of Plantation Types

As a measure of the level of technological development applied to coffee plantations producers were grouped into three categories, according to the state of their plantations. These plantation categories were defined by a number of technical parameters (see Table 3.5). For a more detailed explanation of the development of different types of coffee plantation in Chiapas see Appendix 4):

**Table 3.5 Categories of Plantation Types and Determinant Characteristics**

| |
|---|
| Group 1. Rustic plantations<br>These stands of coffee are covered with natural shade trees or unpruned *Inga* Spp. Old (>10 years old), tall growing varieties of coffee predominate (Typica, Mondo Neuvo, Bourbon and Maragogipe). The bushes are planted at low densities ususally 800-1300 (> 2.8 m between plants) per hectare. |
| Group 2. Transitional plantations<br>These stands are transitional between group 1 and group 3. In the Cho'l zone, where the largest number of farmers were questioned this group was divided into two sub-groups: (a) those who were in the process of improving their rustic plantations by replanting, pruning and shade regulation and (b) those who were allowing a previously advanced plantation to decline, through neglect (or concentration upon another activity). |
| Group 3. Advanced Plantations<br>These stands were covered by low levels of shade provided by regularly spaced, shade trees (*Inga* Spp). Young (<10 years old), short growing varieties of coffee predominate. (Caturra, Garnica, Catuai). The bushes are planted at densities above 1300 plants per hectare. |

Inputs and Outputs of Coffee Systems in the Three Zones

The inputs of land, labour and cash to coffee systems in the Cho'l, Tzeltal and Tzotzil zones were compared. The number of farms in each plantation category were also compared, along with the outputs in terms of harvested yields and income.

Analysis of Productivity

The productivity of the coffee system was calculated in relation to a number of parameters:

- Average production per household in each zone (1987-89)
- Average yield per hectare in each zone (1987-89)
- Average income per household from coffee (1987-89)
- Productivity in relation to plantation type
- Productivity in relation to labour invested
- Marginal productivity of labour invested[7]

he economics of plantation improvement were examined by comparing the effort required to transform a rustic plantation to an intermediate or advance level with the increased returns from the improved stand of coffee.

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7 Curves were derived by Linear Regression and Correlation and also by Polynomial Regression: average yields from 1987-89 was plotted against the amount of labour expended per hectare in coffee cultivation.

## 3.4 Systems Modelling

### 3.4.1 Building a Conceptual Model of a Peasant Farm, using SSM

As outlined in section 3.1, SSM techniques for building conceptual models (Checkland, 1985, p286) were employed to determine an appropriate framework for the exploration of system behaviour, by *harder* modelling techniques (these are justified and described in sections 3.4.2 - 3.4.7). SSM was chosen as an appropriate initial stage in the overall systems analysis as it has been designed for, and applied to, the analysis of "human needs centred problems" (Checkland, 1985). The following soft system model of a human activity system contains a set of activities (described by verbs) connected together. The model contains the minimum number of verbs necessary for the system to be the one named and concisely decribed in the *root definition*. These are connected together in order to represent the system as an entity by using arrows to indicate logical dependencies. Where it seems essential to represent a flow (of energy, materials, money etc.) different arrow forms are used.

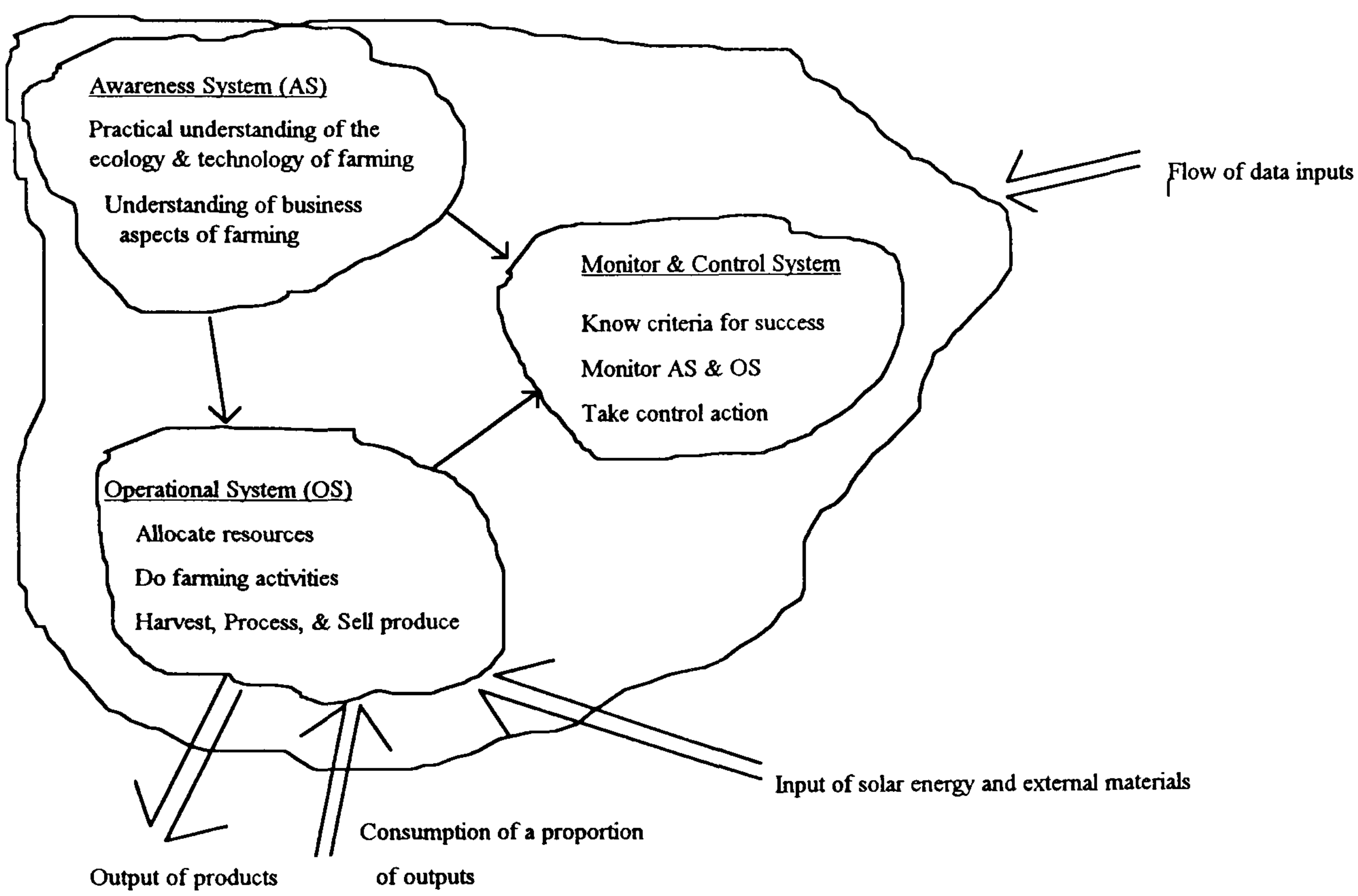
The Root Definition (RD) of a Peasant Farm

> An indigenous peasant-manned, and owned system concerned with the management of scarce labour, land, biotic, aquatic and cash resources, that are required to transform incident solar radiation and agricultural inputs into plant and animal products. By this management the system should provide the long-term security (in terms of food, shelter and other commodities) required by its owners.

The CATWOE mnemonic is used to test and clarify the RD. The task is then to build the conceptual model implicit in it. The basic transformation (T) which this system brings about is evidently to take in energy from the sun, and external inputs such as fertiliser, and to transform these, using existing knowledge and new information (both technical and economic) into useable (saleable, edible, workable, wearable) products, that satisfy the needs of the owners (O). This transformation also requires energy inputs in the form of work by the owners and any hired labour, who together form the actors (A), mentioned in the RD. This energy must be provided by outputs from the system itself. The members of the *farm family* are clearly also the system's beneficiaries or victims (C). The environmental constraints (E) in this case are complex, and include the constrained availability of resources, the biological processes such as the photosynthetic potential of the various crops available, the legal, political and market constraints on the farmer's activity - that determine the availability of certain inputs such as credit and fertiliser, the potential expansion of the available land resource and the cash value of given products, and also the consumption requirement of the farm family. The *Weltanschauung* (W) implicit in the RD involves the peasant's indigenous traditions, knowledge and experience, and encompases parameters such as the farmer's attitude to risk.

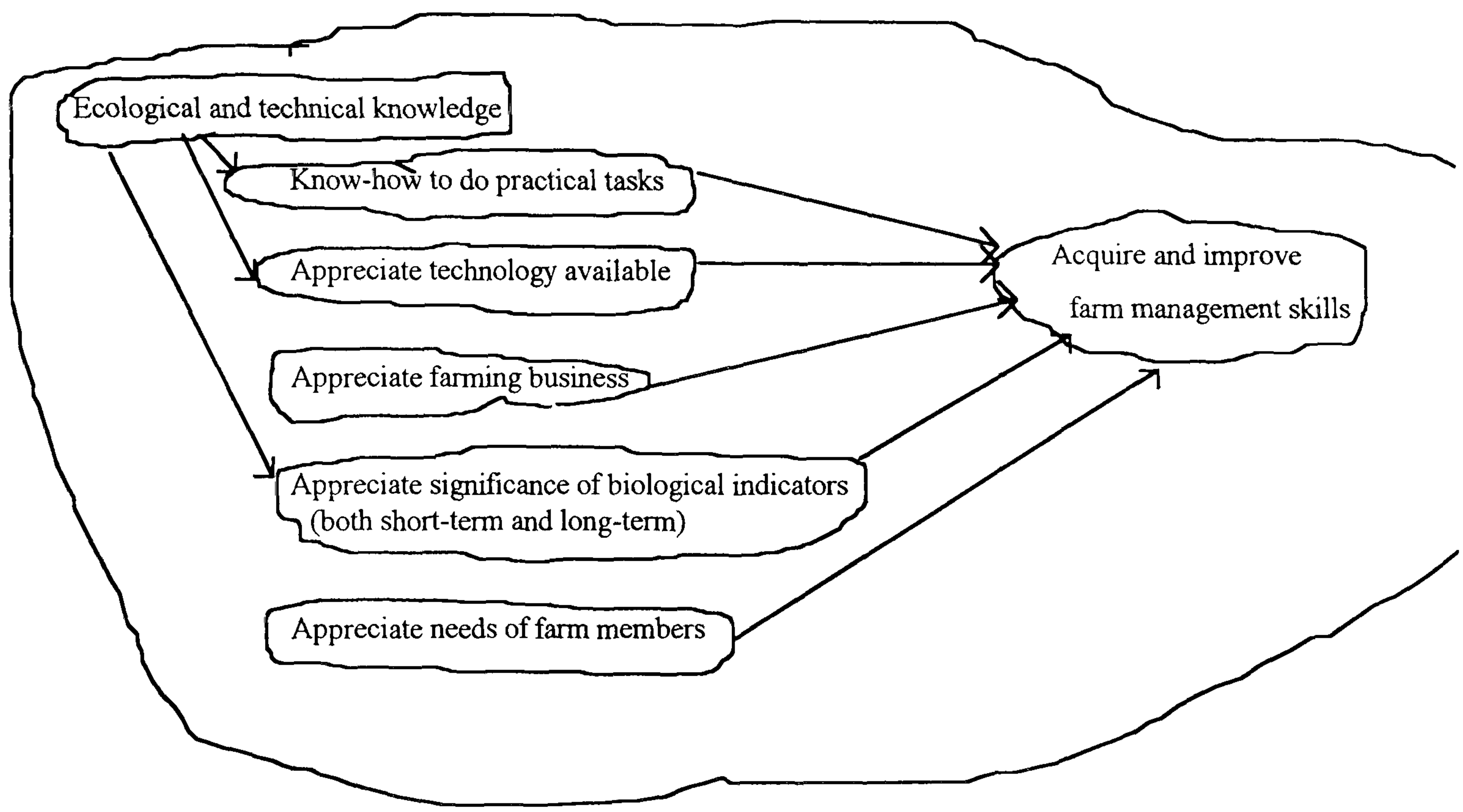
The activities that are minimally necessary to satisfy the requirement of the RD can be shown in a basic structure that is shown in Figure 3.ii The general structure of the system described in the root definition consists of three sub-systems.

**Figure 3.ii The General Structure of the Peasant Farm System**




Consider first the awareness that is required for the system to function: There must be a practical understanding of farming techniques - how, when, and where various tasks should be done, the significance of biological indicators (such as crop development) to the short and long-term processes of agricultural production must be appreciated, the food and material requirements of the farm members must be understood in terms of the outputs necessary to fulfill them, and an awareness of the "business" of farming encompassing knowledge about the ratios of inputs to outputs for the various processes, (including financial transactions as well as farming operations). In order to survive changes in the external environment the awarenss system must also aquire new knowledge and skills. The Awareness System is shown in greater detail in Figure 3.iii.

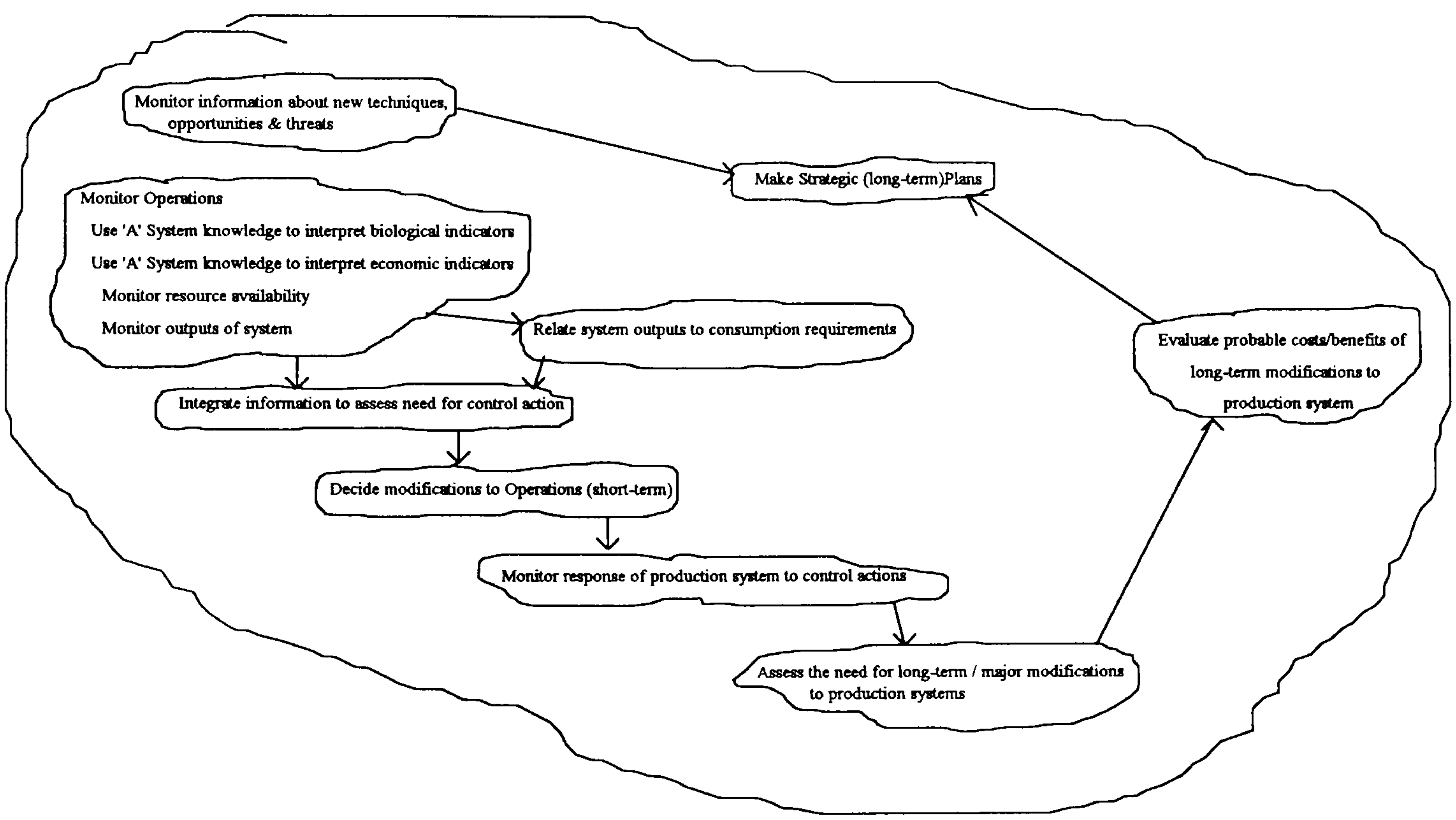
**Figure 3.iii The Awareness System Modelled in more Detail**




The operational system will have available the knowledge gained in the awareness sub-system. Its main activities are to allocate resources (ie. make production decisions), to do the farming activities and to harvest, process, and then sell or consume the outputs. An important aspect of the RD should be highlighted here - the description of resources as scarce. This word has meaning at two levels: Firstly, it is part of the definition of the Peasant Farm, as opposed to other types of farms, indicating relative poverty; secondly, it stresses the importance of allocation decisions in the efficient management of the system.

Implicit in the management of natural resources to provide a sustainable level of output is the need for a system to monitor and control operations, to respond to external and internal changes. As with the operational sub-system, the monitoring and control sub-system will required knowledge gained in the awareness sub-system to correctly interprete physical, financial and biological indicators. A crucial activity within this sub-system concerns decisions about short-term versus long-term investments (such as whether to forgo current income in order to improve a coffee plantation, conserve soil etc.). Figure 3.iv shows a more detailed model of the monitoring system. It is concluded that the combination of scarcity of resources and the importance of short-term / long-term decision problems is a key characteristic of the peasant farm *holon*.

**Figure 3.iv Detail of the Monitoring and Control System**




While the above conceptual models provide a structured view of the complexity of the Peasant Farm Management problem, they do not enlighten the observer about the sizes of the flows of materials / resources, nor the sensitivities of the technical-ecological sytems (within the operational system) to different management decisions[8]. To do this requires a more detailed, quantitative examination of the

[8] However, "hard modelling" alone would not have provided the same level of understanding of the

transformation processes (T), and environmental constraints (E). Indeed, it is these technical, biological, and resource parameters that determine the "real world" limits to the performance of the system as a whole. Furthermore, as the field research produced a substantial amount of quantitative data (as well as qualitative information) about peasant farm systems, (Chapter 5), it was sensible to try to understand the significance of these data in a *systems* sense. Modelling techniques, described in the next section, were therefore applied to the two most important "Production Problem Systems" (Coffee and *Milpa*), that were identified and characterised during the action research process (5.2.1 & 5.3.6). The models were used as a means of drawing out the significance of data about production process, resource contraints and prices within the context of the behaviour of the peasant farm system as a whole (not as means of pinpointing *optimum* solutions for peasant farmers).

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significance of the production problem systems to the overall farm system.

### 3.4.2 Structure and Relationships of Problem Systems

The lexical and parsing phases[9] of the analysis of agricultural problem systems were based upon the "systemisation" of the information and data provided by, (i) the conceptual model of the farm system from the previous section and (ii) the field studies of maize and coffee production in Chapter 5. Tentative models of the problem structure were modified and refined by farmers and extension agents within the training forum, and an agreed "working" structures for the maize and coffee sub-systems models were evolved. The quantitative relationships used in the modelling phase were similarly examined. The results of these phases formed the basis for the modelling exercises. Conceptual diagrams of the "working problem systems" for subsistence and cash crops are shown in (5.2.1) and (5.3.6). Descriptions of the models used to explore these problem systems are presented in the following sections. The definition of the overall structure and dynamics of systems in the lexical phase concluded that the system models should be based upon the simulation of goal-driven allocation of productive farm resources (rather than the flow of materials or energy). However, as the model was also required to reflect the effects of changing economic and environmental constraints over time, a dynamic component was also necessary. It was therefore decided to utilise a modelling programme capable of integrating linear programming (LP) and dynamic - interactive[10] techniques.

### 3.4.3 The Hard Model Format

A spreadsheet format, using the Quattro Pro, Version 1 (Borland, 1990) package was chosen for the system models for the following reasons:

a) Capacity to combine linear programming facility with dynamic equations and logical arguments within the model.

b) Easy input of data from conventional databases or spreadsheet databases. QPRO is

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[9] The following four phases of systems analysis are defined by Huggett (1980) p20-22.: lexical, parsing, modelling, and analysis.

[10] The models are not dynamic in the real time sense, of conventional dynamic programming, but they are dynamic infsofar as they include mechnanisms to feedforward outptuts from one time period to succeeding periods. Thus the state of the system at time t=n influences the state of the system at t=n+1.

compatible with software most commonly used for data storage: dBase, Paradox, Lotus and Excel.

c) The models are relatively transparent and easy to modify. This gives the user a great degree of flexibility in the application of the models to different areas or the incorporation of different crops and production functions. While the application of the spreadsheet within this study is in the context of research, the user-friendly interface of the software means that the models are potentially useful educational tools. The interactive tabular structure enables the user to trace through, in terms of cause and effect, the results of changing any of the technical or economic parameters on either the performance of the system as a whole, or on its constituent parts.

d) Model output is readily tabulated, graphed, stored and can be exported to word processing packages

e) Relatively simple programming skills required. Spreadsheets are one of the most widely used types of software world-wide and any one with a grasp of the basic skills can be taught to use the model in a few hours.

f) The QPRO software or similar packages are readily available in all Latin American countries.

### 3.4.4 Comparable Hard Modelling Methods Used in Farming Systems Analysis

Spreadsheets have been used for modelling agricultural systems in the contexts of research and education and decision-support. Thomas (1991) devised a spreadsheet model to examine agroforestry systems, and Bennett (1993) used spreadsheets to model Leptospirosis in dairy herds. Lorrain-Smith (1993) has developed a number of spreadsheet based programmes for decision-support in forestry investment. Upton (1993) constructed a (non-optimising) dynamic spreadsheet model to measure livestock productivity on small farms. The main advantages of spreadsheets are given in the previous section, they include flexibility, ease of use and a host of inbuilt features for data analysis and display.

The models described in the following section make use of the linear optimisation features and the capacity for automated dynamic modelling that are to be found in most modern spreadsheet packages. No previous reference to the combined application of these features in spreadsheet modelling has been found.

Previous applications of integrated LP and dynamic programming in agriculture are few: Dudley *et al* (1976) formulated optimum cropping and irrigation plans using LP, subject to parametric variation of constraints on water availability, However, in the later models Dudley (1993) replaced LP by numerical-solution dynamic programming. Yaron and Dinar (1982) used LP to find the plan which maximised the income of a farm producing cotton and dynamic programming, dynamic programming is then used to formulate new LP activities given the shadow prices of water obtained from the previous run. New LP activities were generated and selected by an iterative process until the solution could no longer be improved. A less integrated approach was used by Kennedy (1986) to optimise farm investment decisions which cover multiple periods. The LP was run for each of the n years with appropriate data on prices, technology and resource availability - giving net returns from production for all n years, and for all tractor capacities. Dynamic programming was then used to determine the optimal scheduling of tractor capacity through time.

The main difference between the above LP models and those applied to the Chiapas peasant system was that the former were designed to produce optimum long-term resource allocation solutions, but the latter were intended as tools to explore the constraints, processes and systematic behaviour of the peasant farm - and in particular to examine the tension between short-run decision making (without planning for the future) and strategic planning (such as use of lower output but sustainable production options, or investing in change). The output from the following models are not meant to provide solutions to allocation problems but rather, generate further hypotheses about the process of technological change. In effect the model is intended for use in a similar way to many other spreadsheet based models - to facilitate the rapid exploration of alternative scenarios, changing assumptions and parameters. Shapiro *et al.* (1993) used a similar year-by-year approach in a stochastic programming model used to evaluate the introduction of new early cultivars of millet and cowpea in Niger.

The LP component of the models ran on a year-by-year basis, rather than over a multi-year period for the following reasons:

(a) The overall assumption, derived from the SSM conceptual model, was that farmers primarily considered how to make "the best use of available resources for the coming year". Longer term considerations, would then be taken into account as modifications to the annual plan: either in the form of restricting the over exploitation of certain, depletable resources, or by the deliberate allocation of inputs towards long-term resource building activities (such as coffee plantation improvement). In this way, the effect of long-term planning can be contrasted with short-term opportunity cost.

(b) The feedforward link between the "state-of-the-system" in one year and the state in succeeding years is reflected more realistically by a "dynamic" model (see footnote 10, page 63), which shows how future production options can be enhanced or diminished by present decisions. Whilst the dynamic component in the milpa model reflected effect of cultivation method upon future yield and weeding requirements, it would be possible to include other dynamic links without radically altering the basic LP tableau.

(c) The extension of the LP tableau to cover a number of years would greatly increase its size and complexity. A relatively simple tableau was desirable as (i) large tableaus are not readily solved by the spreadsheet optimiser programme, and (ii) the model user is provided with a more readily understood concept of the production system at a given time.

(d) Separation of optimisation and dynamic components of the model (by time periods) gives reasonably fast run-times: Run times on an IBM portable PC with a 286 processor (no maths co-processor) for all three models were between 20 - 80 seconds, depending upon the number of iterations required to complete the LP stages (iterations dependent upon the input values used).

In summary, the use of a spreadsheet based LP model using a single year tableau, but with a feedforward mechanism to link the outputs of one year to the next was chosen because: (i) LP provides an optimising / allocation mechanism which is analogous to a farmer's short-run decision-making[11], (ii) the spreadsheet, with control panels, graphic tools and other features is familiar to many users. The small size of the single-year tableau enhances ease of use and transparency of comprehension (iii) The use of a feedforward mechanism separating the run of the model for each year allows for user interaction on a year by year basis. (iv) The separation of optimising and dynamic features of the model makes it computationally feasible for relatively low powered PCs that may be available in developing country situations.

### 3.4.5 The *Milpa* System Model

<u>Outline of the Model</u>

The layout of the spreadsheet model of the *milpa* sub-system is shown in Figure 3.v. The components of the model are described as follows:

(a) A control panel provides an interface for the user, facilitating the input of the various parameters of the system: available resources, number of people available for agricultural work at different times of year, days required for various tasks, expected output from each production option and product prices. The control panel could also be used to change the resource availability automatically in given year (See Table 3.6).

(b) A tableau was defined on the spreadsheet using the in-built "optimisation" tool (See Table 3.7, See following section for a description of the components of the tableau). Instructions on how to use this facility are provided in the QuattroPro manual. However, in an important extension of the basic LP method, the numbers in the body of the tableau were generated by formulae, rather than values[12]. The use of formulae in the tableau allows two useful features: (1) The values in the tableau can be modified automatically from the control panel, wherein the parameters of the system can be entered. (2) The values in the tableau can also be recalculated automatically, and can be linked to (so, that they are dependent upon) previous solutions

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[11] Another software tool specially designed for modelling dynamic systems is Stella for Macintosh computers. This uses compartment - flow type analysis. However, it does not have optimising features and was not available to the researcher at the start of the study.

[12] Later versions of Quattro Pro do not allow formulea to be contained in the body of an optimisation tableau. Therefore only Version1 is suitable for this type of model.

generated by the optimiser. The output from the optimisation, which includes dual values, was automatically entered into a range of cells in the spreadsheet.

(c) In a row of cells below the body of the tableau formulae referring to previous output from the optimiser link back to the body of the tableau. In this way, the values in the body of the tableau are recalculated (modified) according to the output of previous optimisations. The feedforward level could also be adjusted from the control panel (See Table 3.8).

(d) A short macro programme was written (instructions of how to record macros are provided in the QuattroPro manual) to automate the optimisation and feedforward procedures, to repeat them several times and to record the results in an area of the spreadsheet assigned for he output (See Table 3.9).

**Structures of Production Systems Models**

**Figure 3.v.**

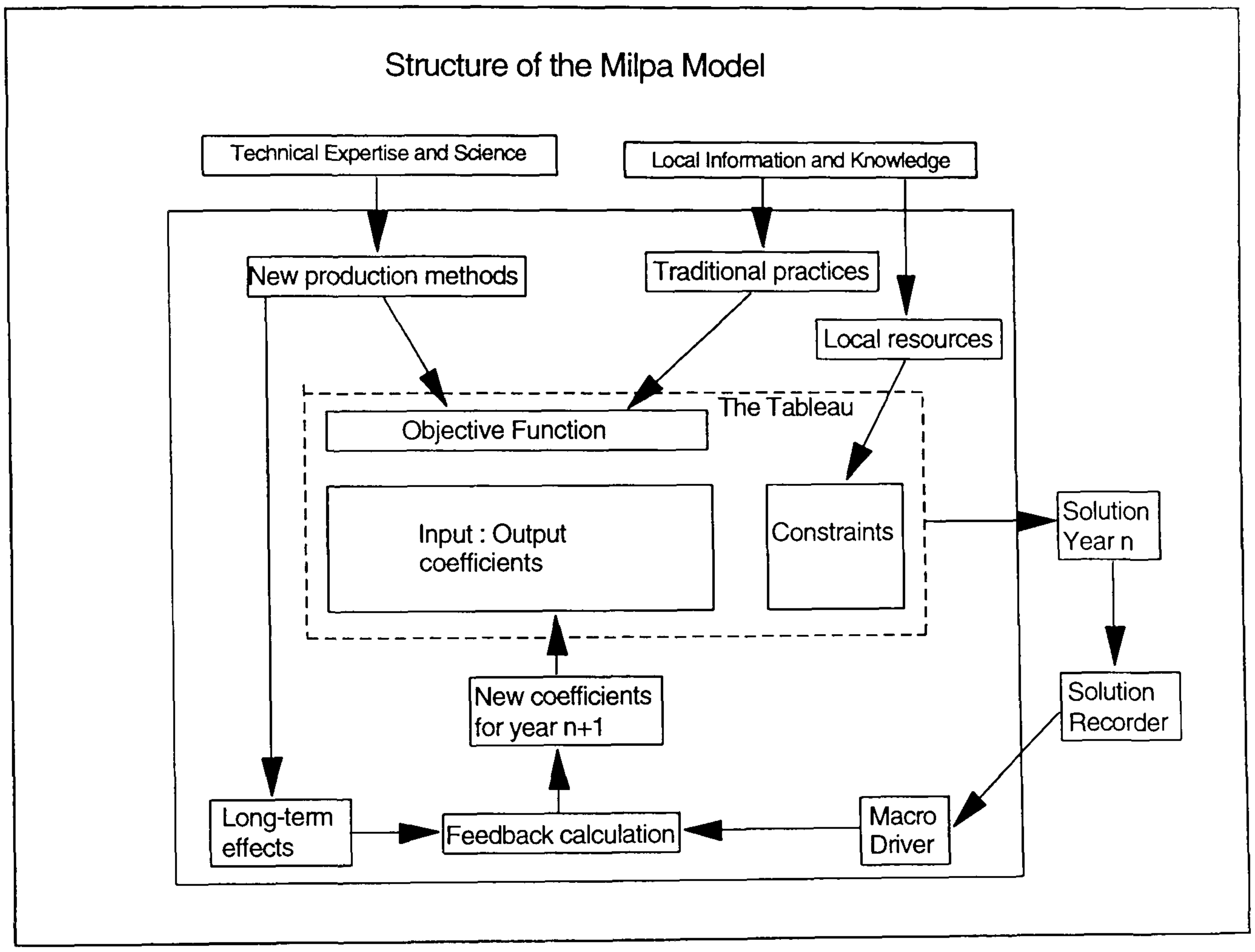


**Table 3.6 Milpa Model Control Panel**

| | | | |
|---|---|---|---|
| Land Available (Ha) | ⇒ | ⇒ | To constraints |
| Workers Available (T1-4) | ⇒ | ⇓ | |
| Days worked / week | ⇒ | Labour days available | To constraints |
| Savings | ⇒ | To coefficients | |
| Annual Spending | ⇒ | Cash available | To constraints |
| Food Requirement of family | ⇒ | Max sale of maize | To constraints |
| Wage Rate (buy / sell) | ⇒ | ⇒ | To coefficients |
| Allowable cultivation options | ⇒ | ⇒ | To coefficients |
| Weeks / season (T1-4) | ⇒ | ⇓ | |
| Labour days required (tasks) | ⇒ | Labour requirement / season | To coefficients |
| Cash requirements (per option) | ⇒ | ⇒ | To coefficients |
| Expected yields / ha (per option) | ⇒ | ⇓ | |
| Price of products, maize / beans | ⇒ | Value of output / ha (per option) | To coefficients |
| Yield Feedforward Factor | ⇒ | ⇒ | To Feedforward gen. |
| Weeding Feedforward Factor | ⇒ | ⇒ | To feedforward gen. |

**Table 3.7 Milpa Model Tableau**

| LINEAR PROGRAMMING TABLEAU | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | ACTIVITIES | | | | | | | | | | | | | | |
| | NOF>5 B | OCF>5 B | OCF1-4B | OCF0 B | ALF1-4B | ALF0 B | OCF1-4N | OCF0 N | ALF0 N | HERBIC | SELL LAB | MAIZE | BEANS | | (RHS) |
| OBJECTIVE FN.> | 0 | -100 | -100 | -100 | -300 | -300 | -100 | -100 | -300 | -40 | 7 | 0.9 | 2.5 | | |
| LAND | 6 | 6 | 3 | 1 | 3 | 1 | 3 | 1 | 1 | 0 | 0 | 0 | 0 | < | 3 |
| Early Spring | 38 | 38 | 28 | 26 | 28 | 26 | 35 | 32 | 32 | 0 | 1 | 0 | 0 | < | 40 |
| Late Spring | 23 | 23 | 23 | 30 | 30 | 30 | 38 | 38 | 38 | -6 | 1 | 0 | 0 | < | 40 |
| Summer | 5 | 5 | 5 | 5 | 5 | 5 | 13 | 13 | 13 | -6 | 1 | 0 | 0 | < | 50 |
| Autumn | 20 | 20 | 20 | 21 | 21 | 21 | 20 | 20 | 20 | 0 | 1 | 0 | 0 | < | 50 |
| CAPITAL | 0 | 100 | 100 | 100 | 300 | 300 | 100 | 100 | 300 | 40 | -1 | 0 | 0 | < | 200 |
| TRANS MAIZE | -1501 | -1971 | -211 | -211 | -211 | -211 | -1491 | -1597 | -2071 | 0 | 0 | 1 | 0 | = | 0 |
| TRANS BEAN | -250 | -250 | -250 | -250 | -250 | -250 | -250 | -250 | -250 | 83 | 0 | 0 | 1 | = | 0 |
| | | | | | | | | | | | | | | | |

**Table 3.8 The Feedforward Formulator For the *Milpa* Model**

| | ACTIVITIES | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | NOF>5 B | OCF>5 B | OCF1-4B | OCF0 B | ALF1-4B | ALF0 B | OCF1-4N | OCF0 N | ALF0 N |
| Sum of area cultivated by each method since Year O | | | | | | | | | |
| Yield factor (from control panel) | | | | | | | | | |
| Yeild feedforward (Area x Yield Factor) - to tableau | | | | | | | | | |
| Weeding Factor (from control panel) | | | | | | | | | |
| Weeding feedforward (Area x Weeding Factor) | | | | | | | | | |

**Note: Abbreviations used in tables**

| Fertiliser options | Rotation options | Cultivation options |
|---|---|---|
| NOF= no fertiliser, | >5= long rotation, | B= cultivation with burning, |
| OCF= occasional fertiliser, | 1-4= medium rotation, | N= non-burning cultivation |
| ALF= always fertilised, | 0= continuous cultivation, | |

**Table 3.9 Macro Programme for Automation of Milpa Model**

```
{CALC} (YEAR0)
{/ OPTIMIZATION;GO}
{/ BLOCK;VALUES}..AW8..BK8~AW25~
..........
{CALC} (YEAR1)
{OPTIMIZATION;GO}
{BLOCK;VALUES}..AW8..BK8~AW26~
..........
```

In summary, the model ran as follows:

(1) LP model determined the optimum allocation of resources between possible production activities (methods of *milpa* cultivation) for a chosen variable, year n. (2) After assuming that the "optimal" annual production plan was implemented, a feedback loop subsequently determined the effects of the plan on the tableau coefficients (and constraints if required) of year n+1 (the effect of chosen cultivation method upon the following years' fertility and weed seed bank). (3) New, additional resource constraints could be entered for each successive year. The model was run for 5 successive years, using several scenarios.

Description of the Decision Path

The solutions provided by this model were not necessarily long-term optima. The model used what may be termed a "greedy algorithm" (Elliott, pers.comm. 1991); the optimum for each successive year was calculated, without taking into account of the possible feedback effects to the production in future years. This could be interpreted as simulating a farmer making production decisions on the basis of the short-term optima. In order to explore other (non-greedy) decision paths resource allocation constraints were applied to the model. These additional, management imposed constraints were added to prevent the excessive use of depletable resources. {justify the reasons for using a year by year approach - logical to examine the options faced by the farmer each year}

Tableau Formulation

The first nine columns in the tableau corresponded to the nine production options (producer categories) which either predominated or appeared viable according to the analysis of actual technical practices in the Tzeltal area (for details of the tableau see Table 3.7).

With two outputs from the *milpa* system (maize and beans) the product mixtures between different production options were variable. To allow the maize : bean ratio of different options to influence the optimum allocation of resources the expected yields of maize and beans were entered in the bottom two constraint rows (as negative values), tied to two transfer columns (transfer to sale). The objective function row of the tableau contained the capital costs of production for each option and the unit prices of maize, beans and labour. The separation of production from sale (or consumption) by this layout was a useful additional handle by which the model could be manipulated: additional constraints such as minimum maize or bean production could be specified, and storage losses between production and sale could be conveniently simulated in the transfer (this feature was not used in this study as insufficient information on these factors was available). The structure of the tableau also reflected the dual character of the peasant household, as both producer and consumer of goods, as defined by Barnum & Squire (1979). To the author's knowledge this unconventional tableau structure is original and has not been previously used in farming systems modelling.

The cost of production for each *milpa* option did not include the cost of labour, as household labour is not paid for. However, the inclusion of an option to sell labour in the external market did effectively impute a base value for household labour. As the Tzeltal households studied used only their own labour in the cultivation of the *milpa*, no labour hiring option was included in the model. However, the model did include an option of saving labour by buying herbicide. Apart from the capital cost of this external input some of the interplanted bean crop was also calculated to be lost by the application of herbicide.

The farmers in the study rarely sold any of their maize production, preferring to store or feed any excess to domestic animals. Thus, while the values of each year's maize and bean production were calculated and presented as "effective income", it was assumed that only earnings from wage labour could be invested in production.

In the model of *milpa* farming there were 6 key farm resources acting as constraints on the production system.

Land:

(1) Land available for cultivation of maize

Seasonal Labour:

(2) Early Spring Labour (land clearing, preparation, burning)

(3) Late Spring Labour (Sowing, fertilising, 1st weeding)

(4) Summer Labour (2nd weeding, occasional fertilising)

(5) Autumn Labour (Doubling, harvesting)

Capital:

(6) Cash available for *milpa* cultivation.

Formulation of Coefficients and Constraint Levels

The coefficients used in the model were taken directly from the Tzeltal *milpa* study; they included the number of man-days required in each seasonal period to complete 1ha. of *milpa* for each method, the capital requirements and the production of both maize and beans of each method (from 4.3). The objective function coefficients at year 0 correspond to the average yields obtained by the different categories of Tzeltal *milpa* farmers between 1987-89 (Table 4.13). The constraints were also formulated to represent the range of resource availability's to be found on farms in the region. For details of the coefficients and constraint levels used in the *milpa* model, see Appendix 6.

Feedback Formulation

Two types of feedback were simulated by the model: (1) the effect of previously applied cultivation methods on the expected yields of maize and beans in succeeding years and (2) the effect of previous cultivation methods on the work required for clearing and weeding. The trends observed in the Tzeltal study were assumed to continue linearly for the duration of the modelling period (5 years). Feedback to yields was modelled as follows:

$$Y_{kn} = Y_{k(n-1)} + F_{yn}$$

Where,

$$F_{yn} = \sum_{k=1}^{k=a} (f_{yk}.A_{k(n-1)})$$

Ykn = Expected yield of maize from 1 ha from production method k in year n.
Fyn = Yield feedback factor in year n
fyk = Yield feedback factor for production method k
Ak = Area cultivated with producion method k
For production methods a to i

Similarly, for weeding;

$$W_{kn} = W_{k(n-1)} + F_{wn}$$

$$F_{wn} = \sum_{k=i}^{k=a} (f_{wk}.A_{k(n-1)})$$

Wkn = weeding requirement for method k in year n
Fwn = weeding feedback factor for year n
fwk = weeding feedback factor for method k
Ak = area cultivated by method k

The Scenarios Examined by Operation of the Model

The following scenarios were chosen to reflect the opportunities (and costs) of implementing non-burning cultivation for farmers with a range of available resources. The various resource availability's chosen were intended to reflect the situations of the range of farmers in the Tzeltal region (4.2):

(a) No capital available, no technical constraints,

(b) Limited capital available ($200), no technical constraints,

(c) Substantial capital available ($800), no technical constraints,

(d) Limited capital available ($200), only sustainable production techniques allowed,

(e) Substantial capital available ($800), only sustainable production techniques allowed.

All scenarios included a steady decline in the land available for cultivation, from 15 has. in year 0 to 3 has. in year 4 to reflect the trend of increasing land scarcity (4.3.1). The labour resource constraints remained constant for all scenarios. For full details of resource constraints for each scenario and each year of production, see Appendix 6 . The results from the operation of the *milpa* model are presented in (6.1).

### 3.4.6 The Coffee System Model

Outline of the Coffee System Model

The model was designed to explore the likely impact of different coffee improvement plans upon the income and optimum resource allocation of smallholder coffee producers over a period of 6 years. The coffee improvement problem system (see Figure 3.vi for diagrammatic representation) consisted of two main components:

(a) The first component was a coffee plantation improvement planning sub-model to make approximate determinations of the input requirements for different coffee improvement plans (See Table 3.10). Three improvement options were included, corresponding to the three plantation types identified as appropriate categories; rustic, intermediate and advanced, following the field study of coffee production in the Cho'l, Tzeltal and Tzotzil zones of northern Chiapas. These options were defined as follows:

(i) The transformation of areas of rustic plantation to intermediate state.

(ii) The transformation of areas of intermediate plantation to advanced state.

(iii) The transformation of areas of rustic plantation directly to advanced state.

Any combination of (i), (ii) and (iii) above, could be chosen in the plan, subject to the land available.

(b) The second component was a linear programming sub-model, with a tableau and additional constraint rows set out on the spreadsheet (See Table 3.11). The tableau was set up to maximise expected income from cultivation activities by optimising the allocation of seasonal labour and cash inputs between different types of plantation available to the farmer. The optimisation of input allocation took account of the following:

(i) The diminishing returns to labour and cash inputs on each unit of land, as approximated by two linear equations (see 3.4.6, section 3 for the modelling of diminishing returns to inputs).

(ii) The varying availability of inputs during the six year period due to the diversion of land, labour and cash from cultivation to planned improvement activities.

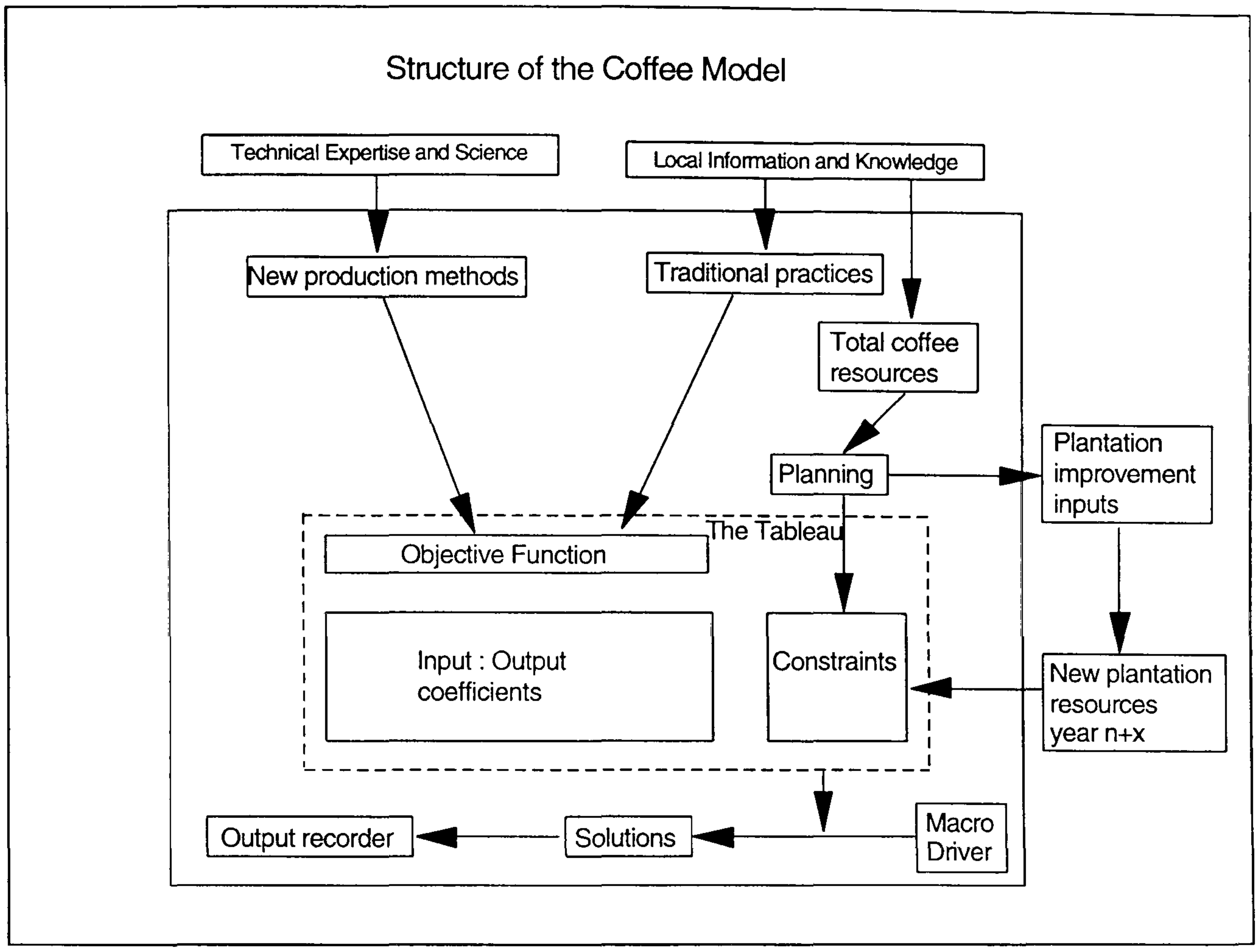
(iii) The possibility of hiring extra labour with any available cash.

The above sub-models were linked by two further components:

(c) A constraint formulation routine which calculated the amount of resource available for coffee cultivation in each year after, taking account of the requirements for coffee improvement (Table 3.10, parts 3-5).

(d) A "driver programme", in QUATTRO macro code that ran the model for a six year period during which time the improvement process was completed (Table 3.12).

**Figure 3.vi.**


Structure of the Coffee Model
Technical Expertise and Science
Local Information and Knowledge
New production methods
Traditional practices
Total coffee resources
Planning
Plantation improvement inputs
The Tableau
Objective Function
Input : Output coefficients
Constraints
New plantation resources year n+x
Output recorder
Solutions
Macro Driver

Description of the Tableau

The tableau had 7 activity columns, 8 constraint rows and 2 additional rows where upper and lower bounds that could be placed on each activity. The first two activity columns represented coffee production in rustic level plantations; the second two columns, production in intermediate level plantations; and the third two, production in advanced plantations. The final column was a transfer column to enable the hiring of additional labour at any time of the year. Of course, cash used to increase the labour supply would not be available for other production inputs. In this model of the coffee system there were 8 key resources acting as constraints on the production system:

Plantation land

1 Rustic plantation land

2 Intermediate plantation land

3 Advanced plantation land

Seasonal labour

4 Spring labour (post harvest weeding and fertilisation)

5 Summer labour (further weeding, pruning and shade control)

6 Autumn labour (some weeding and additional fertilisation in advanced plantations)

7 Winter labour (harvesting and processing)

Capital

8 Cash resource available for coffee production

For details of the tableau see Table 3.11.

**Table 3.10 The Plantation Improvement Planning Sub-Model**

**Part 1) Total Resources Available for Coffee Production (Values for Base Case Farm Shown)**

| | Year0 | Years 1-4 |
|---|---|---|
| Rustic Plant. (ha) | 3 | |
| Intermed Plant. | 0.5 | |
| Advanced Plant. | 0 | |
| Cash ($) | 40 | 40 |
| SPR LAB (d) | 50 | 50 |
| SUM LAB (d) | 60 | 60 |
| AUT LAB (d) | 40 | 40 |
| WINT LAB (d) | 90 | 90 |

d= working days

**Part 1) Input Requirements For Plantation Improvement (1ha)**

Rustc to intermediate - normal
Intermediate to advanced - *italic*
Rustic to advanced - **bold**

(year of improvement)

| Resource | 1st Year | 2nd Year | 3rd Year | 4th Year |
|---|---|---|---|---|
| Cash ($) | 460<br>*750*<br>**900** | 320<br>*460*<br>**570** | 0<br>*110*<br>230 | -320<br>*-460*<br>0 |
| SPR LAB (d) | 0<br>*0*<br>**24** | 16<br>*18*<br>**20** | 16<br>*18*<br>**18** | 16<br>*16*<br>**16** |
| SUM LAB (d) | 30<br>*32*<br>**40** | 15<br>*15*<br>**25** | 15<br>*15*<br>**25** | 15<br>*22*<br>**25** |
| AUT LAB (d) | 16<br>*16*<br>**16** | 17<br>*17*<br>**16** | 18<br>*18*<br>**16** | 18<br>*18*<br>**18** |
| WINT LAB (d) | 0<br>*0*<br>**0** | 0<br>*0*<br>**0** | 15<br>*20*<br>**20** | 25<br>*30*<br>**30** |

**Part 3) Improvement Plan Control Panel (abbreviated): Areas (ha) at each stage of Years0-5**

| Transformation | | Year0 | Year1 | Year2 | Year3 | Year4 | Year5 |
|---|---|---|---|---|---|---|---|
| Rustic | Ist Year | 0 | 0.3 | 0 | 0 | 0 | 0 |
| to | 2nd Year | 0 | 0 | 0.3 | 0 | 0 | 0 |
| Intermed. | 3rd Year | 0 | 0 | 0 | 0.3 | 0 | 0 |
| | 4th Year | 0 | 0 | 0 | 0 | 0.3 | 0 |

**Part 4) Resources Allocated to Plantation Improvement (abbreviated)**

| | Year0 | Year1 | ............ |
|---|---|---|---|
| Resource allocated | (Area x Resource usage) | | |

**Part 5) Resources Available for Annual Production (abbreviated)**

| | Year0 | Year1 | ............ |
|---|---|---|---|
| Resource available | (Resource available - Resource allocated) | | |

**Table 3.11 The Coffee Model Tableau**

| OPTIONS | RUSTIC PROD | | INTERMED PROD | | ADVANCED PROD | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | RP1 | RP2 | IP1 | IP2 | AP1 | AP2 | HIRE LAB | | CONSTRAINTS |
| FUNCTION | 623.16 | 623.16 | 1269.4 | 1269.4 | 2077.2 | 2077.2 | 0 | | |
| L1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | <= | 3 |
| L2 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | <= | 0.5 |
| L3 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | <= | 0.01 |
| SPR LAB | 21 | 28 | 20 | 36 | 20 | 26 | -1 | <= | 50 |
| SUM LAB | 26 | 36 | 24 | 39 | 18 | 25 | -1 | <= | 60 |
| AUT LAB | 0 | 0 | 5 | 20 | 5 | 9 | -1 | <= | 40 |
| WINT LAB | 43 | 54 | 46 | 90 | 70 | 78 | -0.6 | <= | 90 |
| CASH | 100 | 110 | 220 | 260 | 320 | 360 | 12 | <= | 200 |
| | | | | | | | | | |
| MINBOUND | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | |
| MAXBOUND | 1.5 | | 0.25 | | 0.005 | | | | |

L1 = Rustic Plantation (ha)
L2 = Intermediate Plantation (ha)
L3 = Advanced Plantation (ha)
RP1= Rustic Plantation Production, lower half of production function curve
RP2= Rustic Plantation Production, upper half of production function curve
IP1= Intermediate Plantation Production, lower half of production function curve
IP2= Intermediate Plantation Production, upper half of production function curve
AP1= Advanced Plantation Production, lower half of production function curve
AP2= Advanced Plantation Production, upper half of production function curve

**Table 3.12 The Coffee Model Driver Macro (abbreviated)**

| | |
|---|---|
| {/ BLOCK; VALUES}AF10..AF17~AM10~{CALC} | (Year0) |
| {/ OPTIMIZATION;GO} | |
| {/ BLOCK;VALUES}B40..J40~B44~ | |
| {/ BLOCK;VALUES}A30..A37~C30~ | |
| {CALC} | |
| {/ BLOCK; VALUES}AF10..AF17~AM10~{CALC} | (Year1) |

Linear Modelling of Diminishing Returns to Inputs

A significant conclusion from the study of inputs and outputs of the coffee systems was that returns to cultivation labour diminished progressively (5.3.3). This feature of the system was included in the model as follows. As mentioned in the description of the tableau, production in each type of coffee plantation was represented by two activity columns. The first of these, in each case, represented cultivation with low levels of absolute labour input, (or production at the low end of the production function): defined for the purpose of modelling as less than 0.5 the maximum amount of labour that could be absorbed by 1 hectare of a given plantation type[11]. The maximum amount of labour that could be absorbed by each type of plantation was determined as being equal to the estimated level of cultivation labour input at which returns to additional labour fell to near zero. The second column of each plantation type represented cultivation with high levels of input, or production at the upper end of the production function: defined for the purpose of modelling as greater than 0.5 the maximum amount of cultivation labour that could be absorbed by 1 hectare of a given plantation type.

As the returns to inputs diminish in the upper portion of each production function it was necessary to place upper bounds on the "low level" production activities (the first of each pair of equations). The bound level is calculated by the spreadsheet formula as 0.5 the amount of plantation land available of that particular type. Once this level has been reached the maximisation algorithm is then forced to "look at" the upper part of the production function. It was not necessary to set lower bounds for the upper section of each production function as any land available will automatically be preferentially allocated to the lower part of the production function if this is possible.

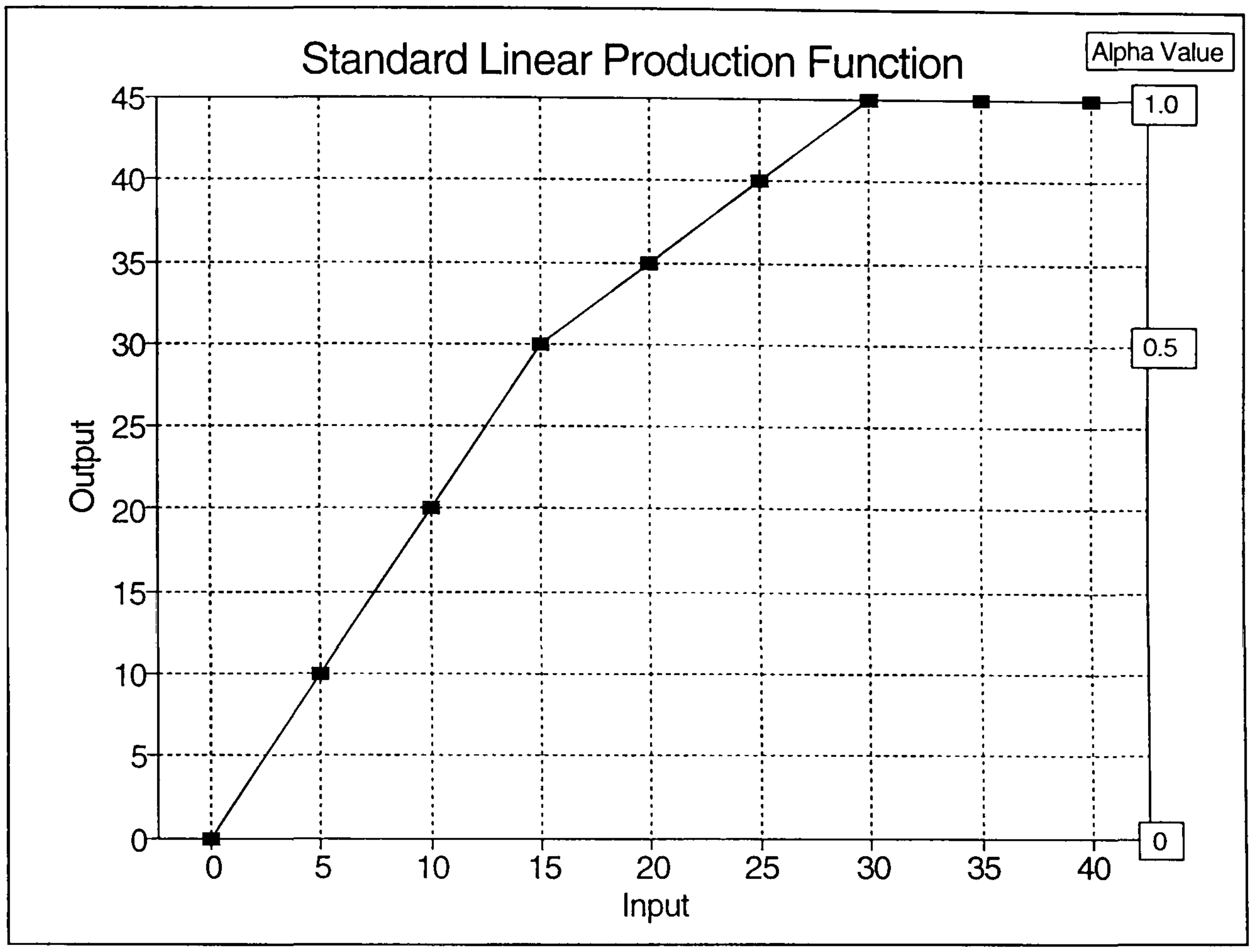
---

[11] Later, sensitivity analysis was carried out to examine the effect of changing the shape of the production function curve (6.2.2).

Interpretation of the Production Function $\alpha$ Values

$\alpha$ values were derived from the model to provide estimates of the position of the farmer on the production function curve of each plantation type; i.e. the level of inputs per unit area. Figure 3.vii shows the values of $\alpha$ for each position on a standard production function that is approximated by 3 straight lines. When $\alpha$ is $< 0.5$ the inputs to the plantation type available for cultivation are on the lower part of the curve (also the steepest part). At an $\alpha$ value of 0.5 the level of inputs into the plantation area is at the point at which returns to each unit of input decline. An $\alpha$ value of between 0.5 - 1 represents production at the upper end of the production function. When $\alpha$ is equal to 1 the plantation unit is being used to its maximum level, (until there are no returns to further inputs). By, definition, the LP optimising model (and any rational farmer) would not allocate inputs above this level. The total area of each plantation type cultivated was given by the sum of the two areas (upper + lower sections of the production function). Inputs of labour and cash to each plantation type were calculated similarly (in reality these inputs would be spread out over the area cultivated).

**Figure 3.vii.**


Standard Linear Production Function
Alpha Value
1.0
0.5
0
Output
45
40
35
30
25
20
15
10
5
0
0
5
10
15
20
25
30
35
40
Input

Formulation of Coefficients and Constraints

As with the *milpa* model, most of the constraints and coefficients used in the coffee system model were derived from the study of actual practices (4.2) and reflected the observed efficiencies and resource availability's of typical farm households in the region. In the case of the activity columns representing production in advanced plantations, coefficients were supplied by extension agents who were promoting the system (it was not possible to find evidence to verify these coefficients). For details of the coefficients and constraint levels used see Appendix 6.

The Scenarios Examined by Operation of Model

The scenarios were chosen in order to reflect the opportunities (and costs) of implementing various coffee plantation improvement plans on farms with a range of available resources. In particular, the modelling operation compared plantation improvement methods that had been advocated by INMECAFE, the state department responsible for coffee production, with the actual methods used by most farmers. The various resource availability's chosen were intended to reflect the situations of the range of farmers in the Cho'l region (4.2). Estimated cash flows, optimum allocations of resources, net present values and shadow prices were the principal model outputs used to describe and compare the following cases:

(a) Coffee production for the "standard" or base case Cho'l farm household without any plantation improvement (Table 6.8).

(b) Comparison of the three observed methods of plantation improvement carried out on the base case Cho'l farm household: (i) adaptive development of rustic plantation, (ii) adaptive development of intermediate plantation, and (iii) recommended transformation of rustic plantation (6.2.3).

(c) Relationship between expected net present values of plantation improvement and the scale of operation (6.2.4).

(d) Comparison of plantation improvement plans for farms with different relative factor scarcities (6.2.5).

(e) The effect of credit availability on the economics of plantation improvement (6.2.6).

The details of the constraints and improvement plans used in the above scenarios are given in the cross referenced sections.

### 3.4.7 The Farm Resource Allocation Model

Outline of the Farm Model

Unfortunately, there was insufficient time in the field to make a detailed study of farmers' decision-making processes regarding the allocation of resources between the two principal agricultural sub-systems, *milpa* and coffee. However, a third model, capable of simulating the allocation of farm resources between these two production systems on the basis of relative "shadow prices" was constructed and operated. The model was used to estimate the potential benefit to be gained by re-allocation of farm resources between sub-systems, in the base case farm. The potential benefits of increasing flexibility in the allocation of resources between productive sub-systems were also examined. Finally, the effect of technological change within each of the production sub-systems on the potential returns to re-allocation of farm resources was estimated.

Structure of the Farm Model

The farm model structure is given in Figure 3.viii. The total pool of farm resources available for agriculture was divided into three categories:

(1) Resources dedicated to *milpa* production

(2) Resources dedicated to coffee production

(3) Labile resources to be allocated according to the logical rules within the model.

By limiting the amount of resources available for re-allocation at any one time, the model should took account of the commonly noted "conservative" element of decision-making by farmers. As the labile fraction of resources could be varied, it was possible to simulate various degrees of conservatism or flexibility. The model consisted of three elements; an input programme, a transformation programme and an output programme (See Table 3.13).

### The Input Programme

The following inputs to the farm model were automatically read from each of the sub-models of *milpa* and coffee production: current resource use, shadow prices of resources and total output. Other inputs were entered manually: the total resources available for production (the same categories of key resources (constraints) were included as in the two sub-models, and the proportions of labile and dedicated resources (these could be made to vary between different resources).

### The Transformation Programme

The model used the logical facility of the QPRO software to re-allocate of labile resources on the basis of relative shadow price. The labile fraction allocated to the sub-system exerting the greatest "pull".

### The Output Programme

Following transformation, the farm model acted as a master programme by entering the new resource constraints into the *milpa* and coffee sub-models, and re-running them to determine the new level of total, combined output.

**Figure 3.viii.**

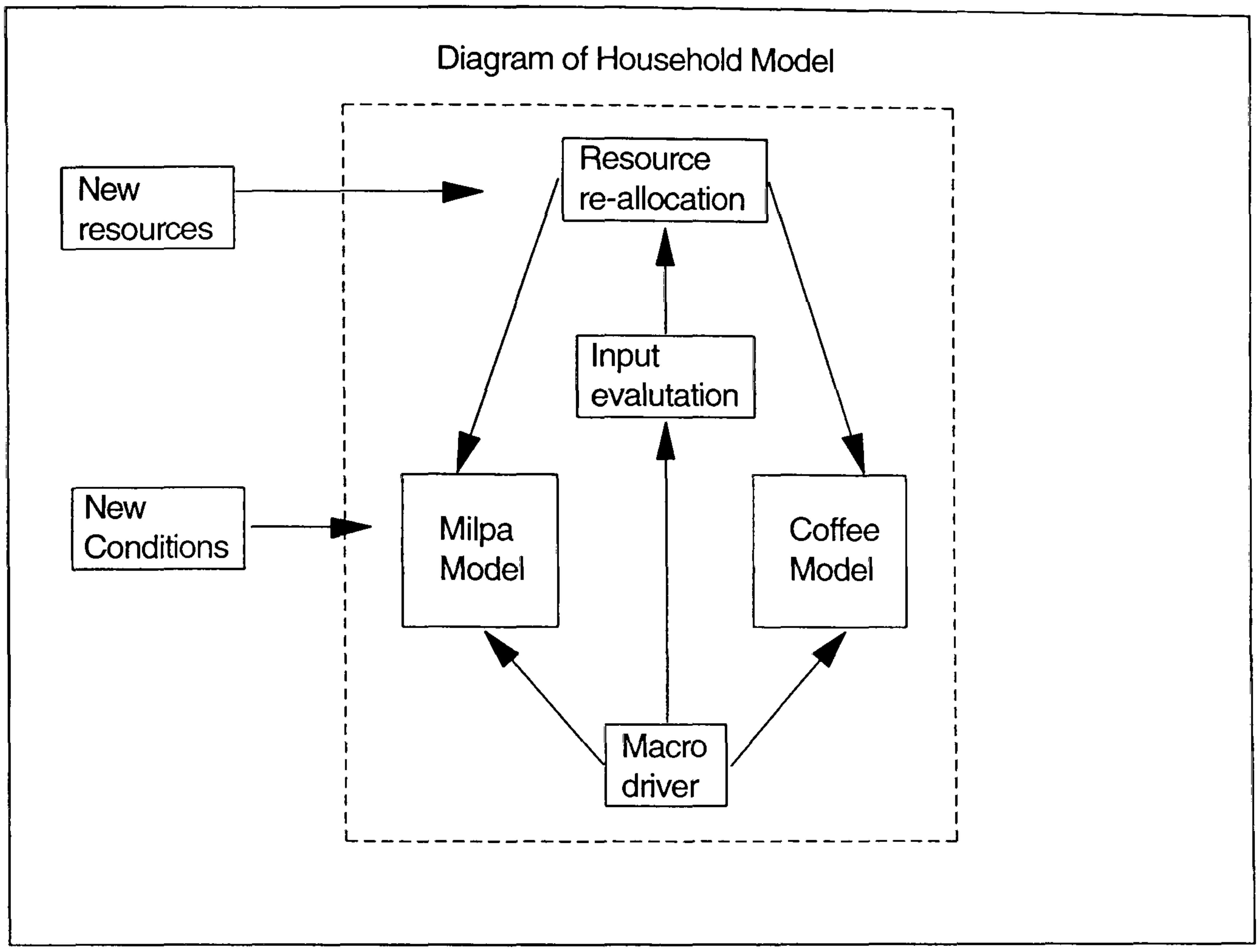


**Table 3.13 The Farm Model Spreadsheet**

**Part 1) Pool of Farm Resources**

| Resource | Milpa dedicated | Coffee dedicated | Labile | Total |
|---|---|---|---|---|
| Land (ha) | 4 | 3 | 1 | 8 |
| E. Spring Lab. (d) | 30 | 20 | 15 | 65 |
| L. Spring Lab. (d) | 30 | 20 | 15 | 65 |
| Summer Labour (d) | 40 | 48 | 22 | 110 |
| Autumn Labour (d) | 45 | 35 | 10 | 90 |
| Winter Labour (d) | 0 | 90 | 0 | 90 |
| Cash ($) | 600 | 350 | 250 | 120 |

**Part2) Shadow Price (-SP) Lookup, Figures in $ (abbreviated)**

| Resource | Milpa model SP (MSP+1) | Coffee model SP (CSP+1) | (MSP/CSP) |
|---|---|---|---|
| Land | 1 | 201 | 1/200 |
| E. Spring Lab. | 40 | 1 | 40/1 |
| L. Spring Lab. | 42 | 1 | 42/1 |

**Part 3) Re-allocation of Labile Resources (abbreviated)**

| Resource | Labile Resource Switch | Labile Resource to Milpa | Labile Resource to Coffee |
|---|---|---|---|
| Land (ha) | @IF (MSP/CSP)>1,1,0 | 0 | 1 |
| E. Spring Lab. (d) | @IF (MSP/CSP)>1,1,0 | 15 | 0 |
| L. Spring Lab. (d) | @IF (MSP/CSP)>1,1,0 | 15 | 0 |

**Part 4) Summary of Macro Programme**

```
{CALC}
 {GOTO[MILPA MODEL] RUN}
{GOTO[COFFEE MODEL]RUN}
{CALC}
```

The Scenarios Examined by Operation of the Model

The model was used to examine the following hypothetical scenarios:

(1) Re-allocation of labile resources on the base case farm:

A control farm, with total resources corresponding to the sum of resources of the control farms used in the *milpa* and coffee models was used (6.3.1).

(2) Re-allocation of varying fractions of labile resources:

The response of total farm output to the independent re-allocation of (i) land, (ii) labour, (iii) cash and combinations of resources was examined. The effect of increasing the labile fraction of farm resources was also estimated (6.3.2).

(3) Re-allocation of resources during coffee improvement:

The re-allocation and corresponding response of total farm output from the control farm with and without simultaneous implementation of a coffee improvement plan (transformation of rustic plantation to an intermediate state) (6.3.2).

The details of the constraints and improvement plans used in the above scenarios are given in the cross referenced sections.

# 4 Results of Fieldwork

## 4.1 Results of Socio-economic Factors from Community Case Studies

The results of case studies of the agro-systems in four locations (1. Chamula and Zinacantán, 2.San Miguel, 3. Coquija and 4. Yaluma) are given in this section.

### 4.1.1 Land

Current Distribution

In all the communities studied the majority of land was divided into holdings of under 8 ha. However, the distribution of land between households was found to vary considerably across the four locations (Table 4.1). Figures for Zinacantán (data for Chamula was not available) showed that there was not only a large number of landless families but also a small number of landowners with relatively large holdings. This concentration of land ownership was confirmed by Rus (1992). In San Miguel and Coquija there were relatively few landless families but many of the original holdings in San Miguel had been sub-divided, to give a large proportion in the range of 0-4 ha. In Yaluma, there were significantly more landless families than in San Miguel or Coquija, however, the heads of families had resisted the break-up of holdings of between 4-12 ha. in size.

**Table 4.1 Land Distribution Between Per-Cent of Families**

| | **Per-cent of Families** | | | |
|---|---|---|---|---|
| **Holding Size (Ha)** | **Zinacantán** | **S. Miguel** | **Coquija** | **Yaluma** |
| **Landless** | 18 | 8 | 4 | 12 |
| **0-4** | 29 | 36 | 18 | 5 |
| **4-8** | 34 | 47 | 53 | 57 |
| **8-12** | 13 | 9 | 19 | 26 |
| **>12** | 6 | 0 | 0 | 0 |

Transactions Within Communities

Despite the laws[1] against the sale or rental of *ejidal* land several informal arrangements were reported: (i) cultivation of the land of absent *ejidatarios* by family or friends by informal share-cropping

[1] Under the new Ley Agraria, passed in 1992, *ejidos* are now permitted to dissolve the communal land status, subject to a vote by all the *ejidatarios*. The *ejidal* land will then be partitioned between individual farmers and subject to sale and purchase.

agreements in Chamula and Coquija (an *ejidatario* is at risk of losing his land if he does not cultivate it for two successive years); (ii) Demands for compensation to elder *ejidatarios* in return for distribution of land to younger members of the community in Yaluma.

Land Purchases from Large Landowners

These transactions were rare as most of the powerful *ladino* landowners had moved out of agricultural production in the northern and central highlands since the 1950's. Land changed hands at very low prices; farmers in San Miguel reported paying around 800 pesos per ha. for rough pasture and 1,500 pesos per ha. for coffee plantation in 1990, due to the constant threat of invasion. It was estimated that farmers in these communities had purchased a total of 600 - 700 ha between 1986-90. Around Chamula and Zinacantán and in the Eastern Highlands, around Yaluma there are few remaining tracts of private land, so prospective buyers must migrate to lowland areas.

### 4.1.2 Labour

Seasonality of Demand

In Chiapas as a whole, and especially in coffee producing communities, there is a marked seasonal increase in the demand for labour during the coffee harvest. This resulted in the observed increases in wage rates during Winter (Table 4.2).

Locational Variations in Wage Rates and Dependency on the Labour Market

The daily wage rates for the Summer in Chamula and Zinacantán were higher than in other, more isolated communities. However, the demand and price of labour during the Winter rose less sharply than in the coffee producing areas. Wage rates for peasants working outside (in towns or on private farms nearby) the communities were higher than local rates, but working away from the community also entails costs of transport and food. The Chamulans and men from Yaluma were most dependent upon wage earnings from work outside their communities (Table 4.3).

Despite the fact that land was becoming quite scarce in San Miguel, the younger members of the communities still said that they saw their futures as being in farming, albeit more commercially oriented than previously. Those that left these communities to work were usually younger males with some specific skill such as welding or driving. There were fewer labour transactions altogether in Coquija than the other communities. Here, most farmers claimed that they were too busy working on their own land to work for other people. However, few farmers had sufficient capital to pay for outside labourers (except during the coffee harvest).

The external labour market was important for Yaluma. The low price of maize and the absence of any successful cash crop production in the area meant that income from agriculture alone was not enough to sustain even the most technically advanced farm families. Furthermore the cultivation of maize as a single crop, both for sale and subsistence, gave rise to slack periods of the year when people were forced to "look for something productive to do".

**Table 4.2 Daily wage rates (pesos) in different locations and seasons, in 1990**

| Community | Inside Community | | Outside Community | |
|---|---|---|---|---|
| | Summer | Winter | Summer | Winter |
| Chamula / Zinacantán | 9.0 | 11.5 | 9.5 | 14.0 |
| San Miguel / Obregon | 6.5 | 12.0 | 8.0 | 14.0 |
| Coquija | 7.0 | 13.0 | 7.0 | 13.0 |
| Yaluma | 7.5 | 9.0 | 12.0 | 12.0 |

**Table 4.3 Numbers of men taking up employment outside their community for various duration's, and percentage of total cash earned from wages during 1989**

| Community | Sample size | Never | <1 Month | >1 Month | % of cash earned |
|---|---|---|---|---|---|
| Chamula/Zinacantán | n=21 | 4 | 13 | 4 | 55 |
| San Miguel/Obregon | n=28 | 22 | 6 | 0 | 10 |
| Coquija | n=15 | 11 | 3 | 1 | 7 |
| Yaluma | n=18 | 5 | 9 | 4 | 20 |

Labour Contracting Practices and Migrant Labour

The tasks most often carried out by hired labour in all the communities were coffee harvesting and weeding in both *milpa* and *cafetal*. Money lending families in Chamula and Zinacantán occasionally accepted payment of debts in work-days. The trading of labour debts was also reported, despite its illegality. The extent and impact of cheap (illegal) Guatemalan migrant labour, especially during the time of the coffee harvest was difficult to quantify; most work for the large landowners in the Socunusco region. However it was estimated by locals, in 1989, that at least 100 Guatemalans arrived to work in the Tila Municipality (Cho'l area) and around 50 arrived in the Bosque Municipality. The pay of Guatemalan migrant workers is usually about two-thirds the normal wage. Chiapas is less affected by the US. labour market than other Mexican states; however, a Californian anthropologist recently met a group of five Chamulan migrant workers in San Francisco!

### 4.1.3 Capital

Credit Availability and Government Schemes

The use of credit as an instrument of political leverage appeared to be widespread in Chiapas, as it has been in other parts of Mexico. It was reported that Zinacanteco farmers who supported an opposition party (the PRD) were unlikely to receive their Credito de Palabra, or (even worse) they might receive it too late in the season to buy or apply fertiliser and so encounter difficulties with repayment (Table 4.4). This situation finally provoked an investigation by Federal Audit Agents in 1991. Many government credit schemes linked to technological development have failed due to incompetence or poor planning: Chamulan farmers related how, in 1983-4 a highly publicised Ministry of Agriculture programme promoted potatoes in these communities as "the ideal cash crop for the Highlands". Seed and credit were distributed liberally and bumper crops were forecast. Unfortunately, insufficient attention had been paid to the likely demand. By three weeks into the harvest the price of potatoes had fallen below the cost of transport between Chamula and the market in San Cristóbal. Most farmers were unable to repay their credits and thus received *Carteras Vencidas*, disallowing further credits for the next five years. Despite these failures there have been some examples of successful credit aid to weaving cooperatives in Chamula, enabling them to set up shops in San Cristóbal and even to export to the US.

**Table 4.4 Distribution of government credits in case studied communities**

| Community | Credito de Palabra | Other Credits |
|---|---|---|
| Chamula / Zinacantán | Discrimination against some families | DIF and INI credits for craft cooperatives |
| San Miguel | Distribution overseen by internal commission | INMECAFE/UC credit for coffee intensification & livestock finance from BANRURAL |
| Coquija | Distribution correct | INMECAFE/UC credit for coffee intensification |
| Yaluma | Delayed by *Presidencia Municipal* | Credit for transport cooperative via UC |

San Miguel had elected a commission to deal with the *Presidencia Municipal*, Banrural and other money lending institutions. These consisted of respected, experienced men used to dealing with bureaucrats and politicians. If necessary, these commissions could always count on a mass mobilisation of farmers to besiege offending institutions! It was reported that this strategy had enabled the community to obtain credit for cattle production and for the purchase of land from neighbouring *fincas*. This was in addition to the *Credito de Palabra* and credit for coffee intensification from the Union de Credito. The farmers of San Miguel also appeared to have a better than average understanding of the mechanisms of the credit market; how to calculate interest repayments, and where best to invest the money. The fact that many of these farmers put the low interest government loans into bank accounts rather than investing in agriculture was an indication of the difficult state of the coffee market.

The main source of credit in Coquija was the Unión de Credito, which encouraged borrowing for coffee improvement for three years prior to the collapse of the international market (1986 - '88). The results of this investment were mixed. Whilst most producers were able to increase their production substantially (by around 70%) many were still unable to repay their loans and the situation was only resolved by a painful porches of negotiation with the banks. Coquija appeared to be an example of a community where the *Credito de Palabra* was distributed fairly and on time.

Despite conflicts with the local *Presidencia Municipal*, in 1992 Yaluma was successful in obtaining credit via the Unión de Credito for a cooperative bus which has since run successfully. The community also hoped to establish a harvest / storage fund that would enable farmers to store harvested maize until the low prices at the time of harvest become more favourable.

**Table 4.5 Money lending transactions within selected communities**

| Community | Transactions | Interest |
|---|---|---|
| Chamula / Zinacantán | Widespread borrowing, large debt burdens on young males | 10 % per month |
| San Miguel | Little lending for interest. Contributions for families in need. | 0% |
| Coquija | Little lending | Not known |
| Yaluma | Terms fixed by community | 5% per month |

Money lending

Moneylenders in Chamula and Zinacantán were reported to have loans out to ten or fifteen families at a time. One Chamulan was reported, to have had 8 million pesos invested in loans; which, at 18% per month would have given an income of 17.28 thousand pesos per year (1990), (considerably more than the salaries of most of the agronomists employed by the Ministry of Agriculture).

When, in both San Miguel and Coquija, families required money due to illness or "bad luck" the communities as a whole responded with donations of either cash, food or work. There was little lending of money for interest between members of these communities. As a result of frequent arguments between borrowers and lenders the people of Yaluma decided to make a law restricting the interest payable on loans to 5% per month (Table 4.5).

### 4.1.4 Transportation

Lively competition and good tarmac roads made transportation between Chamula and Zinacantán, and San Cristóbal cheaper than the other locations (Table 4.6). However, on the road to San Miguel there was also sufficient competition for prices to be kept reasonable. The community contained some individually owned vehicles and a cooperatively run truck (Table 4.7). These allowed villagers to return home after the Bochil market closed, as there was very little commercial traffic along this road in the afternoons. Transport costs were highest in Coquija due to the state of roads and the lack of transportation. Costs in Yaluma were higher than might have been expected; this was probably due to the local oligopoly of *ladino* truck owners.

**Table 4.6. Transport between community and nearest market town**
**(Vehicles are 3 tonne trucks, normal capacity 12 people)**

| Community | Number Of Trucks / Day | *Cost / Km per person (pesos) |
|---|---|---|
| Chamula / Zinacantán | >30 | 0.16 |
| San Miguel | 7-10 | 0.21 |
| Coquija | <1 | 0.45 |
| Yaluma | 15-20 | 0.25 |

* These prices, for transport in 3 tonne trucks compared with an average price of 90 pesos per kilometre per person for larger 2nd class buses travelling over established routes.

Table 4.7 Number of trucks / Type of ownership

| Community | Individually Owned | Cooperatively Owned |
|---|---|---|
| Chamula / Zinacantán | >20 | 0 |
| San Miguel | 2 | 2 |
| Coquija | 0 | 0 |
| Yaluma | 2 | 3 |

### 4.1.5 Agricultural Inputs

Proximity to San Cristóbal assured the supply of most agricultural inputs in Chamula and Zinacantán. Most farmers used fertilisers whenever they could (Table 4.8). The main limitation on demand was the ability of farmers to pay. The farmers of San Miguel made sporadic use of fertilisers for both coffee and maize production. This was reported to be due partly to irregular supplies and partly to the lack of available cash at the times of the year when fertiliser is needed. When coffee prices were high in the early 1980's, credit was also available through the credit union and all farmers used fertiliser. Yields rose from around 7 sacks per ha. to around 15. Since the collapse of the international coffee market (see cash-crop markets) credit has not been available (see credit market) and average yields have fallen back to below 10 sacks per ha. In an effort to improve the fertiliser supply situation the communities around San Miguel had recently completed a joint project, with government aid, to build a fertiliser store for the area. Only one or two of the younger, more enterprising farmers in Coquija fertilised their coffee. Maize in this area is rarely fertilised as the soil fertility was maintained by rotations, the use of non-burning cultivation techniques and legume cover crops. In Yaluma, fertiliser use was widespread and relatively intensive. Some farmers had even experienced problems of soil acidification as a result of the overuse of ammonium sulphate; a source of nitrogen that was popular during the 1970s' and 80s'.

**Table 4.8 Fertiliser use by proportion of farmers**

| Community | Non-Users | Sporadic Users | Regular Users |
|---|---|---|---|
| Chamula / Zinacantán* | 0.1 | 0.2 | 0.7 |
| San Miguel | 0.2 | 0.6 | 0.2 |
| Coquija | 0.4 | 0.5 | 0.1 |
| Yaluma | 0 | 0.4 | 0.6 |

Source Pajal Survey, 1990; * FERTIMEX estimate 1991.

#### 4.1.6 The Coffee Market

Of the four locations, only San Miguel and Coquija were coffee producing communities. Farmers in San Miguel and Obregon used several different outlets for their coffee production; merchants from Bochil, merchants from outside the State, the Unión de Credito, and in 1991-2, following the dissolution of INMECAFE, the State Governor even tried to act as an intermediary. Most farmers sold to more than one outlet during the 1990 season.

The coffee market in Coquija was dominated by local merchants, even after the intervention of INMECAFE. This was reflected in the 20% inferiority in the price of coffee sold there, compared with San Miguel during the 1970's. With the development of cooperative commercialisation in the 80's the market became more uniform, and since 1989 the strong penetration of large merchants from Puebla and Veracruz has pushed end-of-season prices in the Cho'l zone above those in other parts of the State (Table 4.9).

**Table 4.9 Coffee prices in different areas during 1990-91 harvest.**
**(prices shown in pesos per kg parchment coffee)**

| Market | December | January | February |
|---|---|---|---|
| Middlemen in San Miguel area | 800 | 1,250 | 3,200 |
| Middlemen in Coquija area | 750 | 1,000 | 3,400 |
| Union de Credito in both areas | 1,020 | 1,200 | ceased buying |

#### 4.1.7 Alternative Cash Crop Markets

Milk from the cooperative livestock project in the San Miguel area was sold to local merchants in Bochil who sold it on (unpastuerised), direct to consumers. Meat was sold on the hoof, at markets, either in Tabasco or Tuxtla. In Coquija and surrounding communities beans emerged as an important cash crop after the decline in the price of coffee. These were sold mainly in the market town of Yájalon, where prices had risen steadily since government price controls were relaxed in 1990, from around 2.4 pesos per kg to between 3.0 and 3.5 pesos per kg by May 1991. There had been a failure to develop any profitable cash crop production in Yaluma other than maize. Soya, sesame, groundnuts and wheat had been grown successfully but lack of demand locally and inadequate marketing channels meant that commercial production was not viable. The fruit grown by Zinacantecos and Chamulans was often of poor quality (poor varieties and often damaged by pests) arrived in a glut on the markets in late summer and was sold at prices that could hardly have justified picking and transport costs (between 0.5 - 0.8 pesos per kg, in 1990, according to the survey).

### 4.1.8 Technological Changes in Agriculture

The following general trends in agricultural change were observed in the four case study locations. For accounts of detailed changes in *milpa* production see section (4.3) and in coffee cultivation, section (4.3).

Chamula and Zinacantán

Subsistence Production

In Chamula and Zinacantán *milpa* production had stagnated relative to cash crop cultivation. The principal changes in *milpa* cultivation noted were:

(1) Continuation of the traditional practice of burning brush fallows.

(2) Increased use of fertiliser, not to increase yields but to prevent yields from declining on the deteriorating soils (despite fertiliser use maize yields have fallen (See Table 4.10)(Short, 1991).

(3) Increased use of herbicide sprays, not to increase yields or area of maize production but to free time for non-*milpa* activities.

(4) Reduced legume component in *milpa* cultivation, partly due to the increased use of herbicides and possibly also due to the availability of cheap, lowland grown beans in the local markets.

### Cash Crop Production

In Zinacantán the principal cash crops are flowers and stone fruit, while the Chamulans specialise in vegetables. Both communities have developed their production methods significantly over the past ten years by increasing use of agrochemicals and new seeds. Another notable development has been the construction of greenhouses by several of the wealthier Zinacanteco flower growers.

## San Miguel

### Subsistence Production

In this community, *milpa* production has remained important despite a growing interest in cash crops. The principal developments in *milpa* cultivation have been:

(1) Use of fertilisers to increase yields (see Table 4.10)

(2) Increased area of *milpa* cultivation, allowed by use of herbicides (1.7 ha. per family 1982 to 2.5 ha. per family 1989).

(3) The search for and use of new maize and bean varieties.

(4) The adoption of non-burning cultivation by several farmers.

### Cash Crop Production

Production for cash income had developed dramatically in this community over the past 10 years: In 1975, yields of coffee were around 5 sacks per hectare compared with current production of approximately 15 sacks per hectare. The other major development in production for cash was the diversification into cattle production by many of the families. Traditionally animals (mainly poultry and swine) have been used in Indian communities as a means of saving excess production and processing waste, and husbandry has been the responsibility of women. The semi-intensive commercial production of meat and milk represented a technological leap for these Tzotzils: when they first bought the cattle some men were afraid to go near them! Coffee production has developed in the following specific ways:

(1) The application of more agrochemical inputs, mainly fertilisers.

(2) Increased densities of coffee bushes (from around 1050 plants per ha. to over 1500 Plants

per ha.).

(3) New varieties; Caturra, Bourbon and Garnica replacing Typica and Maragogipe.

(4) Increased attention to pruning and shade control.

(5) Improved processing, with the purchase of mechanical de-pulpers and the construction of concrete drying patios and fermentation tanks, leading to better quality coffee.

Coquija

Subsistence Production

The main change in *milpa* agriculture in this community has been the development of a low capital, non-burning cultivation technique. This method lead to an increase in the productivity in inter cropping of both maize and beans (see Table 4.10). The main components of this new system are:

(1) Non-burning of brush fallows.

(2) Use of legume green manure and cover crops.

(3) Selection of local land races of maize and beans.

The development of this system was an effective reaction to the agricultural supply and transport markets that were unable to deliver inputs, or supply food reliably. Although the *milpa* now demands more labour, especially during the Spring, the community is confident that it can produce staple food crops in excess of its own requirements. Self-sufficiency in these products has become a necessity since the fall in the price of coffee.

Cash Crop Production

As in San Miguel, development of production for cash had diversified since the fall in the price of coffee. The terrain in this region was unsuitable for cattle raising and the main alternative main alternative chosen was winter beans. The coffee production system itself was also becoming diversified, with two strategies emerging. The first of these was a capital intensive system in which coffee were grown without shade in contour hedges: While the coffee bushes are young there was space between the rows to grow annual crops such as beans and squash.

These annuals also helped to control weeds. This system was being developed as part of a programme of cooperation between the government and a local cooperative. The second system emerging was low-intensity, agro-forestry production, involving a mixture of tree and bush species (mangoes, avocados, bananas, cardamom, etc.) with no chemical inputs. Little labour or capital was applied apart from harvesting and tree planting, so although the system was relatively low yielding (per ha.) it was also efficient in terms of labour productivity.

## Yaluma

### Subsistence Production

Technical development of *milpa* production in Yaluma had followed a capital intensive path. However, despite the proximity of suppliers of agricultural inputs and labour in Comitán, and programmes of agricultural development, involving SARH, Banrural and the Unión de Credito, there had been little or no sustained improvement in the production technology for maize. In 1985 Yaluma had three cooperatively managed tractors and most farmers used commercial varieties of maize seed. In 1991 there was only one tractor, in poor mechanical condition and the use of commercial varieties had been abandoned. Also in 1991 representatives of the community reported that most families relied on selling their own labour for a greater proportion of their income than five years previously. Almost a third of families said that wage labour was now more important than maize production (Informal survey, May 1991). The main technical components of *milpa* development in Yaluma were as follows:

(1) The use of agricultural machinery for tillage, seeding and spraying.

(2) The use of commercial varieties of seed.

(3) The use of substantial quantities of fertiliser.

(4) Since 1985, non-burning maize production had been promoted in this area. However, adoption appeared to be proceeding very slowly.

### Cash Crops

A viable cash crop alternative to maize has not developed in Yaluma despite various initiatives. Medium scale trials have shown that it is possible to grow wheat, sesame, sunflowers, soya and groundnuts successfully in the area.

**Table 4.10 Average yields from *milpa* production in selected communities (kg / ha) 1982 and 1989.**

| Community | 1982 | | 1989 | |
|---|---|---|---|---|
| | Maize | Beans | Maize | Beans |
| Chamula | 1500 | NA | 800 | NA |
| San Miguel | 1200 | NA | 1800 | NA |
| Coquija | 950 | 570 | 1500 | 980 |
| Yaluma | 1600 | 800 | 2300 | 850 |

## 4.2 Results of Field Study of Land Use at Village Level

Data derived from hand drawn maps and transects showing the use of land within 39 communities in three indigenous zones is displayed in Table 4.11.

**Table 4.11 Community land use in three zones (Hectares, except * and %)**

| | CHO'L | TZELTAL | TZOTZIL |
|---|---|---|---|
| Number of communities | 22 | 9 | 8 |
| Forests * | 1474 | 1421 | 1634 |
| Coffee (natural shade) | 1835 | 1857 | 1633 |
| Coffee (planted shade) | 1924 | 0 | 988 |
| Coffee (unshaded) | 20 | 0 | 0 |
| Pasture | 170 | 112 | 2273 |
| Fallow brush | 3989 | 4299 | 2853 |
| Milpa | 1460 | 1407 | 2314 |
| Beans | 323 | 496 | 860 |
| Fruit Trees | 0 | 0 | 33 |
| Total | 11195 | 9592 | 12588 |
| % Maize (total) | **48.7** | **59.5** | **41.0** |
| % Maize (annual) | **13.0** | **14.7** | **18.4** |
| % Coffee | **33.8** | **19.4** | **20.8** |

Data Source: maps made of community lands by hand, with assistance from farmers (Appendix 3).

The Cho'l and Tzeltal zones cultivated smaller proportion of land for maize annually, than the Tzotzil zone. However, the Tzotzil zone had a lower total proportion of land area available for maize cultivation (see discussion on rotation length (3.3.1). The Cho'l zone dedicated a greater proportion of land to coffee (around 34%) compared with the Tzeltal and Tzotzil (both around 20%). Furthermore, the Cho'l zone had larger proportions of artificially shaded and unshaded coffee. All the coffee in the Tzeltal region was planted below natural shade. Cattle production was becoming important in the Tzotzil zone but the broken terrain and steep slopes have made this unfavourable in the Cho'l zone. The Tzeltal zone was characterised by a large area of fallow brush or *Acahuales*. This land type is produced when areas are cleared and burned for maize production and then left to recover for several years.

## 4.3 Results of Field Study of Change in Milpa Production

The results of detailed studies of changes in milpa cultivation during the 1980s by 27 farmers from 10 Tzeltal communities are presented in the following section. The methods used are presented in (3.3) and the discussion of these results is presented in section (5.2).

### 4.3.1. Changes in Milpa Cultivation Between 1984-89.

Figures 4.i, 4.ii and 4.iii show the changes in rotation length, fertiliser usage and the practice of non-burning or traditional cultivation made by each farmer between 1984 and 1987. Of a total of 27 farmers, 15 made some changes to their cultivation methods and 6 farmers were new entries (began farming on their own, after having received an allocation of *ejidal* land or inheriting land).

Changes in Rotations (Fig. iv)

6 farmers decreased the length of their rotations during the period (4 from long to medium, 2 from medium to short). No farmer increased the length of rotations. 5 out of the 6 new entries began cultivating in short or continuous rotations. Between 1984-89 the balance of rotations shifted from 2:9:10 (short:medium:long) to 9:12:6.

Changes in Fertiliser Use (Fig. v)

8 farmers increased their use of fertiliser, while only one decreased its use. During the period the balance of fertiliser use shifted from 7:10:4 to 4:15:8 (zero:occasional:always). The main fertilisers used in *milpa* production were urea, ammonium sulphate and super-phosphate.

Adoption of Non-burning (Fig. vi)

5 farmers adopted non-burning cultivation, while one farmer reverted to burning having begun the period using non-burning techniques. Of the 6 farmers who began to cultivate land in their own right during the period studied only 1 adopted non-burning methods. Between 1984-89 the ratio of non-burning:burning shifted from 1:21 to 5:22. Despite the trend of non-burning adoption there were more farmers burning to cultivate at the end of the period than at the beginning.

Fig. 4.i.

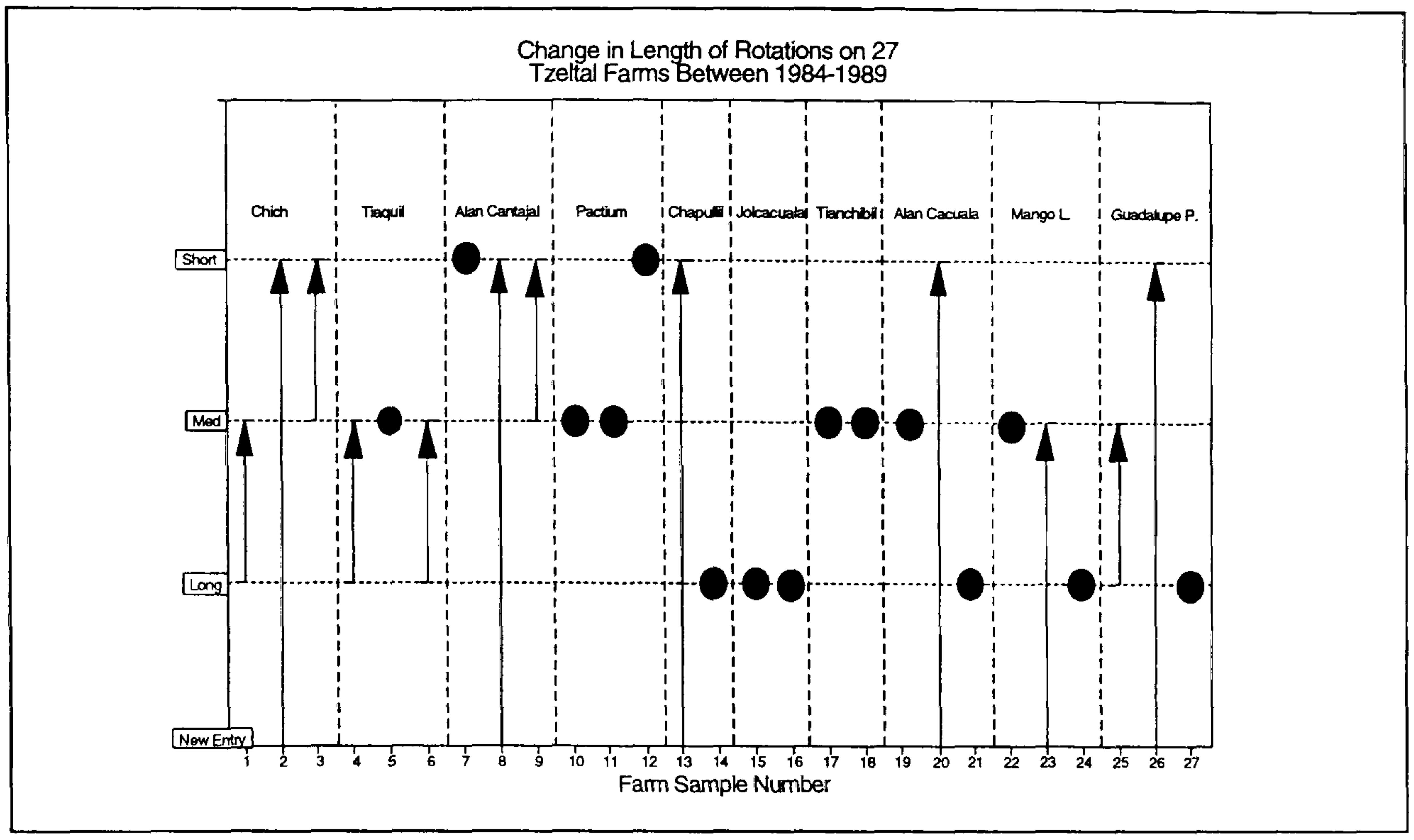



Fig. 4.ii.

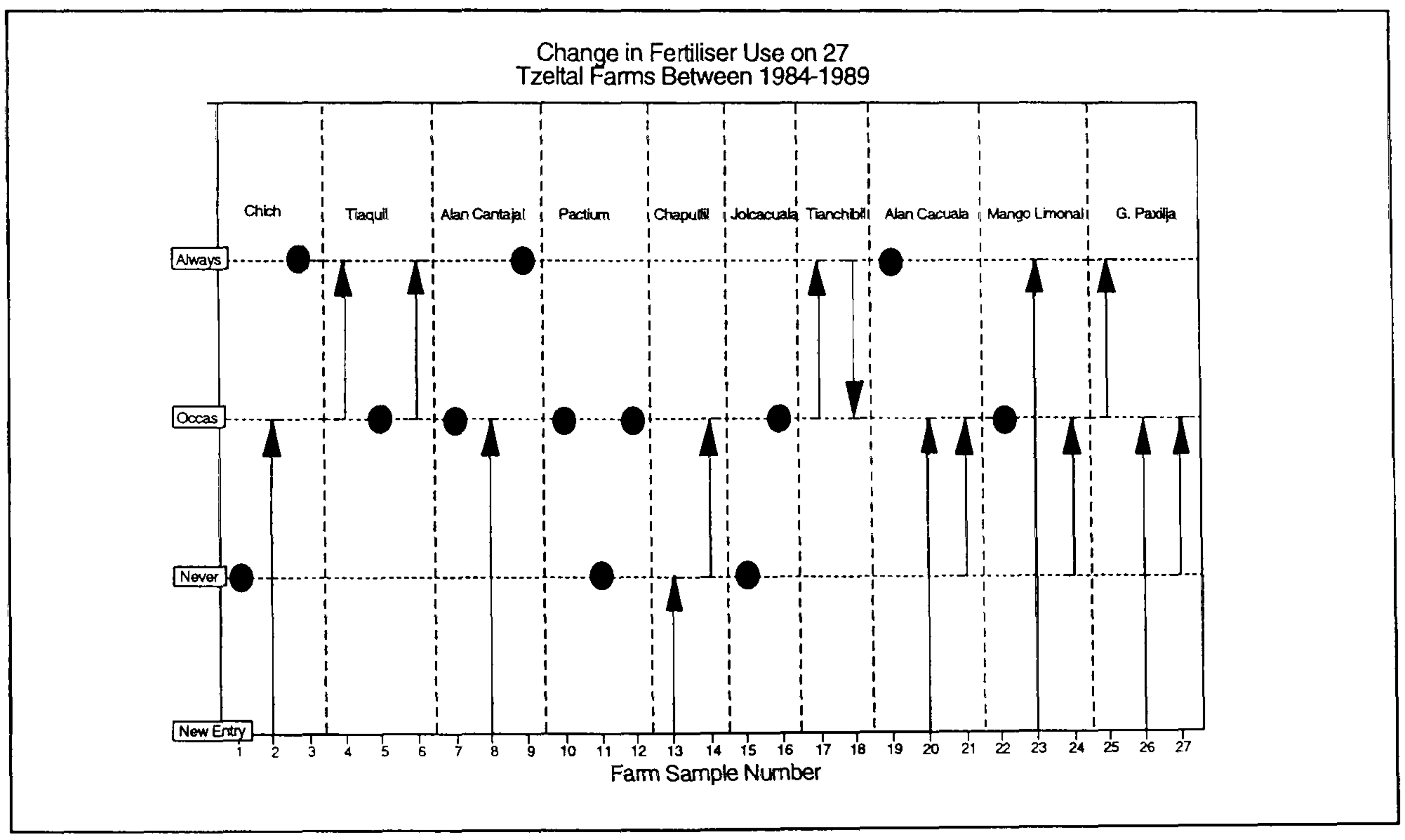
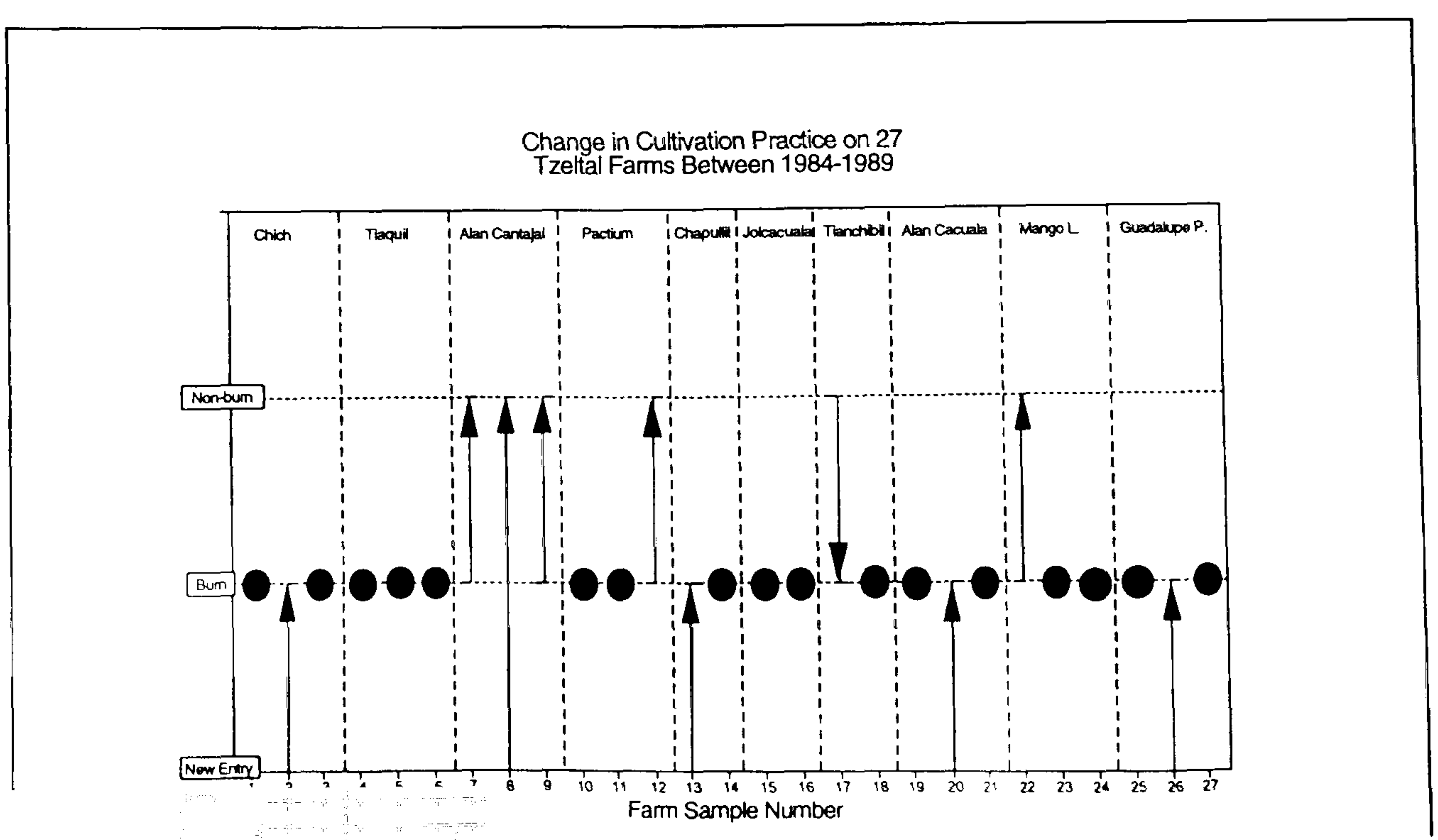



Fig. 4.iii.



Use of Herbicides

Unfortunately, the data collected on herbicide adoption was incomplete. However, general results of herbicide usage, according to the 1989 categories of farmers are given in Table 4.12. Overall, 22 out of 27 farmers made use of herbicides between 1987-89. Of the 5 farmers who did not use herbicides, 3 also used no fertiliser. The most common substance used was gramoxone. Despite the apparently high rate of usage none of the farmers said that they would apply weed killer every year. The following factors would be taken into consideration before spraying: (1) the availability of cash to buy herbicide, (2) the growth of weeds in relation to the crop, (3) the possible value of the time saved by spraying as compared with conventional weeding. Farmers estimated, on average, weed killers saved about 15 working days per hectare.

Other Changes

Seed Varieties

Whilst some farmers had experimented with commercial seed the general opinion was that any benefits obtained from yield increases were lost due to the poor storage characteristics and inferior taste. One farmer made the interesting comparison that a ball of *pozol* (drink made with ground maize and water) made from local maize supplied enough *fuerza* (energy) for three hours' weeding but the same ball made from commercial maize would only sustain him for only two hours.

Planting Density

Few changes had been made to traditional plant spacing's usually 40x50 cm or 50x50 cm, with 4-6 seeds sown in each hole.

Green Manures

Two farmers were using a leguminous cover crop (*Mucuna sp.*) to smother weed growth in part of the *milpa*. This was cut back and partially incorporated into the soil before maize planting. Apparently this is an old Mayan technique which may be coming back into use. The small black beans produced by this vine can be brewed to produce a beverage reminiscent of granulated coffee; hence its local name, *"Nescafé"*.

Change According to Geographical Location

Both the frequency and nature of the changes in cultivation practices on each farm varied between communities, with Pactium and Jolcacuala showing no change over the period. Farmers in Chich adopted shorter rotations but did not increase their fertiliser use whilst those in Tiaquil, Alan Cacuala, Mango Limonal and Guadalupe Paxilja tended to shorten rotations and increase fertiliser use. All farmers in Alan Cantajal adopted non-burning cultivation but the two farmers interviewed in Tianchibil appeared to have "regressed" technically; one abandoning non-burning cultivation and the other reducing the input of fertiliser.

**Table 4.12 Use of herbicides by farmers 1987-89, according to categories of fertiliser use and rotation.**

| Rotation | Use of Fertiliser | | |
|---|---|---|---|
| | Never | Occasional | Always |
| Short | 0/1 | 6/6 | 2/2 |
| Medium | 0/2 | 4/4 | 5/5 |
| Long | 1/1 | 4/5 | 0/0 |

Number of farmers using herbicides / Number in category

### 4.3.2 The Results of Changes in Milpa Production

Table 4.13 summarises the results obtained from questions about *milpa* productivity during the period 1987-89.

Average Yield of Maize from *Milpa* Cultivation 1987-89

The highest of the average yields, (around 2.2 tonnes / ha). were obtained by the regularly fertilised, short rotation *milpa*. The lowest yields of about 1 tonne / ha. were from the unfertilised, short rotation *milpa*. The average yields from non-burned cultivation was 200-400 kg / ha lower than the equivalent category of conventionally cultivated *milpa*. Variations in the length of rotations had no clear effect on average yields within this period.

Average Changes in Maize Yields from 1987-89

During the period from 1987 to 89 climatic conditions in the Tzeltal region were relatively stable. Several farmers did comment however, that the total yearly rainfall was now lower and more sporadic than ten years ago. Despite this fact, soil moisture deficits did not appear to be critical, as they have been for some time in the Comitán Plane, just 150 km to the north. All conventionally cultivated *milpas* with short or medium rotations gave decreasing yields over the period. Yields decreased most rapidly in the non-fertilised, short rotation *milpa*. Stable yields were obtained from conventionally cultivated, long rotation *milpas*. Yields in all *milpas* cultivated using non-burning methods increased (Table 4.14).

**Table 4.13 Average yields of maize from 1987-89 (kg/ha) according to categories of Tzeltal farmers**

| Rotation | Use of Fertiliser | | |
|---|---|---|---|
| | Never | Occasional | Always |
| Short | 1080 [ - ]<br>(n=1) (n=0) | 1580 [1386]<br>(n=3) (n=3) | 2240 1860]<br>(n=1) (n=1) |
| Medium | 1320 [ - ]<br>(n=2) (n=0) | 1566 [1280]<br>(n=3) (n=1) | 1542 [ - ]<br>(n=6) (n=0) |
| Long | 1290 [ - ]<br>(n=1) (n=0) | 1760 [ - ]<br>(n=5) (n=0) | |

[]= Average for non-burning cultivation; ()= number of farmers in category

**Table 4.14 Average change in maize yields between 1987 - 1989 (kg/ha) according to categories of Tzeltal farmers.**

| Rotation | Use of Fertiliser | | |
|---|---|---|---|
| | Never | Occasional | Always |
| Short | -240 [ - ]<br>(n=2) (n=0) | -60 [+493]<br>(n=3) (n=3) | -180 [+120]<br>(n=1) (n=1) |
| Medium | -240 [ - ]<br>(n=2) (n=0) | -120 [+300]<br>(n=3) (n=1) | +250 [ - ]<br>(n=6) (n=0) |
| Long | 0 [ - ]<br>(n=1) (n=0) | -8 [ - ]<br>(n=5) (n=0) | |

[ ] = average for non-burning cultivation

The Productivity of Labour

Data on labour productivity was collected for 9 different categories of production (Table 4.15).

Labour requirements per hectare:

It was found that under conventionally cultivated (burned) *milpa*, short and medium rotations required less labour for clearing. Non-burning *milpa* required more labour for clearing, sowing and weeding. Conventionally cultivated, long rotation *milpa* required the least weeding during the Summer and the lowest total amount of labour. Non-burning *milpa* required the highest amount of labour.

Yield per work-day:

The highest yield per work-day (around 18 kg maize / w.day) was achieved by conventionally cultivated, regularly fertilised, short rotation and occasionally fertilised, long rotation *milpas*. The Non-burning production gave low labour productivities (approximately 11-14 kg maize / w.day).

### 4.3.3 Sources of Information on Technological Innovations.

Artificial Fertilisers and Herbicides

All the farmers expressed the opinion that the advantages and disadvantages of these inputs were now common knowledge. Most of them became aware of these innovations through observing neighbours and farmers in other communities. Some farmers first experience of using fertiliser in the *milpa* was in 1976, when an INMECAFE programme distributed fertiliser which was supposed to be used for improving coffee production.

Non-burning Cultivation

Farmers had heard about the benefits of non-burning cultivation from various different sources. Some of these sources were more credible than others. Those farmers who had adopted non-burning methods stated that personal experience or trying out a new method of production was the only sure way of finding out whether it really worked. Everyone was observant of their neighbours methods and of the results that were obtained, but could not always believe what their neighbours told them. Extension agents, from either the churches or the local cooperatives were more credible than government sources. This was because these workers actually went into the fields to explain and talk to farmers, rather than just visiting the village centre. The language used to convey messages was also important: one farmer commented that "...when we speak in Tzeltal it comes from the heart and the *milpa* is a thing of the heart".

**Table 4.15. Estimated work-days required to complete task over 1 Ha. for each type of cultivation.**

| Fertiliser Rotation Burning/Non | No Long B | Occas Long B | Occas Med B | Occas Shor B | Always Med B | Always Short B | Occas Med N | Occas Short N | Always Short N |
|---|---|---|---|---|---|---|---|---|---|
| Clearing (E. Spring) | 32 | 32 | 24 | 22 | 24 | 22 | 35 | 32 | 32 |
| Burning (E. Spring) | 6 | 6 | 4 | 4 | 4 | 4 | 0 | 0 | 0 |
| Sowing (L. Spring) | 18 | 18 | 18 | 18 | 18 | 18 | 20 | 20 | 20 |
| Fertilising (L. Spring) | 0 | 5 | 5 | 5 | 16 | 16 | 5 | 5 | 16 |
| Weeding 1 (L. Spring) | 7 | 9 | 17 | 19 | 19 | 21 | 19 | 18 | 23 |
| Weeding 2 (Summer) | 7 | 7 | 15 | 16 | 15 | 16 | 17 | 18 | 17 |
| Doubling (Autumn) | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| Harvesting (Autumn) | 15 | 16 | 15 | 16 | 18 | 18 | 17 | 17 | 18 |
| Total | 90 | 98 | 103 | 105 | 119 | 120 | 118 | 115 | 131 |
| Yield/day | 14.3 | 18.0 | 15.2 | 15.0 | 12.8 | 18.7 | 10.8 | 12.1 | 14.2 |

E. Spring= Early Spring, L.Spring= Late Spring, B= Burning, N= Non-burning.

<u>Obstacles and Constraints to Production Improvements</u>

Responses to an open question about the obstacles to improvement in the *milpa* were varied. Some farmers seemed to blame themselves, saying that they could not think clearly about the future and that they just kept doing things in the same way even though they could see that the results were not good. In one community, a discussion on the importance of credit produced two conflicting opinions. One group maintained that credit was necessary in order to buy inputs and increase production while another said that credit was more of a hindrance as it always arrived late and people ended up spending it on food or alcohol, after which they could not repay it. Several farmers mentioned that they needed more land but that there was little chance of being able to get any. Technical advice was also mentioned as being important, with farmers particularly interested in how best to use fertilisers and control weeds.

## 4.4 Technological Change in Coffee Production

The results of the survey of the inputs and outputs of coffee systems on 85 indigenous smallholder farms in three ethnic zones are presented in this section. Coffee production is described as a component of the farm household system. The process of technological change, resulting in plantation improvement is then described. The methods used are described in (3.3), for discussion of these results see (5.3).

### 4.4.1 Inputs to Coffee Production

Household Land Use

Data for land use on the farms included in the survey are given in Table 4.16.

**Table 4.16 Household Land Use in Three Zones (hectares)**

| ZONE | CHO'L | TZOTZIL | TZELTAL |
|---|---|---|---|
| No. of Farms Sampled | 59 | 24 | 25 |
| Av.Tot.Area | 5.73 | 5.25 | 16.08 |
| Av.Maiz.Area | 1.31 | 1.52 | 1.14 |
| Av.Coffee.Area | 2.09 | 1.89 | 1.80 |

Data Source: Questionnaires from 2-3 "typical" farmers from each community

The Cho'l and Tzotzil households had between 5 - 6 hectares of land, on average. In the Cho'l zone families had the greatest ratio of coffee : maize area (1.59/1). Despite having the largest total area of land available for cultivation per family the Tzeltal farmers tended to grow fewer hectares of coffee. This indicated that labour availability for weeding the coffee plantations could have been a constraining factor in the Tzeltal region.

Labour

Average labour inputs to coffee per hectare and per family are given in tables 4.17 and 4.18, for each zone. The total amount of labour invested in coffee production each year per family varied from 177 man-days in the Tzotzil zone to 254 man-days in the Tzeltal zone. Interestingly, the amount of labour invested in coffee harvesting for each of the three zones was similar to the amount of labour invested in coffee cultivation activities (see description of coffee labours in Appendix 5).

Families in the Tzeltal zone invested substantially more labour in coffee production both on a per family and a per hectare basis. This occurred despite cultivating smaller areas of coffee per family. This was explained by farmers who said that the growth of runner grass weeds in the Tzeltal zone was more vigorous. This is probably due to the lower mean altitude of coffee plantations in the Tzeltal zone (700-800m compared with 800-900m in the Cho'l and Tzotzil regions) and associated higher temperatures.

**Table 4.17 Labour Input To Coffee Production in Three Zones**

| **Average number of labour days invested in coffee per family per year** | | | | |
|---|---|---|---|---|
| **Zone** | **Production** | **Harvest** | **Processing** | **Total** |
| Cho'l (n=59) | 93 | *95 | 33 | 222 |
| Tzotzil (n=24) | 77 | 78 | 21 | 177 |
| Tzeltal (n=25) | 112 | 109 | 32 | 254 |

*estimated from smaller data set (n=12)

**Table 4.18 Labour Input to Coffee Per Hectare in Three Zones**

| **Average number of labour days invested per hectare each year** | | | | |
|---|---|---|---|---|
| **Zone** | **Production** | **Harvest** | **Processing** | **Total** |
| Cho'l | 43 | NA | NA | NA |
| Tzotzil | 39 | 41 | 12 | 93 |
| Tzeltal | 60 | 61 | 18 | 139 |

Cash

In all cases, it was found that cash inputs to coffee production were highly variable and depended upon the availability of money within households at the times when inputs were needed. The availability of credit for coffee production was the main factor determining the use of capital in coffee production. Unfortunately for the farmers in the study the local credit union had been unable to distribute credits for the past two seasons due to economic problems associated with the collapse of the international coffee market and the over-valuation of the Mexican peso on international exchanges.

Hired Labour

Many farmers hired additional labour during the coffee harvest. Most of this came from the central highlands and from landless peasants within the area. However, there were a growing number of Guatemalan seasonal workers entering the Cho'l and Tzeltal zones during the harvest months. The Tzotzil zone is less accessible from the Guatemalan border. Table 4.19 shows the average and maximum amount of cash spent on hired labour during the 1989-90 coffee harvest. Cho'l farmers hired the most labour (on average around 130 $US) and Tzotzils the least (only about 35 $US).

**Table 4.19 Cash spent hiring labour for coffee harvest in 1989-90 season**

| Zone | Average | Maximum |
|---|---|---|
| Cho'l | 392.5 | 2,300 |
| Tzeltal | 309.6 | 1,280 |
| Tzotzil | 107.0 | 1,390 |

Transportation Costs of Coffee Commercialisation

Unfortunately, reliable figures for the cost of transport of harvested coffee to receptions points were only obtained for the Tzotzil zone (Table 4.20). However, given the greater distances between the coffee reception centres and the greater costs of transport per kilometre in the Cho'l zone it can be estimated that transport costs would be almost double those of the Tzotzil zone. Transport costs in the Tzeltal zone were thought to be minimal due to the relatively short distances involved.

**Table 4.20 Cash spent transporting harvested coffee to reception points. (pesos)**

| Zone | Average | Maximum |
|---|---|---|
| Tzotzil | 36.5 | 80.0 |

Many farmers reduced their cash outlays at the beginning of the harvest by selling at the farm gate to intermediaries (*Coyotes*), who provide their own transport. These buyers offered low prices: 30-50% below those of the regional merchants. However they provided farmers with some cash with which to pay for harvest labour and transport for the bulk of the crop.

Fertiliser

The cash spent on fertiliser was highly variable, as purchases depended upon both the supply of material and credit. When both were available, farmers usually applied between 7-12 sacks of "18-12-6" or "17-17-17" per hectare, at a cost of between 180 pesos to 290 pesos.

#### 4.4.2 Outputs From Coffee Production

The average outputs of parchment coffee from the production systems, for all types of producers from the three zones from 1987-1989 were as shown in Table 4.21.

**Table 4.21 Production and yields of coffee from farms in three zones between 1987-98 (Sacks of Parchment Coffee (57.7kg)).**

| ZONE | CHO'L | TZOTZIL | TZELTAL |
|---|---|---|---|
| **Av.Prod. '87** | 16.37 | 16.85 | 16.48 |
| **Av.Prod. '88** | 17.08 | 17.25 | 16.40 |
| **Av.Prod. '89** | 16.06 | 17.46 | 16.80 |
| **Av.Prod. '87-9** | 16.50 | 17.18 | 16.56 |
| **Av.Yield '87** | 7.84 | 8.94 | 9.16 |
| **Av.Yield '88** | 8.18 | 9.15 | 9.11 |
| **Av.Yield '89** | 7.69 | 9.26 | 9.33 |
| **Av.Yield '87-9** | 7.90 | 9.12 | 9.20 |

In general, the average outputs were remarkably similar in each of the three zones and for each of the three years. The average production per family stayed between 16 and 18 sacks each year. Average yields per hectare stayed between 7.5 and 9.5 sacks. Yields in the Tzotzil and Tzeltal zones rose by about 10 per cent over the period. In the Cho'l zone however, yields fell by 10 percent in 1989. This was probably due to frost damage (though, according to reports by farmers, only plantations above 950 metres were affected).

Many farmers in the Tzotzil zone also complained of frost damage in the 1989-90 cycle. This was said to have affected plantations where the shade had been reduced (normally these would be the higher yielding plantations). Furthermore, Tzotzil farmers complained of small bean size; possibly a combination of effects of cold spells during the fruit filling stage, poor fertilisation and an increase in some areas of leaf rust. While the yield per hectare of plantations was highest in the Tzeltal zone, the production per family was greatest in the Tzotzil.

**Table 4.22 Annual family income from coffee production ($=US):**

| | | Cho'l | Tzotzil | Tzeltal |
|---|---|---|---|---|
| 1987 | Production (qq) | 16.37 | 16.85 | 16.48 |
| | Price ($/qq) | 85 | 92 | 87 |
| | Income ($) | **1391** | **1550** | **1444** |
| 1988 | Production | 17.08 | 17.25 | 16.40 |
| | Price $/qq | 94 | 94 | 89 |
| | Income $ | **1606** | **1622** | **1460** |
| 1989 | Production | 16.06 | 17.46 | 16.80 |
| | Price $/qq | 64 | 58 | 60 |
| | Income $ | **1028** | **1013** | **1008** |
| | AV. Income | 1342 | 1395 | 1304 |

qq = 1 quintal (sack of 57.7 kg)

Average household incomes from coffee production rose and then declined over the three year period (Table 4.21). This was due mainly to fluctuations in the national and international price of coffee, beyond control of buyers in the Chiapas region. Average family income from coffee for all three zones ranged from about $1000 to $1620 US, over the period. While the study did not cover prices in any detail outside the three year period it is known that the average price per quintal fell again, substantially to around $50 in the 1990-91 harvest, causing considerable hardship among many coffee producers.

### 4.4.3 Categories of Farmers Within the Three Zones

As explained in the methodology (3.3.2), farms were divided into three general categories according to the state of their plantations at the time of the survey. In the Cho'l zone, where the survey covered a total of 59 farmers the intermediate category of plantations was divided into two sub-groups: (a) those who were developing previously rustic plantations towards a more advanced level and (b) those who had allowed previously advanced plantations to decline. This "regressive" group was not detected in either of the other two zones (probably due to the smaller number of farmers sampled) however, they represented an important phenomenon: The discontinuance[2] of the adoption of more advanced coffee production methods. In the Tzeltal zone the state of coffee plantations was such that no producers could be described as advanced. Table 4.23 shows the distribution of plantation types surveyed in the three zones.

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2. Discontinuence is defined by Rogers (1962) as the decision to cease use of an innovation after previously adopting. Most farmers of this category explained that they could get better income from bean production or that they could not afford the costs of fertiliser and wages of harvesters.

**Table 4.23 Numbers of farms in each plantation category detected in three zones**

| Plantation Type | Cho'l | Tzotzil | Tzeltal |
|---|---|---|---|
| Rustic | 30 | 10 | 14 |
| Intermediate | 9 | 7 | 11 |
| Advanced | 12 | 7 | 0 |
| Declining | 8 | 0 | 0 |

### 4.4.4 Coffee System Productivity

Production per Household

Figures 4.iv, 4.v and 4.vi show that there was little variation in the total amount of coffee harvested annually by families with different types of plantations: in each of the three zones the advanced households produced only slightly more than those with intermediate or rustic, plantations. Indeed, there is some indication that total production from households with intermediate plantations is lower. This may have been due to the extra labour committed to plantation improvement. The variations within all groups of producers were as great as the variations between them.

Average Coffee Yields

Figures 4.vii, 4.viii and 4.ix show that, unlike total household production, coffee yields were very dependent upon the state of coffee plantations.

**Figure 4.iv.**

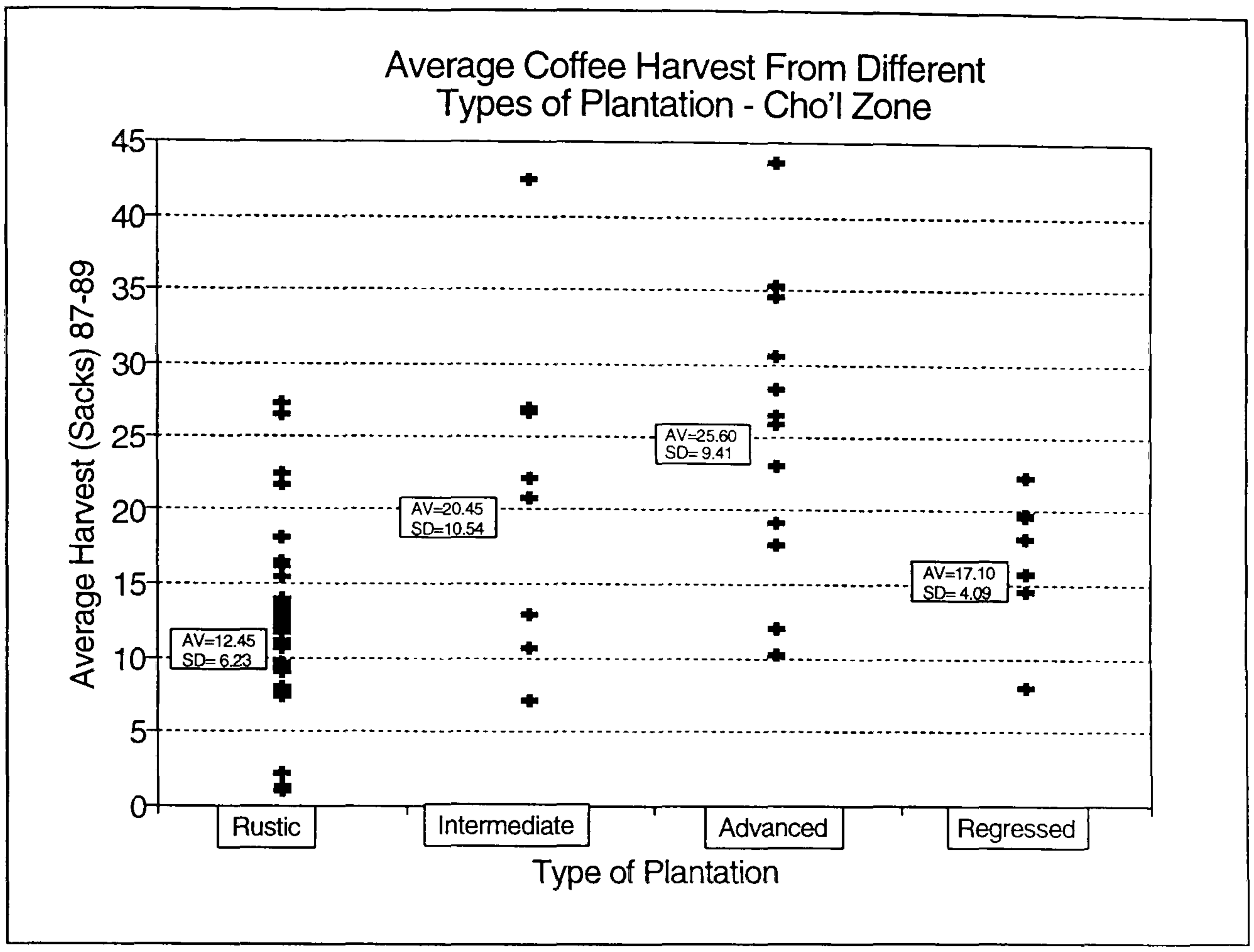



**Figure 4.v.**

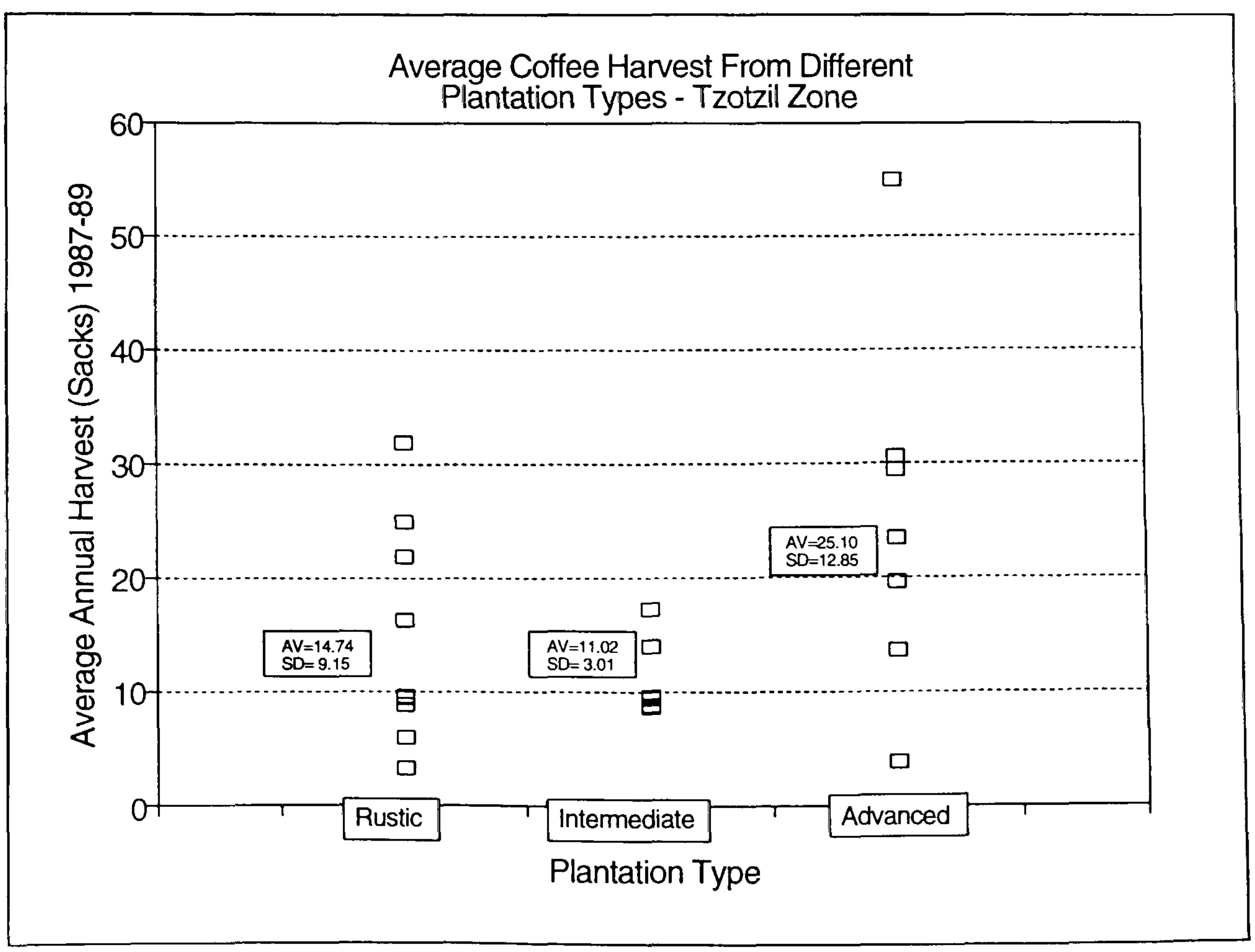


Figure 4.vi.

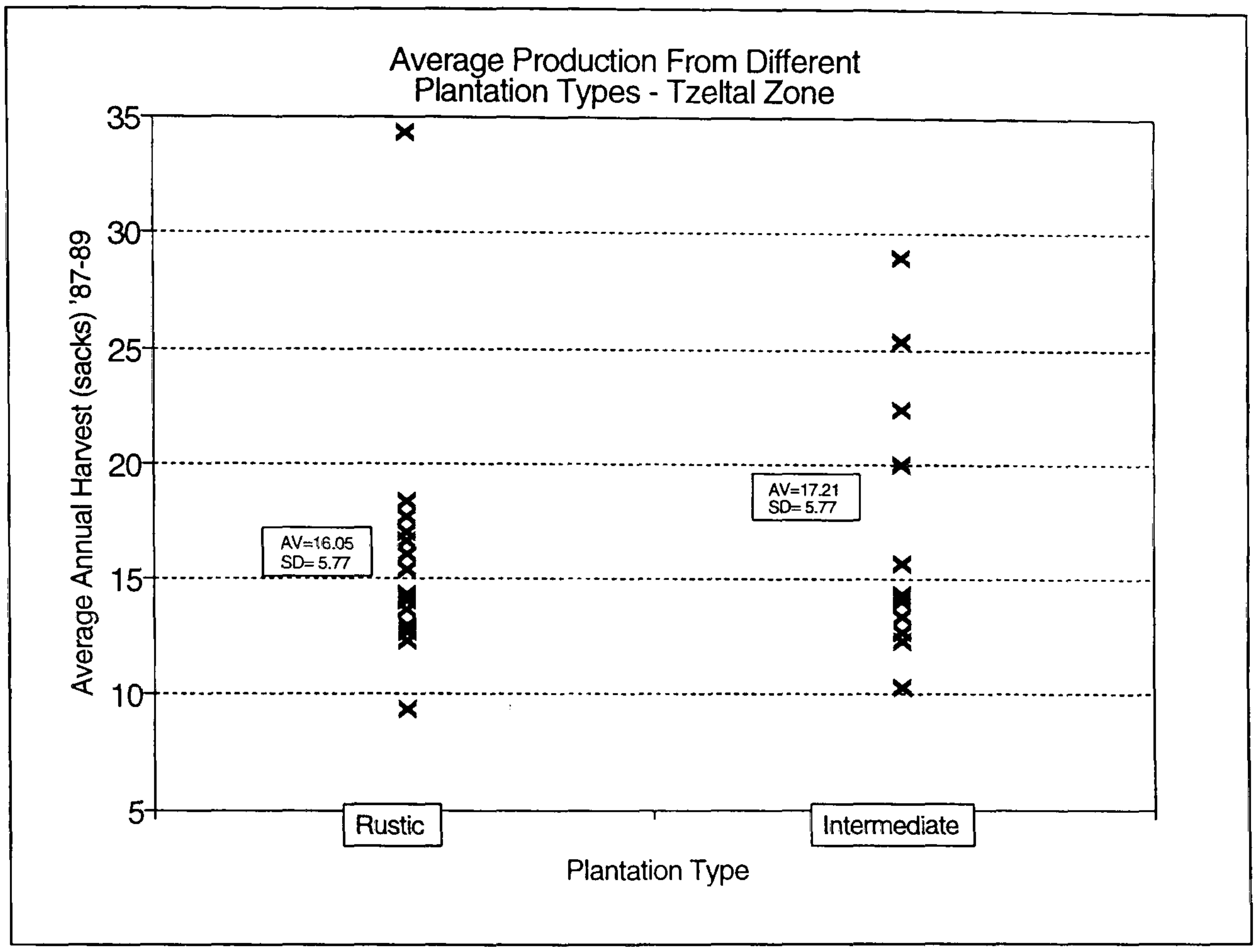



Figure 4.vii.

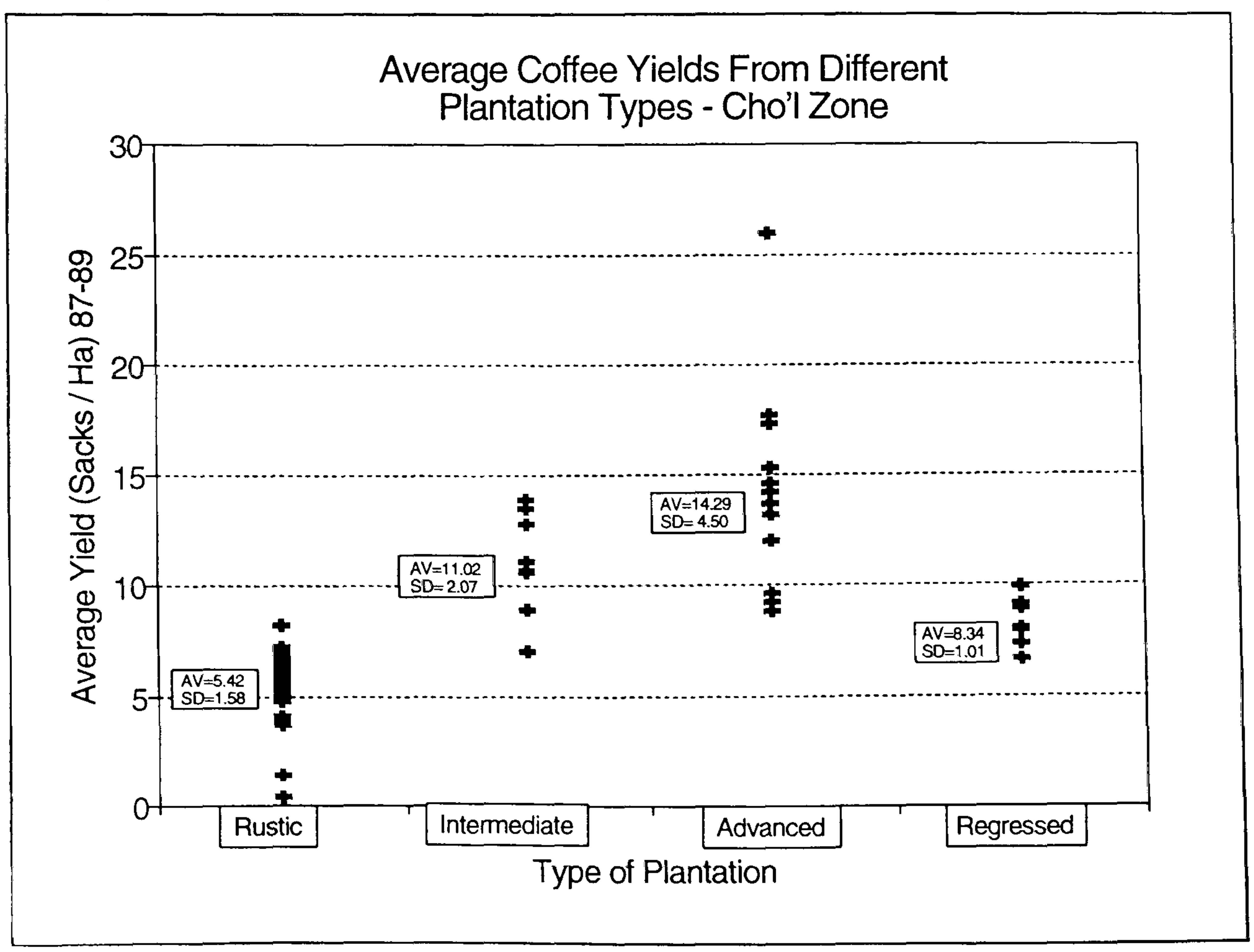


**Figure 4.viii.**

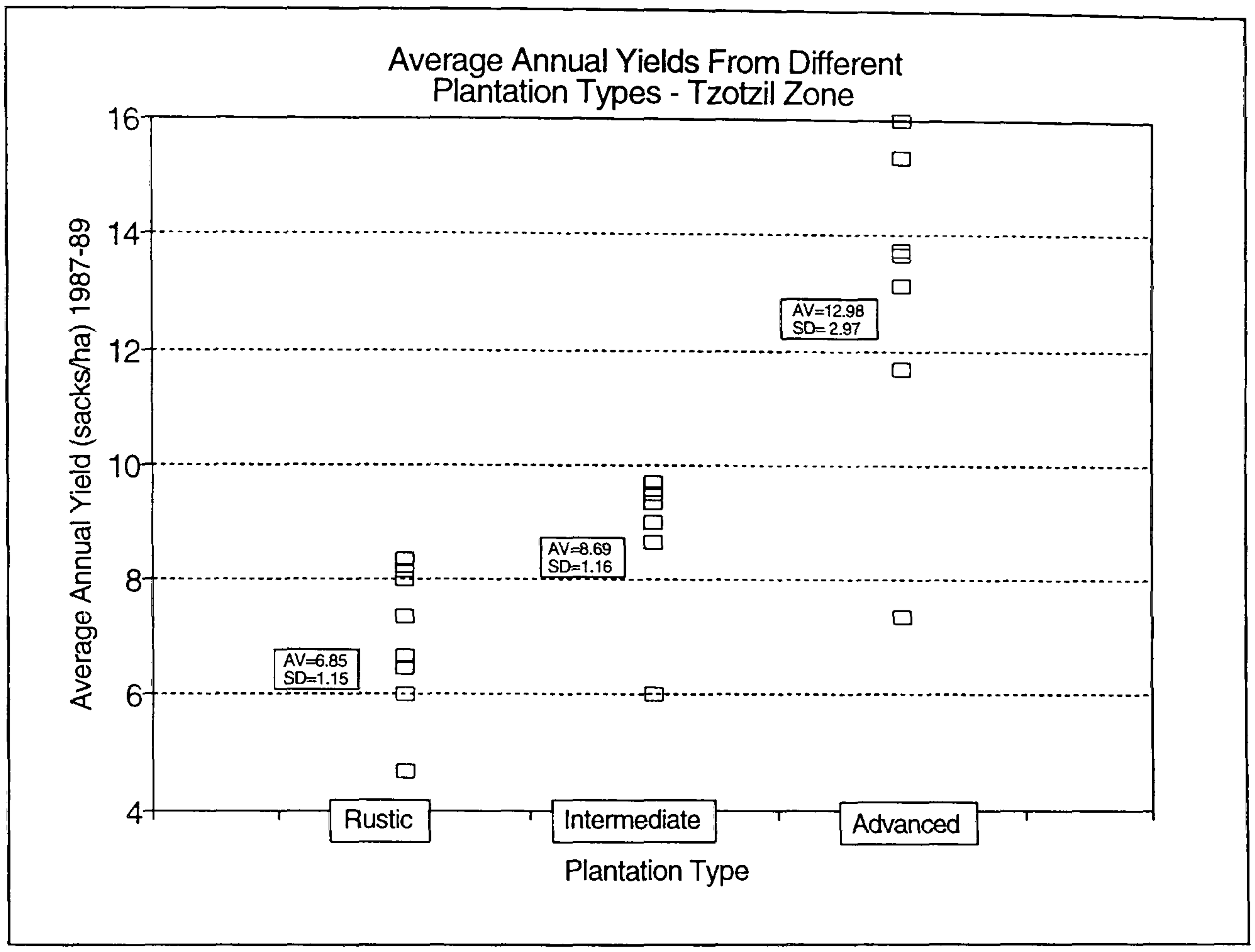
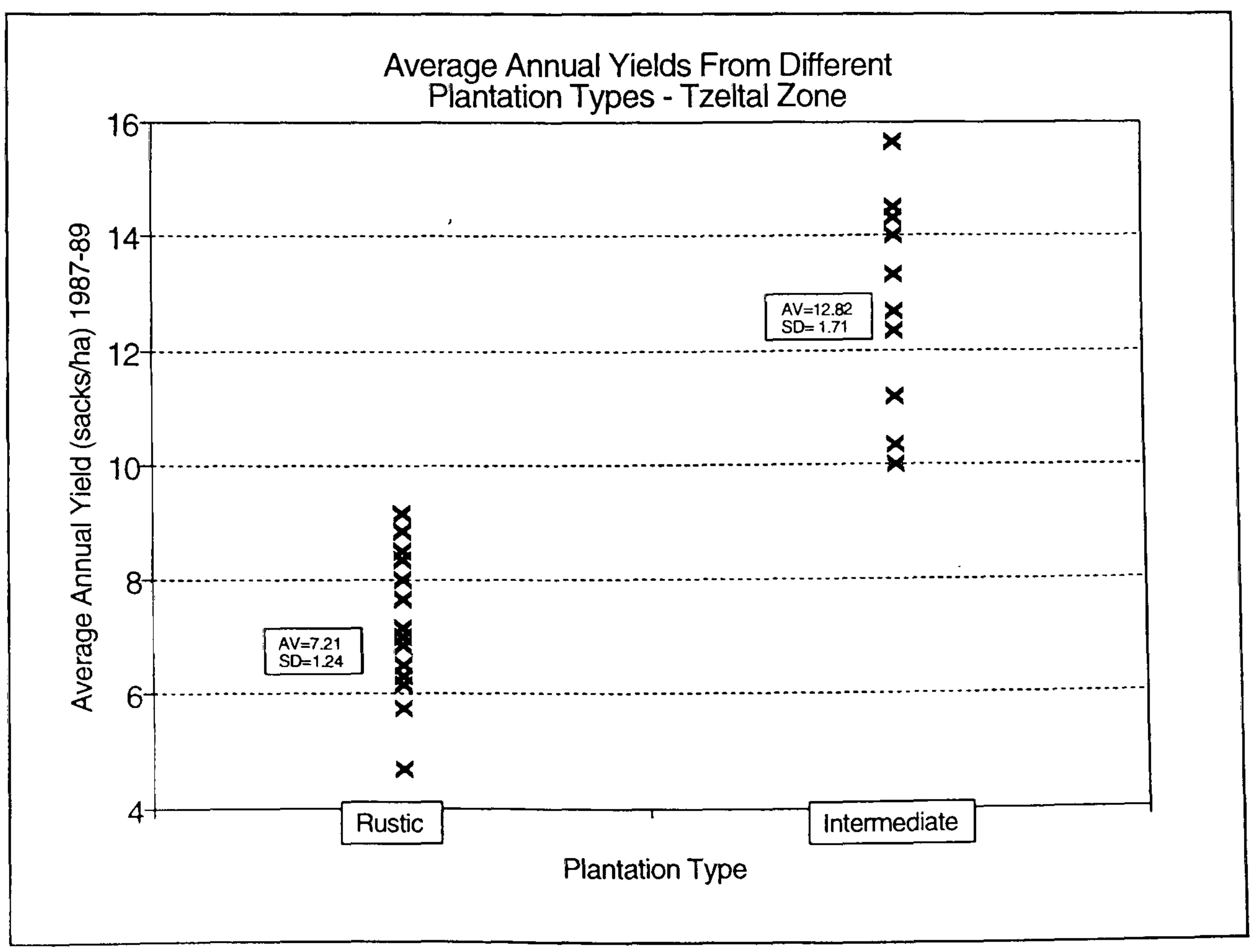



**Figure 4.ix.**



Labour Productivity

Average yield data from 1987 - 1989 was plotted against the amount of labour expended per hectare in coffee cultivation. Positive relations between yields and the number of days work were found for all categories of producers in all three zones.

Results of Linear Regression Analysis

Linear regression was carried out on these plots[3] and it was found that three correlation coefficients were significant at 95% the confidence level (Table 11).(For a full account of linear and polynomial regression analysis see Appendix 7)

Table 4.24 shows how the productivity of cultivation labour increased in more advanced plantations (e.g. from 5.8 kg harvesteable coffee produced per cultivation labour day in rustic plantations to 15.8 kg, in advanced plantations in the Cho'l zone). Furthermore, the productivity of cultivation labour in the Cho'l zone appeared to be greater than in both Tzotzil and Tzeltal zones. However, this was compensated by higher estimated constants for the untended plantations in the second and third zones.

Polynomial Regression Analysis

Polynomial regression analysis was undertaken to test the hypothesis that, for each type of plantation, any increases in the input of cultivation labour would yield diminishing returns of potentially harvesteable coffee. Polynomial regression analysis to two degree coefficients was carried out on the yield versus cultivation data for each type of plantation in each zone (full results are shown in Appendix 7). All 2nd degree coefficients were negative apart from two, which were near to zero. In Table 12 the polynomial correlation's have been converted to approximations of the expected average productivity to be achieved for (i) the first 20 man-days cultivation and (ii) the second 20 man-days cultivation (these productivity estimates do not take account of the constants estimated in the analysis).

[3] It is known that coffee systems will give a certain yield even if left completely untended during the year. Therefore, in the regression analysis the constant was not forced to zero.

While the actual values in several categories appear unrealistic (i.e., negative yield increases for increasing labour input above a certain value) due to the curve fitting algorithm used, Table 4.25 shows that the polynomial regression values indicate cultivation labour does yield diminishing returns. Furthermore, in rustic plantations the returns to increasing labour inputs become minimal at lower absolute levels of labour input.

**Table 4.24 Results of linear regression analysis of yield versus cultivation labour**

| | Slope & Constants | Cho'l | Tzotzil | Tzeltal |
|---|---|---|---|---|
| Rustic Plantations | kg / day | **5.8** | **2.0** | **3.5** |
| | constant (kg) | 117 | 390 | 235 |
| Intermediate Plantations | kg / day | **14.7*** | **8.15** | **5.1*** |
| | constant (kg) | 289 | 335 | 497 |
| Advanced Plantations | kg / day | **15.8** | **5.4** | |
| | constant (kg) | 232 | 410 | |
| Declining Plantations | kg / day | **9.11*** | | |
| | constant (kg) | 187 | | |

* Correlation coefficients ($r^2$) > 0.8.

**Table 4.25 Expected Productivity's derived from Polynomial Regression Analysis of Yield versus Cultivation labour input**

| | Productivity (kg / day) | Cho'l | Tzotzil | Tzeltal |
|---|---|---|---|---|
| Rustic Plantations | 1st 20 days | 31.3 | 12.2 | 0.1 |
| | 2nd 20 days | 6.4 | -0.8 | 1.7 |
| Intermediate Plantations | 1st 20 days | 17.9 | 56.7 | 14.5 |
| | 2nd 20 days | 12.6 | -45.7 | 9.7 |
| Advanced Plantations | 1st 20 days | 39.0 | 85.9 | |
| | 2nd 20 days | 22.3 | 55.8 | |
| Declining Plantations | 1st 20 days | 6.3 | | |
| | 2nd 20 days | 6.3 | | |

### 4.4.5 Plantation Improvement

The improvement of a coffee plantation is not an instant process, nor is it without considerable cost in terms of labour and in some cases cash. Farmers did not gain the full benefits of improvement in terms of increased yield until the fourth or fifth year. A programme of coffee plantation improvement initiated by INMECAFE in the northern highlands had promoted specific techniques to be applied by farmers across all three zones. These recommended methods had also been promoted by coffee producers cooperatives.

Replanting and Rehabilitation of Plantations

Extension agents reported two conventional techniques of coffee plantation improvement: (1) The replanting of areas where the bushes have become too old and unproductive and (2) the rehabilitation of old but sound areas of the plantation by rejuvenating pruning (*recepa*). Both methods were practised by the farmers in these areas, in many cases however it was difficult to clearly distinguish the extent of each method. Farmers would replant a few trees here and there, often underneath older trees; *recepas* would also be carried out on an *ad-hoc* basis. Even if a specific plot of land had been chosen for improvement *recepa* and replanting were often combined.

When replanting occurred farmers usually increased the density of the coffee stand. This was sometimes done by uprooting the old coffee bushes and planting a completely new stand, in most cases however, new bushes were planted in the spaces between existing ones. Most farmers also used new varieties when replanting, such as Caturra and Garnica (these are more compact therefore allowing greater densities of plants) although Bourbon is still a popular variety, particularly at higher altitudes.

Before replanting could begin farmers needed to procure new plant stock. Occasionally, one or two year old plants, ready for planting, were supplied by INMECAFE or cooperative projects. In other cases, farmers obtained their own seed, either by purchase or from their own or a neighbours plantation. These were then tended in a small "nurseries" in a part of the plantation near to the homestead. The most sophisticated of these nurseries were carefully tended and used fairly high levels of inputs to ensure the best development of seedlings (including shade provided by sacking hung on wires above the plants, fertiliser and soil disinfectant - against nematodes). A more rustic method was to allow a certain number of spontaneous seedlings to grow up around the bases of the older coffee plants; to be transplanted as and when required.

The labour efforts in replanting also varied greatly between farms. Some farmers carefully marked out the area to be replanted, with stakes placed at regular intervals along rows measured with string. A few farmers had even adopted the practice of planting in contours using simple levelling devices (water in a transparent hose, or an A-frame). Planting holes were then dug, using a short hoe (*asadon*) either 40 x 40 x 40 cm or 30 x 30 x 30 cm in size. Selected plants, topsoil and leaf trash from the nearby plantation would then be gathered and applied before the young bushes were carefully planted out. A more rustic, or ad-hoc approach to replanting would be for the farmer to bring a few young plants to the selected area each day after work and plant them in there without any careful measuring of distances or preparation of compost. The costs in time and materials for both ad-hoc and "recommended" replanting methods are shown in Table 4.26.

**Table 4.26 Input requirements for different plantation improvement methods**

| Method | Preparation of Plants (2000 plants = 1 ha) | Preparation of Land (1 ha) | Planting |
|---|---|---|---|
| Ad-hoc | Labour:<br>(15 days x 3 yrs) | None | Carrying, Making holes and Planting:<br>(45 days) |
| Recommended | Seed cost: ($50,000)<br>Nursery costs: ($400,000 x 2yrs)<br>Nursery labour:<br>(35 days) | Measuring:<br>(2 days)<br>Compost prep:<br>(6 days)<br>Planting holes:<br>(16 days) | Planting labour:<br>(16 days) |

Data source: conversations with several farmers and technicians; direct field labour measurements (1989)

No comparative results in terms of long-term productivity increases from different plantation improvement methods were available. However, most farmers and all technicians agreed that nursery propagation followed by planned replanting did give significantly superior results. Ex-nursery plants were: (1) better developed, so they would begin to yield after only two years from being transplanted (2) have lower mortality rate and longer plant life therefore requiring less replacement planting and giving rise to fewer gaps in the plantation, and (3) usually better formed and of newer varieties.

Shade Control in New or Renovated Plantations

When planting new areas of coffee farmers often used bananas to provide provisional shade. Most farmers recognised that bananas were less than satisfactory as shade for mature coffee plants: they compete strongly for water and potassium (which is required for fruit formation). However, planting with bananas ensured that the land with pre-productive coffee bushes would, at least, yield something of value. Other species used as an upper storey in the coffee system were mango, avocado, citrus, *zapote-mamey*, and *zapote-negro*. Again, these were planted mainly for the benefits of their fruits rather than for ease of shade control. Some farmers in the Tzeltal region were found to be planting timber species: caoba, caobilla and cedar despite anticipating problems with harvesting (large trees will tend to crush the coffee bushes below when they are felled).

### 4.4.6 Characteristics of Households With Different Plantation Types

Area of Coffee Cultivated

The area of plantations cultivated by different categories of farmer were not statistically different (Table 4.27). However, for all three zones there did appear to be a tendency for rustic producers to have slightly larger plots. This supports the view that intensification has taken place, at least partly, in response to reduced land availability.

**Table 4.27 Area of coffee cultivated by different classes of coffee producers in three zones (hectares)**

| | | Cho'l | Tzotzil | Tzeltal |
|---|---|---|---|---|
| Rustic Plantations | Average | **2.26** | **2.06** | **2.14** |
| | SD | 0.811 | 1.04 | 1.12 |
| Intermediate Plantations | Average | **1.83** | **1.29** | **1.12** |
| | SD | 1.00 | 0.364 | 0.48 |
| Advanced Plantations | Average | **1.85** | **2.11** | |
| | SD | 0.616 | 1.05 | |
| Declining Plantations | Average | **2.06** | | |
| | SD | 0.527 | | |

Inputs of Labour

Tables 4.28, 4.29 and 4.30 show the average annual inputs of labour to cultivation, improvement and harvesting per hectare of coffee for each type of plantation in each zone. The amount of cultivation, improvement and harvesting labour used in the advanced plantations were all greater than in the rustic and intermediate plantations. However, in the intermediate farms slightly less labour was used for annual cultivation and more was used for plantation improvement than on the rustic farms. In the Cho'l and Tzotzil zones the total amount of pre-harvest labour was actually lower in the intermediate group than in all other groups. The large amount of labour inputs into harvesting in the advanced plantations were indicative of the larger yields of coffee. In the Tzotzil zone, there appeared to be a greater emphasis on annual cultivation labours than on plantation improvement as compared with the other two zones.

**Table 4.28 Labour inputs per hectare for different categories of plantation owners in the Cho'l Zone.**

| | | Rustic | Intermediate | Advanced | Declining |
|---|---|---|---|---|---|
| **Cultivation Labour** | Av | 33.10 | 22.40 | 35.30 | 31.40 |
| | SD | 7.70 | 7.73 | 9.34 | 5.58 |
| **Improvement Labour** | Av | 9.93 | 16.80 | 14.30 | 11.60 |
| | SD | 5.42 | 6.03 | 4.19 | 4.99 |
| **Pre Harvest Total** | Av | 43.10 | 39.20 | 49.60 | 43.00 |
| | SD | 10.65 | 8.50 | 11.56 | 7.95 |
| **Harvest Labour** | Av | 27.20 | 42.40 | 47.10 | 32.10 |
| | SD | 7.95 | 7.98 | 14.73 | 3.88 |
| **Total Labour** | Av | 70.30 | 81.60 | 96.70 | 75.10 |
| | SD | 16.10 | 15.50 | 20.80 | 11.60 |

**Table 4.29 Labour inputs per hectare for different categories of plantation owners in the Tzotzil Zone.**

| | | Rustic | Intermediate | Advanced |
|---|---|---|---|---|
| **Cultivation Labour** | Av | 29.20 | 20.50 | 56.90 |
| | SD | 19.70 | 4.89 | 16.39 |
| **Improvement Labour** | Av | 2.70 | 3.70 | 9.40 |
| | SD | 4.61 | 1.75 | 7.33 |
| **Pre Harvest Total** | Av | 31.90 | 24.30 | 66.30 |
| | SD | 21.86 | 5.89 | 12.99 |
| **Harvest Labour** | Av | 39.20 | 33.90 | 52.70 |
| | SD | 19.34 | 7.49 | 26.66 |
| **Total Labour** | Av | 71.10 | 58.20 | 119.00 |
| | SD | 36.62 | 12.13 | 22.46 |

**Table 4.30 Labour inputs per hectare for different categories of plantation owners in the Tzeltal Zone.**

| | | Rustic | Intermediate |
|---|---|---|---|
| **Cultivation Labour** | Av | 51.4 | 47.1 |
| | SD | 14.70 | 13.80 |
| **Improvement Labour** | Av | 8.50 | 12.90 |
| | SD | 3.13 | 3.98 |
| **Pre Harvest Total** | Av | 59.90 | 60.10 |
| | SD | 13.10 | 16.20 |
| **Harvest Labour** | Av | 59.90 | 61.50 |
| | SD | 14.70 | 13.80 |
| **Total Labour** | Av | 119.80 | 121.60 |
| | SD | 17.64 | 21.36 |

Other Characteristics in Relation to Plantation Type

Several different characteristics are shown in relation to plantation type and zone in tables 4.31, 4.32 and 4.33.

Age of Farmers

There were no significant or consistent differences in the ages of farmers with different types of plantations. In each zone the average age of the head of the farm household was in the mid-30s.

Ratio of Land Dedicated to Subsistence and Cash Crops

In the Cho'l and Tzotzil zones the advanced coffee producers had fewer hectares of maize to each hectare of coffee. The differences between zones showed similar trends to those observed at a larger scale in the estimation of land use allocation from community land-use maps (see 4.2 and Appendix 3): the Cho'l farmers had generally lower ratios of coffee to maize than the Tzotzil farmers. The differences in maize : coffee ratios for farmers with different plantation types were not significant.

Family Size and Number of Field Workers

There were slight (non-significant) differences in the sizes of families and the supply of labour in terms of the numbers of field workers, between plantations types. Rustic households had larger families and more field workers. When these factors were multiplied (family size x number of workers) the differences were more significant. It appeared that large families with fewer workers were less likely to modernise.

**Table 4.31 Household characteristics according to plantation type in the Cho'l Zone**

| Average / Plantation | Age | Maize / Coffee | Family Size | Field Workers | Family x Workers |
|---|---|---|---|---|---|
| Rustic | 38.2 | 0.86 | 5.8 | 4.0 | 24.0 |
| Intermediate | 45.7 | 0.54 | 5.2 | 3.0 | 16.0 |
| Advanced | 33.5 | 0.50 | 5.0 | 2.8 | 13.3 |
| Declining | 36.1 | 0.49 | 5.5 | 2.5 | 14.0 |
| **SD** | | | | | |
| Rustic | 11.00 | 0.569 | 2.52 | 2.14 | 16.5 |
| Intermediate | 9.35 | 0.257 | 2.60 | 1.33 | 11.0 |
| Advanced | 10.63 | 0.191 | 1.93 | 1.74 | 8.19 |
| Declining | 13.30 | 0.209 | 1.66 | 0.50 | 5.89 |

**Table 4.32 Household characteristics according to plantation type in the Tzotzil Zone**

| Average / Plantation | Age | Maize / Coffee | Family Size | Field Workers | Family x Workers |
|---|---|---|---|---|---|
| Rustic | 36.3 | 1.0 | 5.3 | 2.4 | 13.8 |
| Intermediate | 33.2 | 1.1 | 5.1 | 2.7 | 12.3 |
| Advanced | 45.0 | 0.8 | 6.4 | 1.5 | 8.9 |
| **SD** | | | | | |
| Rustic | 14.1 | 1.07 | 3.16 | 1.20 | 17.26 |
| Intermediate | 7.71 | 0.56 | 1.81 | 0.69 | 7.34 |
| Advanced | 10.4 | 0.34 | 1.59 | 0.49 | 4.02 |

**Table 4.33 Household characteristics according to plantation type in the Tzeltal Zone**

| Average / Plantation | Age | Maize / Coffee | Family Size | Field Workers | Family x Workers |
|---|---|---|---|---|---|
| Rustic | 31.1 | 0.63 | 6.0 | 3.4 | 22.4 |
| Intermediate | 34.6 | 0.86 | 4.8 | 2.5 | 13.3 |
| **SD** | | | | | |
| Rustic | 10.78 | 0.25 | 2.10 | 1.24 | 14.3 |
| Intermediate | 9.12 | 0.22 | 2.32 | 1.07 | 11.4 |

# 5 Discussion of Fieldwork Results

In this chapter, observations made in the field, and results of the analysis of survey data are discussed. In the first section, the evidence, provided by the case studies of four contrasting locations (4.1), of socio-economic determinants of technical change within rural systems is discussed. The second section discusses the results obtained from the study of 27 Tzeltal farmers experiences of *milpa* cultivation, and leads to a systematic view of the "*milpa* improvement problem". The third section discusses the results of the survey of coffee production, and leads to a systematic view of the "coffee improvement problem".

## 5.1 The Socio-economic Context

In this section, the evidence of socio-economic determinants of technical change is discussed, for each of the four locations studied, in turn. The characteristics and effects of the land, labour and capital factor markets are presented for each location.

### 5.1.1 Chamula / Zinacantán

The main reason for the stagnation of the development of subsistence agriculture appears to be the dominating attraction of other activities; wage labour in the case of poorer families and cash crop production in the case of those who can afford to invest; see Table 5.2.

**Table 5.1 Characteristics of the socio-economic environment and likely influences on technological change in Chamula and Zinacantán.**

| Factor | Characteristics | Likely Effects |
|---|---|---|
| **Land** | (1) Skewed distribution (2) Scarcity (3) Rental and share cropping | (1) Increased intensity of production and emphasis on cash cropping for those with land. |
| **Labour** | (1) Large supply of landless labourers (2) Easy access to external labour market where wages are higher | (1) Use of hired labour for farmers with capital. (2) Reliance on external labour market by those without, thus reducing incentive to innovate. |
| **Capital** | (1) Concentration of capital distribution (2) High internal rates of interest | (1) Only those with own capital likely to invest in technology (2) Cash crops favoured. |
| **Other** | (1) Inputs readily available (2) Transport cheap (3) Food supplies secure (4) Urban market for fruit, veg. | (1) Investment and innovation in cash crop markets favoured. |

The technological development of *milpa* agriculture in Chamula and Zinacantán was not constrained by the unavailability of either inputs, credit or information. However, it was probable, that another important constraint on technological change in the *milpa* has been cultural or political. Since evangelical churches began preaching to the Tzotzils in the 1970's, many converted families have been expelled from these communities by the Catholic authorities. As non-burning maize production was one of the activities promoted by Protestant missionaries it appears to have become associated with evangelical conversion, putting those who adopted this technique under suspicion.

The development of relatively intensive cash crop production technology in Zinacantán would not have been possible without the internal markets for credit and labour. The main constraints on the further development of these systems were the capacity of the markets for clearing produce. In the case of the flower market, the main customers were Indians of other communities, who made ceremonial use of flowers. The fruit and vegetables produced in these communities were mainly consumed in San Cristóbal, which had a local population of about 85,000, and an ever increasing tourist population.

It appeared that technological change in Chamula and Zinacantán was developing along the lines of social stratification; with richer families investing in capital intensive cash crop production whilst poorer families were becoming increasingly reliant on selling labour or becoming share croppers. Local innovation in *milpa* agriculture was consequently stagnant.

### 5.1.2 San Miguel

The self-sufficiency provided by *milpa* agriculture had remained important in this area due to the uncertainty of income from cash crop markets and the poorly developed food supply markets. The main market constraint on *milpa* technology development appeared to be the lack of available credit; see Table 5.2

**Table 5.2 Characteristics of the socio-economic environment and likely influences on technological change in San Miguel.**

| Factor | Characteristics | Likely Effects |
|---|---|---|
| **Land** | (1) Even distribution (2) Purchase of land from ladino owners. | (1) Interest in increasing productivity of purchased land, both subsistence and cash crops. |
| **Labour** | (1) Small supply of landless labourers (2) Limited use of external labour market (3) Seasonal increase in demand due to coffee harvest | (1) Labour saving innovation, especially in the Winter (2) Diversification to smooth labour demand peak. |
| **Capital** | (1) Credit obtained through credit union and agencies. | (1) Capital investment and innovation favoured. |
| **Other** | (1) Inputs sporadically available (2) Transport fairly cheap (3) Food supplies insecure (4) Powerful intermediaries in coffee market. | (1) Innovation in subsistence crops favoured by the imperfections in the food supply and cash crop markets. |

The development of more intensive methods of coffee production had been made possible by the efficient transport market and the availability of agricultural inputs, but widespread adoption of these methods had been constrained by the fluctuating availability of credit. The decline in the market price of coffee has also retarded technological development as farmers concentrated on diversification of their cash sources.

In the future, both *milpa* production for food and the production of coffee and other crops for cash will probably continue to develop concurrently as long as cash crop markets remain subject to large fluctuations.

### 5.1.3 Coquija

The inadequacy of transport and agricultural supplies to Coquija were identified as the main constraints on the development and widespread adoption of more capital intensive systems. The lack of access to non-traditional product markets for selling the diverse produce from the new agroforestry systems (4.1.8, and Appendix 8), and the inadequate supplies of high quality propagative material appeared to be the main constraints on the development of alternative, improved, low-intensity systems (Table 5.3).

**Table 5.3 Characteristics of the socio-economic environment and likely influences on technological change in Coquija.**

| Factor | Characteristics | Likely Effects |
|---|---|---|
| **Land** | (1) Little activity (2) Even distribution | (1) No direct effect. |
| **Labour** | (1) Small supply of landless labourers (2) Very limited use of external labour market (3) Seasonal increase in demand due to coffee harvest | (1) Labour saving innovation, especially in the Winter (2) Diversification to smooth labour demand peak. |
| **Capital** | (1) Credit obtained through credit union and agencies (2) Little internal money-lending. | (1) Capital investment and innovation favoured. |
| **Other** | (1) Inputs almost unavailable (2) Transport very expensive (3) Food supplies insecure (4) Powerful intermediaries in coffee market (5) Increasing demand for consumer goods. | (1) Innovation in subsistence crops necessary due to imperfections in the transport, supply and cash crop markets but (2) increasing demand for capital and consumer goods has raised interest in cash crops. |

The community of Coquija is experimenting with a variety of new agricultural technologies despite the problems with inadequate markets that it faces. Indeed, these market constraints appear to have stimulated the farmers here to develop appropriate, low risk technologies.

### 5.1.4 Yaluma

It was difficult to attribute the failure of the technical recommendations given to the farmers, in this location, to purely economic factors (Table 5.4). Much of the advice given to farmers in the past ten years by technical "experts" has been inappropriate. In particular, agronomists working for the banks administering government credit refused credit to farmers who were pioneering non-burning methods of maize production, accusing them of laziness and incompetence. Other problems relating to corruption in the credit market have also been mentioned (4.1.3). The poor management of cooperative projects was another reason for the failure to develop more efficient agricultural systems. In the case of alternative cash crop development, there was inadequate demand in the local markets to make production of any of these crops profitable.

**Table 5.4 Characteristics of the socio-economic environment and likely influences on technological change in Yaluma.**

| Factor | Characteristics | Likely Effects |
|---|---|---|
| **Land** | (1) Several landless families (2) Increasing problem of drought and pests | (1) Incentive for problem solving innovations |
| **Labour** | (1) Fair supply of landless labourers (2) Substantial use of external labour market (3) Little seasonal increase in demand. | (1) Labour saving innovation only favoured if external wages available. |
| **Capital** | (1) Limited credit obtained through credit union and agencies (2) Little internal money-lending. | (1) Capital saving innovation favoured due to scarcity |
| **Other** | (1) Inputs readily available (2) Food supplies secure (3) Limited demand for alternative cash crops | (1) Innovation in alternative crops constrained by markets. |

## 5.2 Technological Change in *Milpa* Production

As expected, the main technological trends showed that *milpa* production in the Tzeltal area is becoming increasingly dependent upon external inputs as a result of decreasing duration of rotations. The yield increases obtained by the use of fertilisers more than compensates for any short term losses due to the reduced fallow. However, the long term decline in soil fertility and productivity confirm the view that the burning of short rotation *milpas* is unsustainable.

Whilst the sample size of farmers within each community was very small, the results also suggest that there may be important differences between communities with regard to both the pressures for change and the response to these pressures: in Jolacacuala, where the average land area per family is 20 hectares, farmers were able to maintain long rotations and low use of fertiliser. In contrast, 2 out of 3 Tiaquil farmers, with 10 hectares per family, both increased fertiliser use and decreased the length of rotations. In Alan Cantajal, with only 7 hectares per family the three farmers interviewed had all adopted non-burning cultivation. The widespread acceptance of this practice in this community may also have been influenced by social factors such as the strong participation by farmers in the regional credit union which has promoted non-burning for several years. The locational clustering of adoption of new farming methods has been observed in other studies of technological change in agriculture such as Robinson (1989) and Cordova *et al* (1981). This pattern of distribution supports theories of the diffusion of technological innovations by social processes involving innovators, opinion leaders and an informal diffusion network (Rogers, 1983).

A summary of the results of technological change indicates the technical and economic sustainability of the various *milpa* cultivation options observed in the Tzeltal area (Table 5.5). Conventional cultivation is only sustainable with long fallow periods or with medium length fallows plus substantial fertilisation (the second option may not be economic). Non-burning cultivation is only economically viable with short or medium rotations and some fertilisation. Remarkably, only 17 out of 27 farmers appeared to be using sustainable cultivation methods at the end of the period of study. Unfortunately, the adoption of non-burning cultivation proceeded more slowly than the adoption of shorter rotations during the period of study. This indicated that the overall processes of technological change are likely to have damaging consequences for the future productivity of agriculture in the region.

**Table 5.5 Technical and Economic Sustainability of Cultivation Options.**

| Rotations | No. Fert. | Occ. Fert. | All. Fert. |
|---|---|---|---|
| Short | N [?]a | N [Y] | ? [Y] |
| Medium | N [Y] | ? [Y] | Yc [Y] |
| Long | Y [N]b | Y [N]b | Yc [N]b |

Y= Yes, N= No; []= non-burning;
a= difficult transition due to low initial yields, b= too much work required clearing and weeding, c= may not be economic.

The need for accelerating the adoption of sustainable production methods is clearly demonstrated, in practice however, there are definite obstacles that need to be addressed: (1) the low yields obtained during the first two to three years of non-burning, (2) low initial labour productivity due to increased weeding and land preparation and (3) the lack of confidence in the recommendations of external agencies, particularly government extension agents.

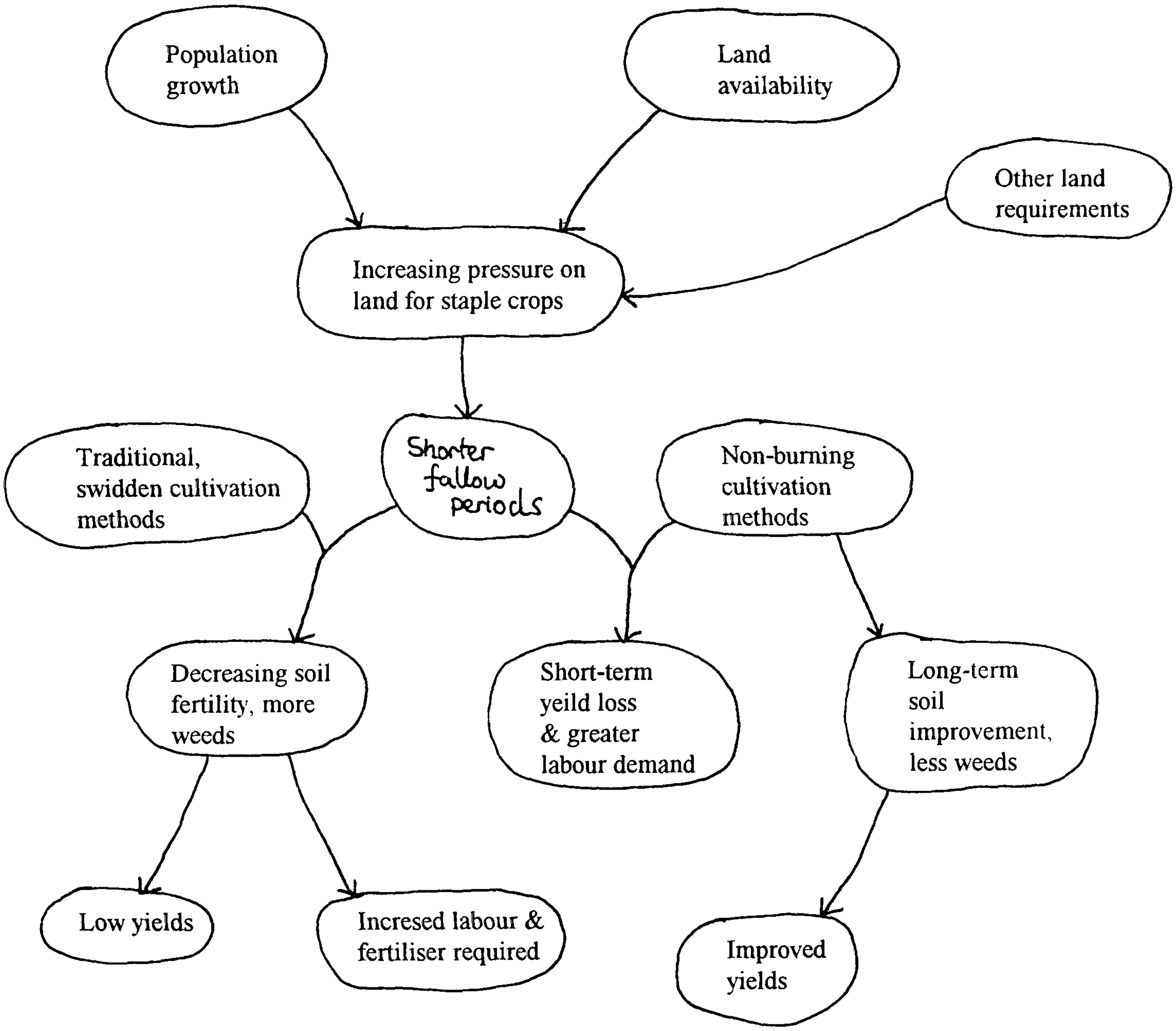
Projects designed to make improvements to the *milpa* systems in this area need to take account of farmers' attitudes towards external information sources. Native Tzeltal fieldworkers, who have themselves experienced the adoption of new techniques, will make the most convincing change agents and local organisations rather than government agencies are more likely to understand the particular constraints and obstacles to improvement that occur in each location. Unfortunately, however, most of these local organisations are currently under resourced and struggling to survive (Harvey,1990).

In (6.1) models based on the on the problem system defined in this section and represented diagrammatically below (5.2.1) are used to enable a further exploration of the problems of conflict between short term and long term maize production strategies, leading also to some predictions of future changes in productivity arising from the empirically observed technical change processes noted here.

### 5.2.1 Diagrammatic Representation of Maize Improvement Problem System

The following diagram (Figure 5.i) illustrates the causal linkages in the *milpa* system described above.

**Figure 5.i.**



## 5.3 Technological Change in Coffee Production

### 5.3.1 Coffee in the Rural Economy of Northern Chiapas

Despite the unfavourable market conditions during the late 1980s', coffee still dominated the region as a cash crop, almost to the exclusion of other alternatives. In the Tzotzil zone there had been some moves by farmers to develop cattle raising on a communal basis, and in the Tzeltal and Cho'l zones many farmers were producing winter beans for the market as well as for home consumption. Farmers throughout the region gave the impression of being worried, but undecided, about the future of coffee. Many said that they would like to improve their production, but, at the current prices it was simply not worth it. The study showed that coffee occupied about 20-35% of the total land area of most communities and demanded about 200 labour days per family, in each year. This represented some 60% of the agricultural labour. Cash inputs appeared to be more variable both between families and from one year to the next than between the three zones. The study failed to obtain accurate results of cash inputs into coffee but a rough estimate for average cash input per family per year would be 250-300 $US. The income from coffee was, on average around 1300 $US per family or 650 $US per hectare. This represented an annual income of roughly 5.4 million $US between the 120 communities surveyed for land use (4.2).

General Productivity in Perspective

The average yields of 7-10 sacks of parchment coffee per hectare would be considered uneconomical by the standards of any modern commercial plantation. In comparison, the average yields from commercial plantations in the Soconusco region of Chiapas were 20-30 sacks per hectare (Anaya, 1990). Very few of the producers in the northern highlands appear to be approaching this level. Even these, "advanced", producers were still of low intensity as compared with modern plantations, that use 2-4 times the level of chemical inputs and unshaded bushes. Apart from access to capital inputs, the commercial planters of the Soconusco also have the important advantage of an almost limitless supply of cheap Guatemalan migrant labour.

Productivity Differences Between Zones

In general, the productivity of plantations was remarkably similar between the three zones studied. While the yield per hectare of plantations was highest in the Tzeltal zone, the production per family was greatest in the Tzotzil. This may have been due to the differences in altitude between the Tzeltal and the other two coffee zones: as the temperature at the lower altitude of the Tzeltal is higher, the bushes grow faster and therefore yield more, but as weeds also grow faster in these conditions more labour input for weeding is required.

### 5.3.2 The Results of the Coffee Improvement Programmes

The results of the study of coffee cultivation practices (4.4) showed that very few farmers had fully adopted the recommendations promoted by INMECAFE and other institutions, since 1970. While nearly all the farmers interviewed in the survey were aware of the benefits[1] of more advanced plantations and most appeared to be familiar with the methods required to implement plantation improvements only 12 out of 59 Cho'l, 7 out of 24 Tzotzil and 0 out of 25 Tzeltal farmers had developed "advanced" level plantations. In the cases where the extension programme had reached farmers the most frequent response was the partial adoption of the recommended techniques to develop an "intermediate" type of plantation[2], that could neither be classified as rustic or advanced. 17 out of 59 Cho'l farmers, 7 out of 24 Tzotzil farmers and 11 out of 25 Tzeltal farmers surveyed had developed intermediate plantations.

Farmers' Adaptations of Recommendations

In almost every case, of those farmers who had developed advanced or intermediate plantations, the recommended improvement methods had been modified or adapted to suit particular, local circumstances. Many coffee growers reduced the costs of plantation improvement by planting new bushes under the old stock, thus allowing some coffee to be produced during the improvement process. The naturally occurring

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[1] The benefits of plantation development: farm data showed that following improvement plantations gave both higher yields per hectare and higher productivity of the labour invested in annual cultivation. Relatively more advanced plantations also had the capacity to absorb higher absolute levels of labour input before returns to additional inputs declined significantly. Average Yields from rustic plantations were 5.4 (Cho'l zone), 6.9 (Tzotzil zone) and 7.2 sacks / ha (Tzeltal zone); from intermediate plantations 8.68 (Cho'l zone) 8.9 (Tzotzil zone) and 12.8 sacks / ha (Tzeltal zone); and from advanced plantations 14.3 (Cho'l zone) and 13.0 sacks / ha (Tzotzil zone). The average productivity of labour was between 2 - 5.8 kg / day for rustic plantations, 5 - 14.7 kg / day for intermediate plantations and 16 - 20 kg / day for advanced plantations (4.4.4).

[2] The plantations types referred to as advanced, intermediate and rustic are characterised in more detail in (3.2.5).

shade provided by remnants of the original montane forest was usually thinned, rather than replaced entirely by *chalum*. The results of these *ad-hoc* improvements were usually plantations of intermediate quality. In the late 80's when fairly extensive areas of intermediate plantation had been established and coffee prices were still high, some farmers made further improvements, usually to selected plots of land, establishing small areas of advanced plantation. In summary, while the reality of plantation development in the northern highlands appears to be a highly irregular and unstructured two contrasting types of plantation improvement could be characterised:

The Promoted Method of Coffee Improvement

The relatively rapid transformation of rustic plantations to an advanced state by: (i) clearance of old plantation, (ii) planting of artificial shade trees at 10m intervals, (iii) preparation of the terrain for re-planting, (iv) preparation of planting material (v) planting, maintenance and fertilisation for three years until the new plantation becomes productive.

Adaptive Improvement Methods

The gradual replacement of the old varieties of coffee by new dwarf plants. New plants were sown below the older bushes or in spaces where old plants had died. The natural shade was reduced slightly but its irregular structure was not altered. The level of chemical inputs was increased gradually. Adaptive improvements could also be made to Intermediate plantations. The establishment of advanced plantations by gradual improvement of intermediate plantations was found to be costly in effort and time. The following activities were required (i) intercalary planting of new varieties amongst existing coffee plants to increase the density of the plantation (ii) replacement or selective thinning of the natural shade to produce an even, light upper canopy.

The Current State of Smallholder Plantations

As a result of different improvement practices being followed at different periods, even within the same farm, contrasting states of plantation development were often found within a very small area. Small (sub-hectare), plots of well-tended modern varieties of coffee, were sometimes found adjacent to areas of old and declining plantation on the same holding. Unfortunately, the farm survey did not measure this diversity of plantation types occurring within each farm[3] but classified the general (overall) state of each farmer's coffee producing area as either "rustic", "intermediate" or "advanced".

Shortcomings of Coffee Extension Programmes

Clearly the extension programmes in cash crop (and *milpa*) production had not achieved the intended results. The actual pattern of adoption of the new methods depended to a great extent upon the initiative of individual farmers, who transformed the promoted technical package in accordance with their particular requirements and limitations. A number of opinions were frequently expressed by a farmers, community leaders, extension workers and technical advisers who were dissatisfied with the current methods of agricultural extension.

a) Farmers and community leaders frequently commented that the recommendations of technical advisers and extension agents took little or no account of the local conditions or the different needs of farmers in widely varying circumstances.

b) Extension workers and technical advisers working in the region expressed frustration at their attempts to find a single solution, or "package" to what were actually many different problem situations. Most technical staff recognised that the incorporation of farmers' various circumstances, experiences and views of the problem of coffee improvement were vital to the success of cash crop development. However, there was no formal method available for including this information in the planning process.

Such problems with the "intervention systems" for the technological development of agriculture appear to be typical for many developing countries, (Chambers, 1983 p149-152) and (Richards,1985 ). These views supported one of the premises of the thesis: That formal methods for integrating local and specialist knowledge, in the context of agricultural improvement, are required (1.3.4).

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[3] Only a few selected farms were surveyed in a more detailed manner: maps were made of the minute differences in land and crop management on different parts of the smallholding.

### 5.3.3 Input-Output Relationships in Coffee Production

Productivity and Plantation Type

While the total amount of coffee produced by families each year showed little relation to the type of plantation from which it was produced, there were strong positive correlations between yields and the level of modernisation of plantations in all three zones. This supported the view that intensification had occurred in response to scarcity of land.

Distinct production functions were found for different plantation types in each zone. In rustic plantations the productivity of labour was very high at low levels of labour input (less than 20 days cultivation labour per year). This could be explained by the fact that the most rustic production of coffee is analogous to a primitive forest gathering system. The coffee plants, once introduced to natural forest, are effectively a wild under storey species that yields a certain amount (100-300 kg), even without any cultivation or maintenance. When these rustic plantations are cultivated the response is limited: the state of the coffee bushes and the low level of light reaching the crop through the natural canopy were the constraining factors. In intermediate plantations the response to cultivation labour was greater but to obtain this benefit it was obviously necessary for the farmer to invest labour and cash in plantation improvement. Furthermore, there was usually some loss of cash income in the short-term as improvement entailed the clearance of old bushes to make way for the new. The labour production function of the intermediate plantations also levelled-off at a higher absolute level of labour input than in the rustic plantations: intermediate plantations are therefore able to absorb more cultivation labour than rustic plantations.

Advanced level plantations were achieved as a result of further inputs of work into improvement labours on intermediate plantations. Once established, they gave even higher labour productivity's and less signs of rapidly diminishing returns to labour at high absolute levels of cultivation labour input. However, there were also some signs that cultivating advanced plantations may be more risky: (1) as with all investment decisions, the additional inputs of labour and capital required for improvement must entail some risk - adverse weather, changes in the price of coffee and illness in the family are some of the many unpredictable factors that could prejudice the investment; (2) the variability of performance of advanced coffee plantations appeared to be greater than that of other categories. However, this may have been due to the small sample size of advanced plantations (3) The damage caused by frosts at high altitudes is worse in plantations where shade is reduced or absent. (4) If annual inputs of fertiliser and weeding labour are not maintained the yields of coffee bushes will decline rapidly, possibly to below pre-improvement levels. In conclusion, for an advanced plantation to be successful, a sustained (high) level of annual inputs over several years is required. This implies some loss in the flexibility of response to changing relative prices and family circumstances.

The experiences and data from the small group of Cho'l farmers with plantations that had declined from previously advanced levels suggested that yields had fallen rapidly when fertiliser inputs had not been maintained. Their productivity had fallen to below that of the "ascending" intermediate group.

Estimated production functions of three levels of coffee systems, for application to allocation modelling using a linear programming technique are used in the following chapter.

### 5.3.4 Technical Change Decision-Making for Plantations

Plantation Improvement: Choice of Method

It was found that the replanting of plantations in an *ad-hoc* fashion, with young coffee bushes planted below the older stock, required low labour input and little cost if carried out on a small scale (usually in conjunction with other labours). A major attraction of the rustic method was that it could be executed without substantially re-scheduling other labours. Furthermore, this method did not require the same degree of forward planning as the recommended method, and as there was less capital required, there was also less risk of incurring any financial loss. Nearly all farmers agreed that this the *ad-hoc* approach did not give as good a result as the replanting a clean, well prepared site, as the younger plants tended to be retarded by competition with the established, older ones and were often cross-infected by diseases and pests. However, this method of replanting also diminished the losses incurred by the uprooting or felling the old bushes. The *ad-hoc* methods of replanting, were sufficient to transform rustic plantation types to intermediate level, but were generally inadequate for the establishment of advanced plantations.

The promoted method of replanting required high initial labour inputs (for the preparation of the terrain and the establishment of a nursery) and high initial costs. However, once the land had been prepared, less effort was required when actually planting. Furthermore, the result was nearly always better. Unfortunately due to the time constraints on the study it was not possible to determine the quantitative differences in the results of rustic and sophisticated methods of plantation improvement.

Coffee Improvement in Relation to Subsistence Production

While the evidence was not conclusive, there was some indication that producers who were in the process of improving their plantations invested less total labour (before harvest) in coffee production than other groups, including the rustic producers. A plausible explanation of this phenomenon would be that since cash was being invested in the improvement process, while income from coffee was still low, or even reduced, a household would have to rely more on the subsistence production.

Spatial, Temporal and Functional Micro-decisions

It was clear that most of the coffee farmers who were questioned, did not often make "hard" production plans, covering the whole plantation at a particular time of year. Planning appeared to be fragmented spatially, temporally and functionally: decisions would not be taken until they needed to be: For example, the allocation of a single day's labour (both where it might be applied and to what task) might not be finally decided until the night before, or even that same morning. This was most extreme with regard to pruning and replanting; nearly all farmers considered the condition of each plant in turn, rather than making systematic decisions about sections of the plantation on the basis of age or general condition. This explains the rather hotch-potch appearance of most intermediate and rustic plantations, with plants of different ages, varieties and states growing amongst each other. The fragmentation of production decision-making allows for great flexibility during the growing season, and to some extent it is inevitable as any production plan will need to be modified in the light of unpredictable factors occurring during the growing season. The lack of "hard" planning does however appear to mitigate against the systematic improvement of many plantations. Whilst micro-decision making was not specifically investigated it was also felt that the more advanced producers tended to target small areas of their plantations for improvement in a rather more systematic way.

Hierarchical Representation of Decision-Making

The decision-making processes relating to the technical change (improvement) in coffee production could be represented by four hierarchical levels of input allocation decisions: (1) allocation between coffee and non-coffee systems, (2) allocation between annual cultivation and coffee improvement, (3) allocation between rustic and sophisticated methods of plantation improvement, and (4) a micro-decision stage, at which any of the above decisions can be modified in the light of changing circumstances or micro-variations that arise during the course of the agricultural year. At each level, a number of important factors, influencing the allocation decision, were identified. Some of these criteria, such as the availability of inputs and the condition of the plantation, might be considered at more than one level, emphasising the iterative nature of the decision-making process. The answer to the questions such as "How much of given inputs should be allocated to given tasks?" depends upon qualitative criteria, such as, "How will the inputs be used?" but these questions depend, in turn, on "How much input is available?". The decision making levels and factors to be considered are shown in Table 4.6.

**Table 5.6 Four hierarchical levels of resource allocation decision criteria in coffee plantation improvement.**

| |
|---|
| 1st Level: Resource allocation between coffee and non coffee system<br><br>• Family needs in terms of food and cash and the substitutability of these goods (a family may have specific aspirations or needs such as wishing to buy a new roof or medicines that create a demand for cash and hence coffee production. However, if savings are low the demand for cash may also reduce the availability of income for investment in coffee).<br>• The availability of inputs (some requirements may be specific to coffee e.g., types of fertiliser, credit, harvest labour; the comparative requirements of other sub-systems are therefore important).<br>• The comparative returns to efforts invested in different production sub-systems based upon the experiences of previous years and the expectations (weather, prices etc.) for the coming years.<br>• The agricultural characteristics of the plantation land (slope, soil, climate) in relation to non-coffee land.<br>• The current state of the coffee plantation - its input requirements if yields are to be maintained and increased.<br>• The current area of the coffee plantation in relation to the land available for annual crops and the amount of labour available (if there is a large area of coffee established then it will require a greater amount of labour). |
| 2nd Level: Resource allocation between improvement and cultivation<br><br>• The current level of inputs into the plantation (if this is low it is likely that increased cultivation effort applied to the same plantation will be more rewarding: If the total area of the plantation is large in relation to the supply of labour then there may be less pressure to intensify).<br>• The current state of the plantation (if it is in a rustic condition there will be more to be gained from improvement)<br>• The farmer's assessment of future prices, demands and risks (particularly if an advanced plantation is being considered).<br>• The agricultural characteristics of the terrain (soil, slope, climate) that will determine the relative response to improvement of increased annual cultivation.<br>• The farmer's attitude to planning and flexibility (if "hard" plans are preferred then the farmer will favour the improvement towards an advanced state; however, if flexibility is desired then intermediate or rustic plantations will be favoured).<br>• The availability of inputs for plantation improvement (particularly new varietal material).<br>• The future availability of inputs to cultivate the improved plantation (particularly harvest labour and cash for fertiliser).<br>• Farmer and family preferences for short-term income rather than long term source of revenue. |
| 3rd Level: Resource allocation between rustic and sophisticated improvement<br><br>• The availability of inputs for sophisticated plantation improvement (labour during the late Spring, fertiliser, nursery materials and modern varieties).<br>• The state of the plantation (if it is rustic then rustic improvements will make a difference but if it is intermediate then a more sophisticated approach will be needed) |
| 4th Level: Decide How, Where and When specific tasks are executed<br><br>• The micro-plot differences between one area of the plantation and another, and between one coffee bush and another.<br>• The micro-time periods available between labours or at the end of the working day.<br>• Unpredictable occurrences during the growing season. |

### 5.3.5 Household Characteristics and Coffee Improvement

There appeared to be little relation between most of the household characteristics measured and the degree of intensification that had occurred in the coffee system. Two factors did appear to be relevant: (1) households with larger areas of coffee appeared to be more likely to be low intensity producers, thus indicating that intensification has occurred to some extent as a result of land scarcity; (2) the product of the number of workers and the total number of people in the family appeared to be negatively related to the level of intensification. This observed relationship was quite surprising, as it might be expected that where labour was available (number of workers) and where cash was in demand (total number in family) then there would be a tendency to intensify productive activities. It is possible that, in larger families, cash was diverted to purchase immediate necessities rather than agricultural investment. It is also possible that a larger number of workers for a given plantation meant that change decisions were taken more slowly or made in a less systematic way. There was no direct evidence to support this hypothesis, but most farmers said that they made important decisions about production only after consulting the other adult members of the family.

According to Chayanov (Durrenberger, 1984) there should be a positive relationship between the amount of work carried out by each worker and the number of dependants (non-workers; children and elderly) that each worker has to support. Data from the Cho'l region confirmed this hypothesis (4.4.6). The number of labour days in coffee production per worker was positively correlated to the ratio of number of workers : number of consumers.

Although the study did not specifically test for social stratification[4] the results did not contradict the general feeling that social and economic differences have not played a major part in the pattern of coffee production development in the region.

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4 This is in contrast to Stavenhagen's study of social stratification in a community in the central highlands of Chiapas (Stavenhagen, 1971).

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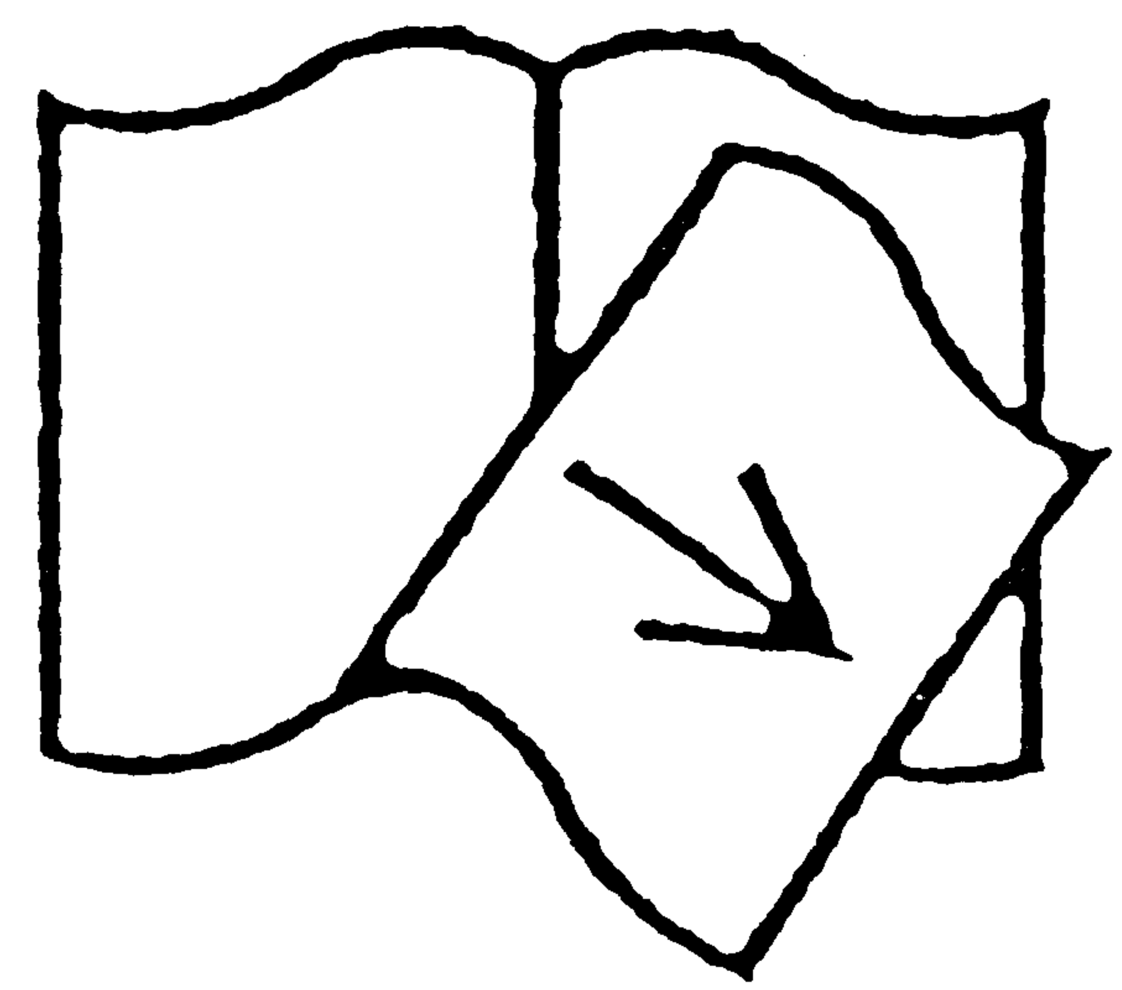
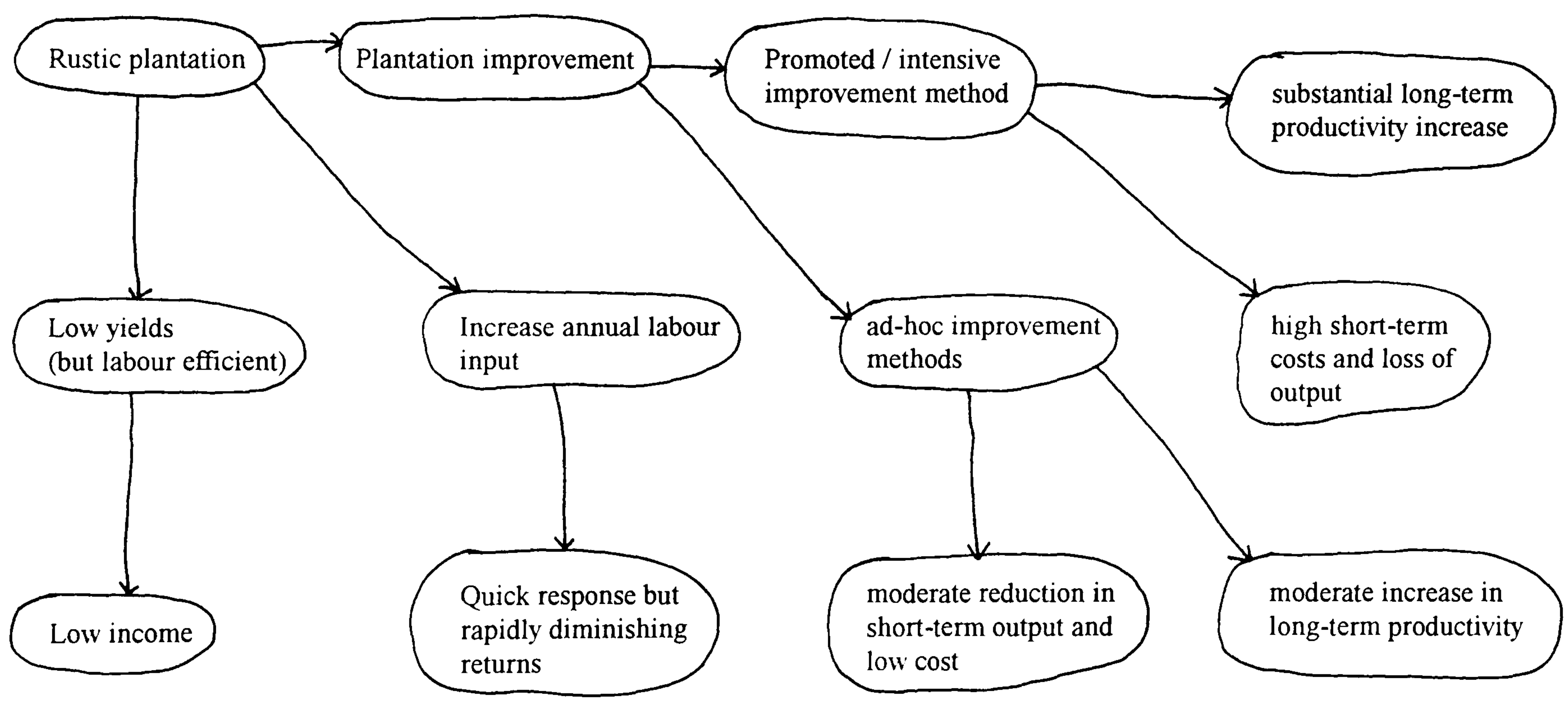
147 - 157



### 5.3.6 Diagrammatic Representation of the Coffee Improvement System

The following diagram (Figure 5.ii) illustrates the causal linkages in the coffee system described above.

**Figure 5.ii.**



# 6 Results of Modelling

## 6.1 Results from the *Milpa* System Model

This section details the results obtained by the examination of various scenarios, over five year periods, using the model (3.4.5) of the *milpa* system as defined in the discussion of the results of fieldwork, and represented diagrammatically (5.2.1). The application of the *milpa* system model included the general assumption of increasing scarcity of land. The scenarios tested were chosen to reflect the cultivation options available to farmers in the region, with the principal objective of evaluating the short and medium term costs and benefits of adopting non-burning methods of cultivation. The effect of increasing availability of cash ($0, $200 and $800) on the costs and benefits of adoption was specifically measured. The scenarios were based upon a "standard" (base case) farm, with levels of available resources that were typical of farms in the region (4.3.1). The levels of other inputs available for *milpa* production on the base case farm are given in Table 6.1. The detailed structure of the model tableau is shown in Appendix 6.

**Table 6.1 Input availability for *milpa* on the base case farm**

| | YEAR 0 | YEAR 1 | YEAR 2 | YEAR 3 | YEAR 4 |
|---|---|---|---|---|---|
| **LAND (ha)** | 15 | 12 | 9 | 6 | 3 |
| **ESPL (wd)** | 40 | 40 | 40 | 40 | 40 |
| **LSPL (wd)** | 40 | 40 | 40 | 40 | 40 |
| **SUL (wd)** | 50 | 50 | 50 | 50 | 50 |
| **AUL (wd)** | 50 | 50 | 50 | 50 | 50 |

wd= work days
ESPL= Early Spring labour, LSPL= Late Spring labour, SUL= Summer labour, AUL= Autumn labour

### 6.1.1 Ist Scenario (No cash available, no other restrictions on cultivation methods)

The first scenario tested with the model was a farm with roughly average levels of available land and labour but with no cash available for *milpa* production. The model showed that a farmer in this situation would be likely to continue to cultivate maize using unfertilised, long rotations, with burning, while sufficient land was available. As the available land was reduced (in year 3), the model predicted that the farmer would resort to selling labour to provide cash for fertiliser (in years 3 and 4). With fertiliser available, the model predicted that a new cultivation option - short rotation, occasionally fertilised cultivation with burning would be favoured (Table 6.2).

In this case, the effective annual income[1] from maize production remained constant until year 3. It then declined rapidly as the farmer was forced to seek wage labour, as a result of land scarcity. Only moderate land degradation was predicted under this scenario. This occurred because the lack of available cash effectively ensured that long rotations remained most favourable until the final year.

**Table 6.2 Scenario of Zero Cash Input (hectares of land cultivated by given method).**

| Year | Income ($) | NOF >5 B | OCF >5 B | OCF 1-4 B | OCF 0 B | ALF 1-4 B | ALF 0 B | OCF 1-4 N | OCF 0 N | ALF 0 N | HERB ICIDE | SELL LAB days |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 1880 | 6.6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1 | 1880 | 6.6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2 | 1880 | 6.6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3 | 1825 | 5.4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 |
| 4 | 1305 | 2.8 | 0 | 0 | 0.2 | 0 | 0 | 0 | 0 | 0 | 0 | 18 |
| Tot. | 8770 | | | | | | | | | | | |

**Note: Abbreviations used in tables**

Fertiliser options
NOF= no fertiliser,
OCF= occasional fertiliser,
ALF= always fertilised,

Rotation options
>5= long rotation,
1-4= medium rotation,
0= continuous cultivation,

Cultivation options
B= cultivation with burning,
N= non-burning cultivation

### 6.1.2 2nd Scenario (Limited cash available, no restrictions on cultivation methods)

With a limited amount of cash available for *milpa* cultivation, the options of fertilised, short and medium rotation *milpas* with their high short-term productivity became viable. Increasing the cash availability had the effect of reducing the (short-term) optimum length of rotations. The model predicted that, with limited capital available, farmers, using the decision criteria specified in the model, would adopt shorter rotations even when land was plentiful, (Table 6.3).

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[1] Effective annual income is the amount that the farmer would earn if he sold all the maize produced at the standard market price (800 $/kg).

The adoption of shorter rotations meant that the external labour market was not used for earning cash. This was predicted despite a projected decline in the effective annual income from $2943 in year 0 to $2248 by year 4 (due to a combination of increasing land scarcity and loss of fertility). The effective annual income from *milpas* with moderate cash inputs was higher than in the zero cash input scenario throughout the five year period. The average return of each unit of capital invested was 4.34 (calculated by comparing income with 0 capital scenario)

**Table 6.3 Scenario of Limited Cash Availability for *milpa* Production (hectares of land cultivated by given method)**

| Year | Income ($) | NOF >5 B | OCF >5 B | OCF 1-4 B | OCF 0 B | ALF 1-4 B | ALF 0 B | OCF 1-4 N | OCF 0 N | ALF 0 N | HERBICIDE | SELL LAB days |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 2943 | 0 | 0 | 2.9 | 0.2 | 0 | 0.3 | 0 | 0 | 0 | 0 | 0 |
| 1 | 2804 | 0 | 0 | 3.3 | 0.1 | 0 | 0.3 | 0 | 0 | 0 | 0 | 0 |
| 2 | 2637 | 0 | 0.6 | 3.0 | 0 | 0 | 0.3 | 0 | 0 | 0 | 0 | 0 |
| 3 | 2480 | 0 | 1.2 | 2.4 | 0 | 0 | 0.3 | 0 | 0 | 0 | 0 | 0 |
| 4 | 2248 | 0 | 0 | 2.5 | 0.1 | 0 | 0.4 | 0 | 0 | 0 | 0 | 0 |
| Total | 13112 | | | | | | | | | | | |

For key to production options, see Ist scenario, page 160.

### 6.1.3 3rd Scenario (Plentiful cash available, no restrictions on cultivation methods)

With $800 available for *milpa* production, it was predicted that the purchase of labour saving herbicide would become profitable, despite the loss of some of the bean crop. The optimum annual production plans suggest that the farmer would use fully fertilised, short rotation cultivation (Table 6.4). As a result of these choices, the effective income from production was predicted to be greater in the first 3 years. However, while the use of herbicides meant that it was possible for the farmer to cultivate a larger area, this also has the effect of increasing the loss of soil fertility due to burning. Consequently, after year 3 the predicted effective annual income fell below that of the previous scenario. The total income from production is only raised by $98, above the previous scenario, at a cost of $300 per year.

**Table 6.4 Scenario with Plentiful Cash for *milpa* Production (hectares of land cultivated by given method).**

| Year | Income ($) | NOF >5 B | OCF >5 B | OCF 1-4 B | OCF 0 B | ALF 1-4 B | ALF 0 B | OCF 1-4 N | OCF 0 N | ALF 0 N | HERB ICIDE | SELL LAB days |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 3221 | 0 | 0 | 0 | 0 | 0 | 1.5 | 0 | 0 | 0 | 1.5 | 0 |
| 1 | 2931 | 0 | 0 | 0 | 0 | 0 | 1.5 | 0 | 0 | 0 | 1.9 | 0 |
| 2 | 2642 | 0 | 0 | 0 | 0 | 0 | 1.5 | 0 | 0 | 0 | 2.3 | 0 |
| 3 | 2353 | 0 | 0 | 0 | 0 | 0 | 1.5 | 0 | 0 | 0 | 2.7 | 0 |
| 4 | 2063 | 0 | 0 | 0 | 0 | 0 | 1.5 | 0 | 0 | 0 | 3.0 | 0 |
| Total | 13210 | | | | | | | | | | | |

For key to production options, see Ist scenario, page 160.

### 6.1.4 4th Scenario (Limited cash available, only long rotations and non-burning cultivation permitted)

When the model was run with only long rotations and non-burning cultivation options permitted, non-burning cultivation was increasingly favoured as land became scarce (Table 6.5). Even when land was not a limiting constraint, it was predicted that some non-burning cultivation would be favoured. A gradual rise in effective annual income was predicted, due to increasing soil fertility. This occurred despite the reduction in land available for production.

The predicted income by year 4 was higher than either of the previous scenarios. However, the predicted total income over the whole period was lower than in the non-restricted cases, where capital was available. This result was based partly on the increased labour requirement for weeding under non-burning cultivation in the early years, which reduced the area that could be cultivated, as compared with conventional cultivation .

**Table 6.5 Scenario with non-sustainable options disallowed and limited capital availability (hectares of land cultivated by given method).**

| Year | Income ($) | NOF >5 B | OCF >5 B | OCF 1-4 N | OCF 0 N | ALF 0 N | HERB-ICIDE | SELL LAB days |
|---|---|---|---|---|---|---|---|---|
| 0 | 2318 | 0 | 4.2 | 0 | 0 | 0.4 | 0 | 0 |
| 1 | 2342 | 0 | 4.2 | 0 | 0 | 0.4 | 0 | 0 |
| 2 | 2366 | 0 | 4.2 | 0 | 0 | 0.4 | 0 | 0 |
| 3 | 2389 | 0 | 4.2 | 0 | 0 | 0.4 | 0 | 0 |
| 4 | 2379 | 0 | 2.2 | 0 | 0.4 | 0.4 | 0 | 0 |
| Tot. | 11794 | | | | | | | |

For key to production options, see Ist scenario, page 160.

### 6.1.5 5th Scenario (Plentiful cash available, only long rotations and non-burning cultivation permitted)

When the model was run allowing only long rotations and non-burning cultivation methods but plentiful cash ($800) the predicted adoption of non-burning cultivation methods proceeded immediately. Full use of fertiliser was predicted for both long and short rotations. Despite the availability of capital, the use herbicide was not favoured (in contrast to the unrestricted scenario), except in the last year. As a result of the adoption of non-burning methods a substantial rise in the effective annual income was predicted by year 4. However, the predicted total income over the 5 year period was still lower than in the unrestricted cases.

**Table 6.6 Scenario with plentiful cash available and only long rotations and non-burning cultivation permitted (hectares of land cultivated by given method).**

| Year | Income (k $) | NOF >5 B | OCF >5 B | OCF 1-4 N | OCF 0 N | ALF 0 N | HERB-ICIDE | SELL LAB days |
|---|---|---|---|---|---|---|---|---|
| 0 | 2381 | 0 | 2.7 | 0 | 0 | 0.7 | 0 | 0 |
| 1 | 2429 | 0 | 2.6 | 0 | 0 | 0.7 | 0 | 0 |
| 2 | 2480 | 0 | 2.4 | 0 | 0 | 0.8 | 0 | 0 |
| 3 | 2533 | 0 | 2.3 | 0 | 0 | 0.8 | 0 | 0 |
| 4 | 2587 | 0 | 2.2 | 0 | 0 | 0.8 | 0.1 | 0 |
| Tot. | 12412 | | | | | | | |

For key to production options, see Ist scenario, page 160.

## 6.2 Results from Coffee System Modelling

This section presents the results obtained by the examination of various scenarios, over six year periods, using the model (3.4.6)) of the coffee system as defined in the discussion of the results of fieldwork, and represented diagrammatically (5.3.6). The scenarios tested were chosen to reflect the cultivation options available to farmers in the region, with the principal objective of evaluating the short and medium term costs and benefits of different plantation improvement methods. The scenarios were based upon a "standard" (base case) farm, with levels of available resources that were typical of farms in the region (4.4.6).

### 6.2.1 Steady State Production for the Base Case Farm

The results of an initial run of the model over one year only, representing a farm with typical levels of rescues available for input to the coffee system, are shown in Table 6.7. This Base Case farm was characterised as having a mainly rustic plantation (3 ha), a small amount of coffee in an intermediate state (0.5 ha) and no advanced plantation[2].

**Table 6.7 Inputs Available for Coffee Production on the Base Case Farm**

| Input Constraints | |
|---|---|
| Rustic Plantation Land (RPL) | 3 ha |
| Intermediate Plantation Land (IPL) | 0.5 ha |
| Advanced Plantation Land (APL) | 0 ha |
| Spring Labour Days (SPL) | 50 |
| Summer Labour Days (SUL) | 60 |
| Autumn Labour Days (AUL) | 40 |
| Winter Labour Days (WIL) | 90 |
| Cash (CAS) | 400 pesos |

The estimated output from coffee cultivation on the base case farm was $1554. The predicted input of labour to the rustic plantation (RP1 + RP2) was half the full potential of the area available ($\alpha = 0.5$)[3]. The intermediate plantation was nearly fully used: only 0.3 ha at the upper end of the production curve remaining available. An estimated eleven days' hired labour was contracted to assist with the harvesting (winter labour constraint). Whilst the cash resource was not fully used, no further labour was hired as

2 For details of the characterisation of plantation types refer to (3.3.2).

3 For an explanation of $\alpha$ values see (3.4.6).

the price of harvested coffee relative to hired labour was too low (the shadow value of extra cash applied was only $0.62 per $1.0).

**Table 6.8 Input allocation and output from coffee production on the Base Case farm for Year 0 (no improvement activities)**

| Output = $1554 | | | | |
|---|---|---|---|---|
| Activities (ha) | | constraint | shadow price (k$) | resources used |
| | | RPL | 0 | 1.5 ha |
| RP1 | 1.5 | IPL | 0 | 0.47 ha |
| RP2 | 0.0 | APL | 894 | 0 ha |
| IP1 | 0.25 | SPL | 0 | 44.7 wd |
| IP2 | 0.22 | SUL | 0 | 53.9 wd |
| AP1 | 0.0 | AUL | 0 | 5.8 wd |
| AP2 | 0.0 | WIL | 12.32 | 96.7 wd |
| HLB (wd) | 11.0 | CAS | 0.62 | 266 k$ |

**Note: Abbreviations used in Tables**

Production Options
RP1= lower half of production function for rustic plantation
RP2= upper half of production function for rustic plantation
IP1= lower half of production function for intermediate plantation
IP2= upper half of production function for intermediate plantation
AP1= lower half of production function for advanced plantation
AP2= upper half of production function for advanced plantation
HLB= hired labour (working days)

Constraints / Inputs
RPL= Rustic plantation land
IPL= Intermediate plantation land
APL= Advanced plantation land
SPL= Spring labour
SUL= Summer labour
AUL= Autumn labour
WIL= Winter labour
CAS= Cash

**Figure 6.i.**

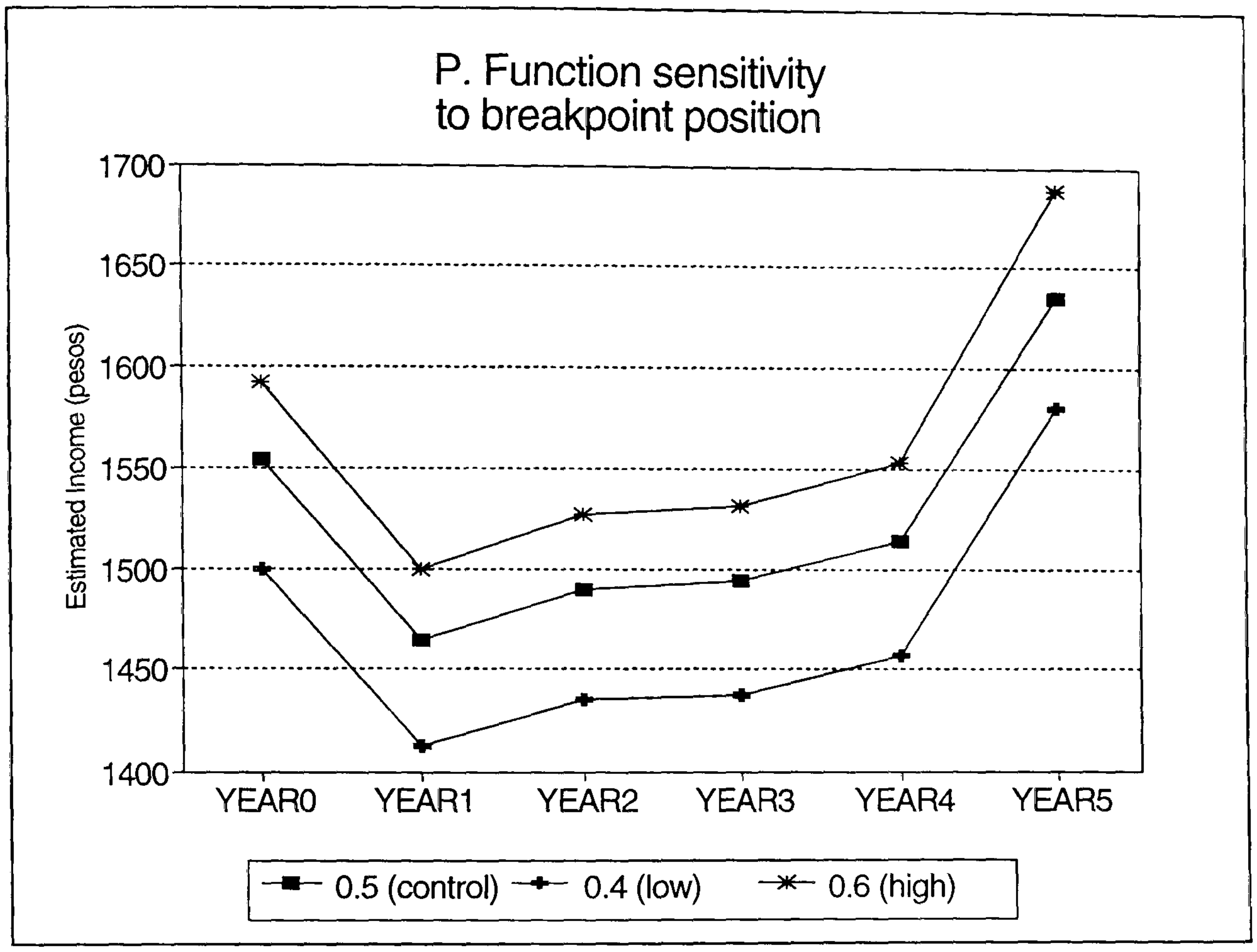
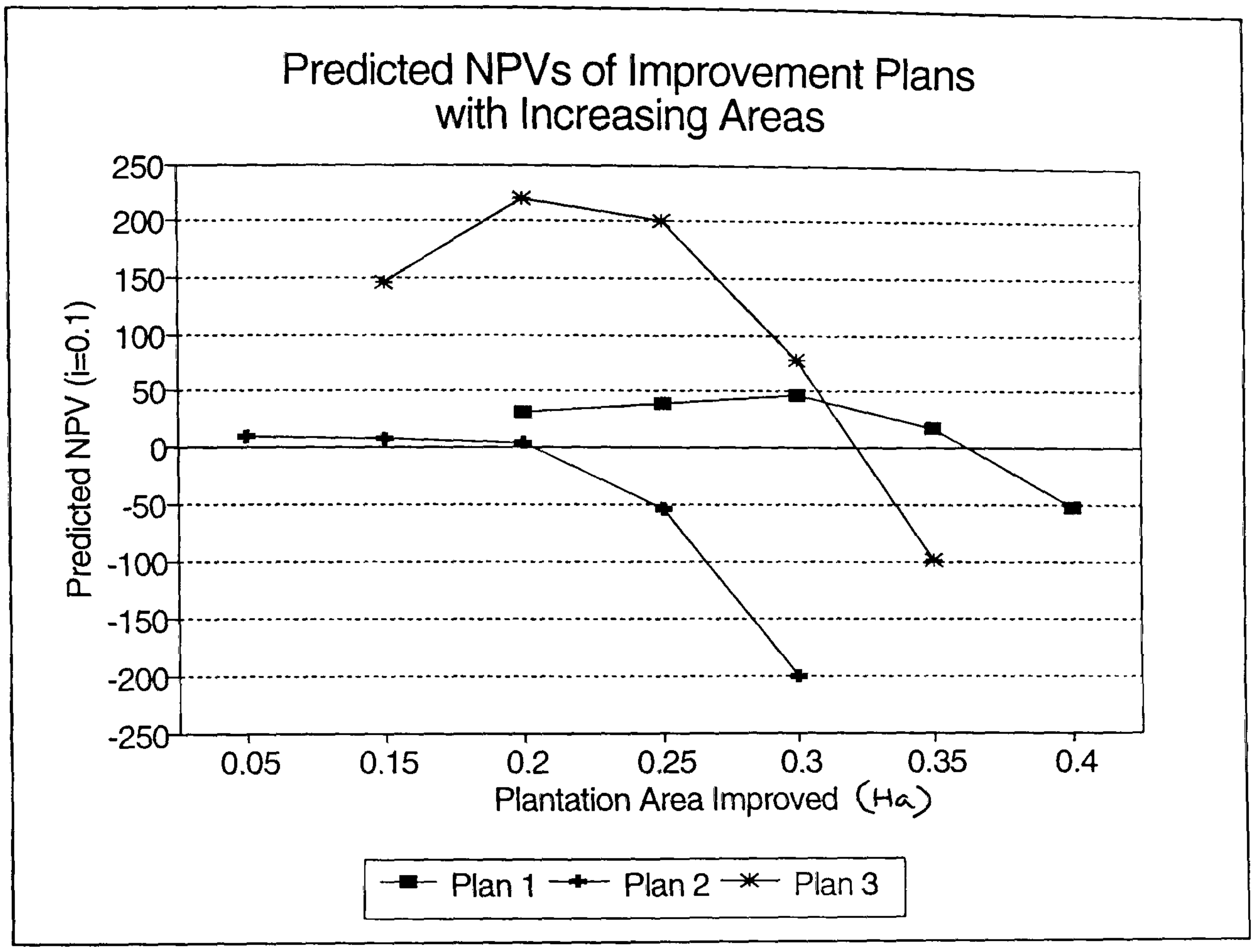

P. Function sensitivity
to breakpoint position
Estimated Income (pesos)
1700
1650
1600
1550
1500
1450
1400
YEAR0
YEAR1
YEAR2
YEAR3
YEAR4
YEAR5
0.5 (control)
0.4 (low)
0.6 (high)

**Figure 6.ii.**


Predicted NPVs of Improvement Plans
with Increasing Areas
Predicted NPV (i=0.1)
250
200
150
100
50
0
-50
-100
-150
-200
-250
0.05
0.15
0.2
0.25
0.3
0.35
0.4
Plantation Area Improved (Ha)
Plan 1
Plan 2
Plan 3

### 6.2.2 Sensitivity Analysis of Production Function Curve

The effect of varying the point at which the returns to inputs to each cultivation option began to diminish was tested. The initial "break point" (used in the above section, and in the following sections) was set at 0.5 the maximum level of inputs for a given area of plantation (as explained in the methodology (3.4.6). Two other break point levels were considered; a low level (0.4), and a high level (0.6). The setting of a low break point in the model caused the predicted income to fall by around 4%, whereas the high break point gave a predicted income of 2% more than the initial setting. By lowering the break point of all production options to the same degree greeter amounts of resources were allocated into the upper ends of the production functions. Conversely, by raising the break points, production was generally carried out at lower levels on the production function. However, the overall pattern of resource allocation between the different types of plantation land was not affected. (Figure 6.i).

### 6.2.3 Comparison of Coffee Improvement Methods

In the following section the model was used to compare three improvement plans for the base case farm (with constraints as shown in Table 6.8). Each plan consisted of the development of an area of plantation to a more advanced level using one of the alternative methods observed and described in the fieldwork results.

1st Method: Adaptive improvement of rustic plantation

OR: Adaptive improvement of intermediate plantation

2nd Method: INMECAFE promoted method for advanced plantation development

The first of the three alternative plans comprised the conversion of 0.3 ha of rustic plantation to an intermediate state. The second plan entailed the conversion of 0.3 ha of intermediate plantation to an advanced state. Under the third plan 0.3 ha of rustic plantation was developed to an advanced level.

Improvement Plan 1. Adaptive Improvement of Rustic Plantation

Table 6.9 shows how some of the main parameters of the base case smallholder's coffee system were predicted to change over the five year development period. The improvement plan was initiated in year

1, with 0.3 has taken out of rustic production to be improved to an intermediate state. The transformation of this unit of land took four years; after which it re-entered the main pool of available plantation land (in an intermediate state).

Expected Income

The expected income from cultivation declined from \$1554 in year 0 by about 6% in year 1 to \$1464, as land and resources were diverted to improvement. Income then recovered gradually over the remaining four years as the area under transformation began to become productive. In year 5 the 0.3 ha re-entered the pool of harvesteable intermediate plantation. The expected annual income from the improved coffee system, as a whole, was \$1634; an increase of 5%.

Input Allocation

The allocation of inputs to the rustic plantation area remained at the centre of the production function ($\alpha$ value around 0.5). The inputs to the intermediate plantation area were at the upper end of the production function for most of the period however, $\alpha$ fell back from 1.00 to 0.76 in the final year, as the improved land became available (see p.60 for explanation of $\alpha$ values).

Labour Hiring

This dropped from 11 units at the beginning of the period to zero in year 1, as most of the available cash was used up in improvement. In year 4 there was a demand for 20 units of labour, as there was a positive net cash flow from the improvement process.

Shadow Prices of Resources

The shadow price of rustic plantation land remained at zero throughout the period. Intermediate plantation land also had a zero shadow value, apart from in year 4, when it rose to \$190 per ha (the same year that the $\alpha$ value for production on this land type rose above 0.5). The shadow price of advanced plantation land varied from \$894 to \$1071 per ha. The shadow prices of Spring, Summer and Autumn labour were zero throughout the period and the constraining input factor was therefore Winter (harvesting labour), with a shadow price of $10.5 to $12.3 per ha. However, the option of hiring more harvest labour was uneconomical, as indicated by the shadow prices of cash of $0.52 to $0.6.

**Table 6.9 Expected income and other system parameters for a coffee improvement plan taking 0.3 ha from a rustic state to an intermediate state.**

| Year | E. Income | Cash to T | *α L1 | α L2 | α L3 | HL |
|---|---|---|---|---|---|---|
| 0 | 1554 | 0 | 0.50 | 0.94 | - | 11 |
| 1 | 1464 | 138 | 0.50 | 0.94 | - | 1 |
| 2 | 1490 | 96 | 0.50 | 0.94 | - | 3 |
| 3 | 1494 | 0 | 0.50 | 0.96 | - | 11 |
| 4 | 1513 | -96 | 0.51 | 1.00 | - | 20 |
| 5 | 1634 | 0 | 0.50 | 0.76 | - | 10 |

HL = hired labour, Cash to T = cash input to improvement activities.
*see p.60 for explanation of α values

Improvement Plan 2: Adaptive Improvement of Intermediate Plantation

Table 6.10 shows the expected income and other parameters, as predicted by the model for an improvement plan taking 0.3 ha of intermediate state plantation land to an advanced state.

Expected Income

The expected income from cultivation fell from $1554 in year 0 to $1080 in year 1, before rising gradually to $1756 in year 5. In comparison with Plan 1, this was a reduction of income of $384 in the first year of implementation, and 110 - 140 k$ in the 2nd, 3rd and 4th years for a net long term annual gain of $122.

Input Allocation:

Allocation of inputs to rustic land rose from the mid-point on the production function (α =0.5) after year 1 to 0.58-0.6 in years 2 to 4. It then fell back to the mid-point, once the improvement plan was completed. Allocation to the remaining intermediate plantation land rose from 0.94 to 1.00 (maximum possible level of inputs) when the 0.3 ha was taken out of cultivation to be improved. Once improvement was completed the level of inputs fell back to 0.7. Once advanced plantation land was available in the final year it was cultivated to its maximum extent (α =1.00).

Labour Hiring

The amount of labour hired fell from 11.2 units in year 0 to zero in year 1, as cash resources were used up at the beginning of the improvement process. The amount of hired labour then increased to 25.1 units by year 4, before falling back to 9.4 (lower than at the beginning of the improvement cycle).

Shadow Prices

The changes in the shadow prices of different types of plantation land were the same as those under the first improvement plan. Labour shadow prices also showed a similar pattern. The exception was the shadow price for cash which rose to $5.77 in year 1, before falling back to below 1.

**Table 6.10 Expected income and other system parameters for a coffee improvement plan taking 0.3 ha from an intermediate state to an advanced state.**

| Year | E. Income$ | Cash to T | α L1 | α L2 | α L3 | HL |
|---|---|---|---|---|---|---|
| 0 | 1554 | 0 | 0.50 | 0.94 | - | 11.2 |
| 1 | 1080 | 225 | 0.50 | 0.49 | - | 0 |
| 2 | 1358 | 138 | 0.58 | 1.00 | - | 2.9 |
| 3 | 1350 | 33 | 0.57 | 1.00 | - | 11.7 |
| 4 | 1408 | -138 | 0.60 | 1.00 | - | 25.1 |
| 5 | 1756 | 0 | 0.50 | 0.70 | 1.00 | 9.4 |

Improvement Plan 3: Transformation of rustic plantation to advanced level

Table 6.11 shows the expected income and other parameters predicted by the model for the coffee improvement plan recommended by the INMECAFE's coffee improvement programme. In this plan 0.3 ha of rustic plantation was developed directly to an advanced state, over 4 years. Under this improvement method, considerable inputs of labour and cash to the area being developed were required. However, the expected productivity of the fully developed advanced plantation was considerably higher than either the rustic or intermediate plantations. The following changes in the expected income, (optimum) resource allocation, labour hiring and shadow prices were predicted for the period of improvement:

Expected Income

This fell lower than in either of the previous scenarios, to only \$810 in year 1, before gradually rising to \$1836 in the final year. In comparison with the first plan, this represented a loss of \$654 in year 1 and subsequently \$75-100 in years 2, 3 and 4. There was a long term gain of \$202 per year in comparison with the initial plan.

Input Allocation

The inputs to rustic plantation were around the mid-point on the production function for the whole period. Inputs to intermediate plantation fell from $\alpha$ =0.94 in Year 0 to zero in Year 1; this was a result of the shortage of cash for cultivation in the first year of the improvement plan. As cash became available so the inputs increased to 0.52 in Year 2 and 0.90 in Years 3 and 4. Once advanced plantation land had become available for cultivation, the inputs to intermediate plantations fell back to 0.55, while the advanced area was cultivated at maximum intensity ($\alpha$ =1.00).

Labour Hiring

As cash was diverted to improvement in years 1 and 2, so labour hiring fell to zero. Subsequently, it climbed back to 8.1 by year 5; still lower than the amount hired in Year 0 (11.2 units).

Shadow Prices

The shadow prices of rustic and intermediate plantation land remained at zero throughout the period, while that of advanced plantation land remained at \$895 apart from year 1, when it fell to zero. Shadow prices of labour were zero, apart from winter labour, which followed the same pattern as under the previous plans. The intensive nature of this improvement plan was reflected in the shadow price of cash reaching \$6.2 in year 1, before falling to \$0.6 in year 3.

**Table 6.11 Expected Income and other system parameters for a coffee improvement plan taking 0.3 ha from a rustic state to an advanced state.**

| Year | E. Income$ | Cash to T | α L1 | α L2 | α L3 | HL |
|---|---|---|---|---|---|---|
| 0 | 1554 | 0 | 0.50 | 0.94 | - | 11.2 |
| 1 | 810 | 270 | 0.48 | 0 | - | 0 |
| 2 | 1379 | 171 | 0.61 | 0.52 | - | 0 |
| 3 | 1433 | 69 | 0.50 | 0.90 | - | 7.1 |
| 4 | 1438 | 0 | 0.50 | 0.90 | - | 12.8 |
| 5 | 1836 | 0 | 0.50 | 0.55 | 1.00 | 8.1 |

### 6.2.4 Expected NPVs for Improvement Plans of Varying Scale

The net present values[4] of plantation improvement plans were predicted, by the model, to vary according to the total area developed over the five year period. Figure 6.ii shows the relationship between the area developed and the expected NPV for each of the three categories of plantation improvement on the control farm.

Rustic to Intermediate Improvement

Improvement plans gave positive NPVs for areas up to 0.36 ha. The maximum expected NPV was $50 with an area of 0.31 ha.

Intermediate to Advanced Improvement

Improvement plans gave only very small positive NPVs (maximum $14, at 0.05 ha) and were negative beyond 0.2 ha.

Rustic to Advanced Improvement

Improvement plans gave large positive NPVs (maximum = $220, at 0.33 ha) but only small areas could be developed profitably (NPVs were negative with areas above 0.33 ha).

4 NPVs for variable area of plantation under development was calculated at a discount rate of 10% over a period of 10 years (See Appendix 6 for details).

### 6.2.5 The Effect of Varying Relative Input Factor Scarcities

Cash flows, optimum resource allocations and NPV's of different improvement plans were estimated for farms with different relative scarcities of input factors: (i) land, (ii) labour and (iii) cash resources, as compared with the control farm used in the previous section. For each of the three farms the availability of the scarce factor was reduced (by 1/3 to 1/2) while the availability of other factors remained the same as in the base case Table 6.12.

**Table 6.12 Availability of inputs for coffee production used for modelling the effect of relative factor scarcities**

| Factor | Scarce Land | Scarce Labour | Scarce Cash | Base Case |
|---|---|---|---|---|
| L1 | 1.5 | 3.0 | 3.0 | 3.0 |
| L2 | 0.35 | 0.5 | 0.5 | 0.5 |
| L3 | 0 | 0 | 0 | 0 |
| SPL | 50 | 30 | 50 | 50 |
| SUL | 60 | 36 | 60 | 60 |
| AUL | 40 | 24 | 40 | 40 |
| WIL | 90 | 54 | 90 | 90 |
| CASH | 400 | 400 | 300 | 400 |

Cash flows and $\alpha$ values for input allocations were estimated for each of the above farms under the three alternative plantation improvement plans tested in the previous section. The results are summarised as follows (details given in Appendix 6):

Cash Flows and Input Allocation with Relative Scarcities

Farm with Land Scarcity

Reduction of land availability by almost 50% caused the baseline income (income in year 0, before improvement began) to fall by only 11%, compared with the control. This was due to a compensatory increase in input allocation to each unit of land ($\alpha$ values rose to 1.0 for both rustic and intermediate land).

Farm with Labour Scarcity

A 40% reduction in the availability of labour caused the baseline income to be reduced by 41%. The predicted input allocation in both rustic and intermediate plantation areas was for $\alpha$ values of less than 0.5, i.e. at the lowest (steepest) end of the production function.

Farm with Cash Scarcity

A 25% reduction in the availability of cash caused only a 5% drop in the expected baseline income. However, in the years when the coffee improvement plan absorbed further amounts of cash the expected income fell sharply. When cash for cultivation became very scarce, such as in Year 1 of the 2nd improvement plan (it fell from $1486 to $467) and Years 1 and 2 of the 3rd improvement plan the only affordable cultivation option was on rustic plantation.

NPVs with Relative Factor Scarcities

Estimated net present values (NPVs) for the predicted cash flows resulting from the three improvement plans on farms with different factor scarcities were calculated for discount rates ranging from 0.5 to 0.25. The NPVs are shown in full in Appendix 6. The results are summarised as follows. The net benefit to farmers of each coffee improvement plan depended upon the type of factor scarcity.

(a) Farms with scarce labour gained most (even more than the control farm) from all improvement plans at discount rates below 0.1 and also benefited from the 3rd improvement plan at a discount rates of up to 0.2.

(b) The farm with scarce land only benefited from the 3rd improvement plan and only then at discount rates below 0.1.

(c) The farm with scarce cash made losses on all improvement plans; the greatest losses were made on the 3rd plan.

(d) The base case farm benefited from the 1st improvement plan at discount rates below 0.15, made losses at all discount rates on the second plan and only benefited on the 3rd plan with discount rates at 0.05.

### 6.2.6 Analysis of credits for farmers with different factor scarcities

The effect of a hypothetical credit programme on the costs and benefits of coffee improvement was tested using the model. Fixed quantities of credit were made available at a range of interest rates during the first three years of the coffee improvement programme, as follows: $300 Year 1, $200 Year 2, $100 Year 3.

The NPVs of the improvement plans for plantations with credit for farms with different factor scarcities are shown in Appendix 6. In general, it was predicted that only the base case and cash scarce farms would benefit from the credit when carrying out the recommended improvement plan, after repayment of the amount borrowed at the current rate of interest. Farmers executing the recommended plantation method were expected to benefit most.

(a) Farms with scarce land for cultivation benefited very little from the credit. The predicted NPVs with credit for the adaptive improvement plans (1 and 2) were no different from the predicted NPVs without credit. While the NPV for the recommended improvement plan was increased by $362 at 10% discount rate and by $304 at a 20% discount rate. The small predicted response to credit was a result of the saturation of available land ($\alpha$ values around 1) during the improvement process. Further cash resources therefore did little to increase production, as the farmer was already at the top of the production function.

(b) Farms with scarce labour benefited from the availability of credit but not sufficiently to repay the loan, with interest, at the end of the improvement period. At a discount rate of 10% the predicted NPV rose by $245 to $374 due to the availability of the extra cash resource. However, the cost of credit was $466k.

(c) Farms with scarce cash resources benefited greatly from the credit scheme. Even with a discount rate of 20% the change in expected NPV was sufficient to cover the cost of credit under all coffee improvement plans.

(d) The control farm, where factor scarcities were balanced, benefited from the credit scheme but only the benefits of the recommended (3rd) improvement plan were sufficient to cover the costs of credit repayment.

## 6.3 Results from the Farm Resource Allocation Model

The results of a final model simulating the re-allocation of the productive resources between the subsistence and cash cropping sub-systems on the base case farm are given in this section.

### 6.3.1 Re-allocation of Labile Resources on the Base Case Farm

Table 6.13 shows the initial allocation of productive resources between *milpa* and coffee production on the base case farm. The columns on the right of the table show the estimated shadow prices for inputs within each of the production sub-systems. The output from each sub-system and the total output from the farm is shown in the penultimate row of the table.

Table 6.14 gives the proportions of each productive resource that were designated as either (a) dedicated to *milpa* production, (b) dedicated to coffee production or (c) available for re-allocation, according to the relative shadow price rules (see methodology (3.4.7). The simulated re-allocation decision for each labile fraction is also shown in Table 6.14, in the right hand column. The predicted output, post re-allocation, calculated by re-running the *milpa* and coffee models, with the new resource allocation, are given in the bottom row of Table 6.13.

The re-allocation exercise yielded only a small increase in total output; just over 1%. In the following section the results of repeating this exercise, using different absolute and relative fractions of labile and dedicated resources, are given.

**Table 6.13 Initial allocation of resources on the Base Case farm, and shadow prices for these resources as calculated by the problem situation sub-models.**

| | Initial Allocation | | | Shadow Prices | |
|---|---|---|---|---|---|
| | *milpa* | Coffee | Total | *milpa* | Coffee |
| Land | 5 | 3.5 | 8.5 | 0 | 131 |
| ESPL | 40 | 25 | 65 | 39 | 0 |
| LSPL | 40 | 25 | 65 | 41 | 0 |
| SUML | 50 | 60 | 110 | 0 | 0 |
| AUTL | 50 | 40 | 90 | 0 | 0 |
| WINL | 0 | 90 | 90 | 0 | 0 |
| Cash | 800 | 400 | 1200 | 0 | 12 |
| OUTPUT 1 | $3221 | $1554 | $4775 | | |
| OUTPUT 2 | $3293 | $1537 | $4830 | | |

OUTPUT1 = predicted output from system before re-allocation
OUTPUT2 = predicted output from system before re-allocation

**Table 6.14 Fractions of dedicated and labile resources on the Base Case farm, and re-allocation decision based on relative shadow prices (Table 6.13).**

| | Dedicated Resources | | Labile Resources | Re-allocation |
|---|---|---|---|---|
| | Maize | Coffee | | |
| Land | .53 | .35 | .12 | to coffee |
| ESPL | .46 | .31 | .23 | to maize |
| LSPL | .46 | .31 | .23 | to maize |
| SUML | .36 | .44 | .20 | to coffee |
| AUTL | .50 | .40 | .10 | to coffee |
| WINL | 0 | 1.0 | 0 | none |
| Cash | .50 | .30 | .20 | to coffee |

### 6.3.2 Re-allocation of Varying Fractions of Labile Resources

In a series of iterations, the model was used to explore the possibilities of varying the absolute and relative fractions of labile resources, (a) under "normal" conditions and (b) with concurrent, planned technological improvement taking place. The ranges of labile and dedicated resources used in the following exploration of the allocation problem are shown in Figure 6.iii.

Case 1. Variable Quantity of Land Available for Re-allocation

The labile quantity of land was varied, while the labile quantities of all other resources were maintained at the same levels as in the initial run (Table 6.14). The model predicted small and progressively diminishing returns from increasing the fraction of labile land, when all other inputs were designated as "dedicated" (not available for re-allocation). The maximum predicted increase in output was only 1.2%, when 1 ha (0.12), land was designated as labile. Figure 6.iv shows the relationship between increasing the labile fraction of land and the predicted benefit from re-allocation.

Case 2. Variable Quantities of Labour, with 1 ha of Land as Labile Resources

When both land and labour were designated as labile resources, the returns to re-allocation were greater (Figure 6.v). A maximum 15.8% improvement in output resulting from re-allocation was predicted.

Case 3. Variable Quantities of Labile Cash and 1 ha Land

When cash and land were designated as the only labile resources returns to re-allocation were lower than with labour and land; a maximum improvement in the total output of 4.2% was obtained (Figure 6.v Maxflex(C)). However, in the case where all resources were labile, a potential increase in output of 18% was predicted, as a result of re-allocation (Figure 6.v Maxflex(LC))

Case 4. Re-allocation of Resources During the Technological Change Process

The effect of re-allocation of resources between subsistence and cash cropping systems as part of a plan for improvement of the coffee system (the development of 0.3 ha of rustic plantation to and intermediate state) showed high marginal return to the re-allocation of small quantities of resources. The benefits of large labile fractions were slightly lower than in the previous case (Figure 6.vi Maxflex(LC)).

**Figure 6.iii.**

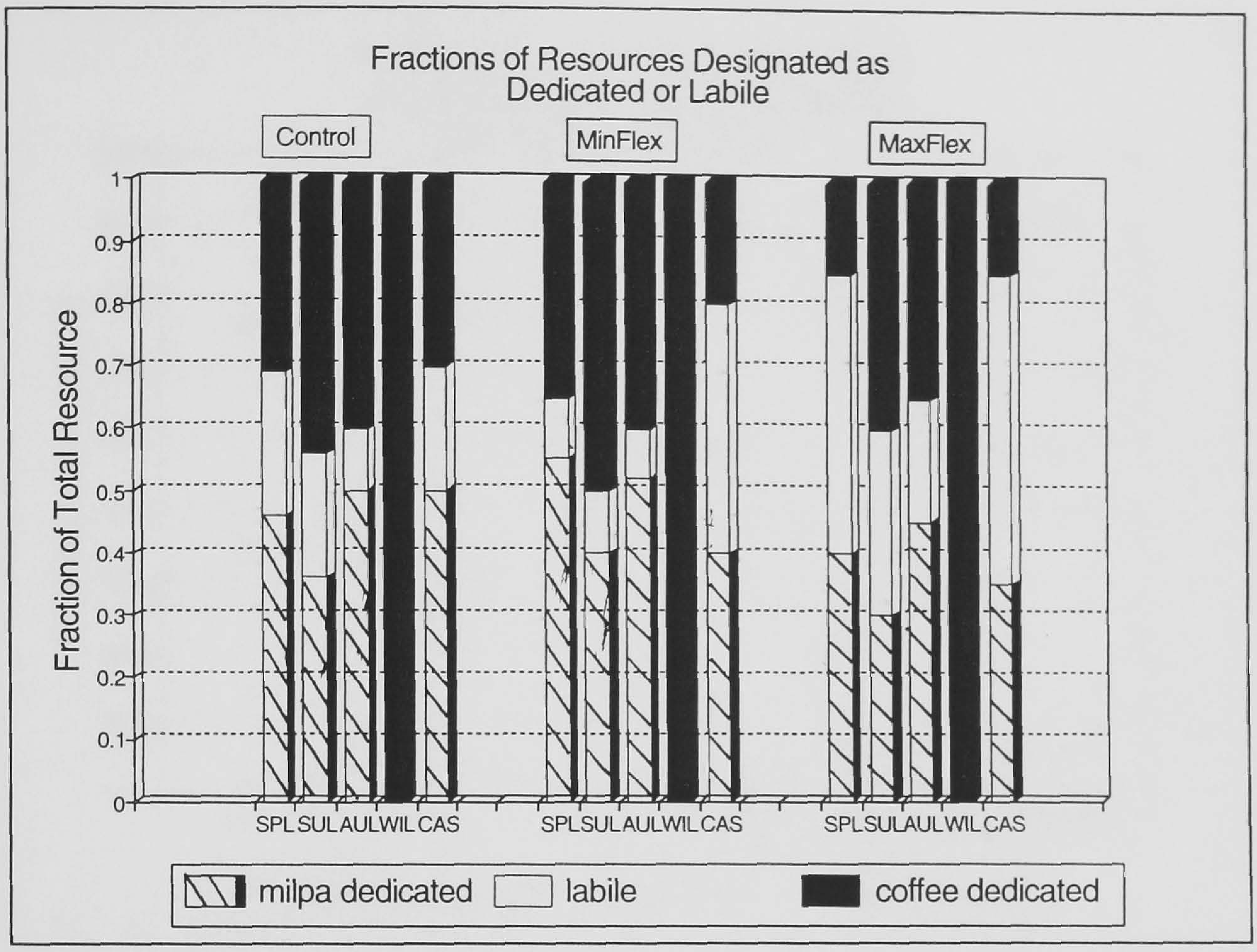
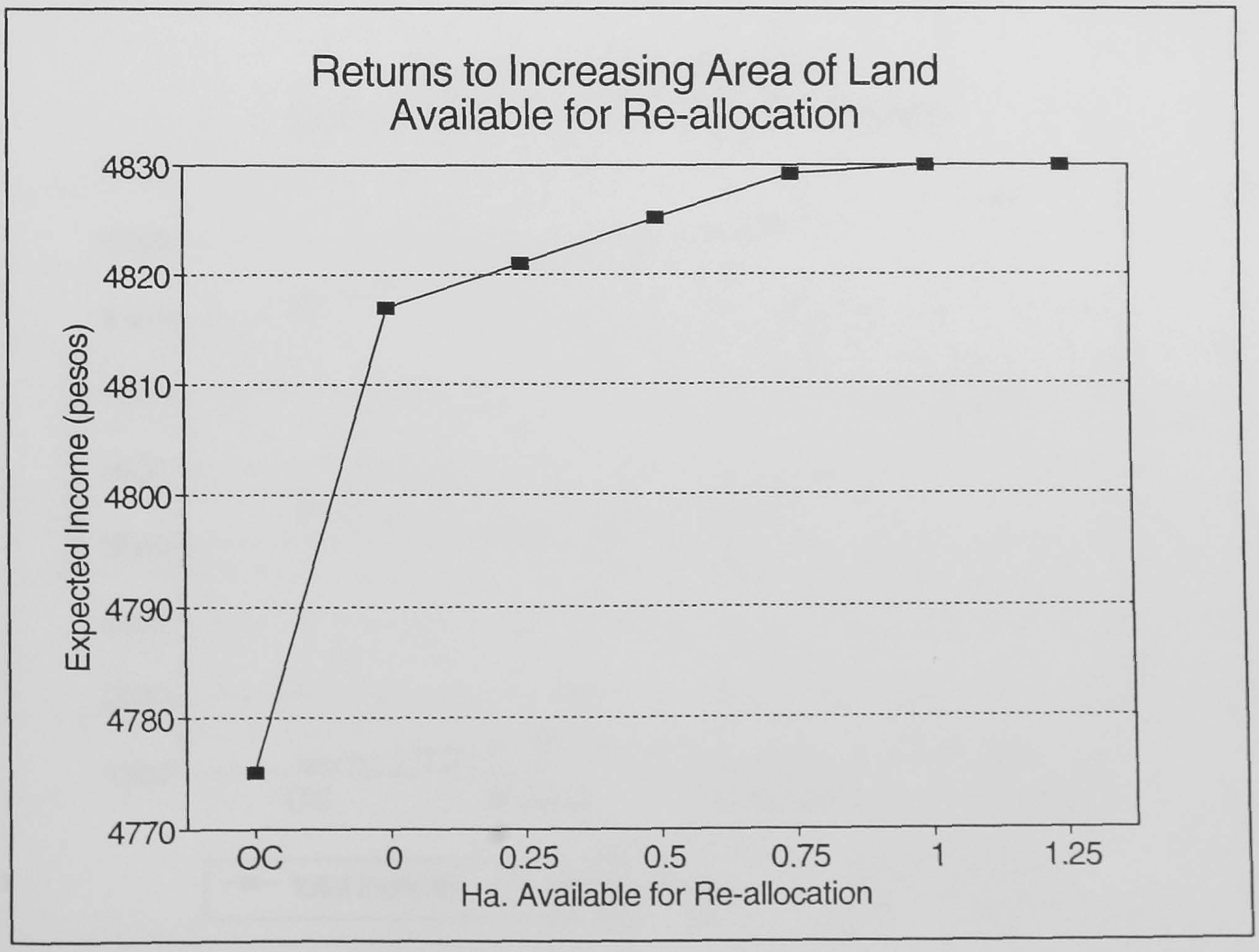



**Figure 6.iv.**




Ctrl=control, Minflex=minimum flexibility, Maxflex=maximum flexibility, (L)labour, (C)cash, (LC) labour and cash.

**Figure 6.v.**

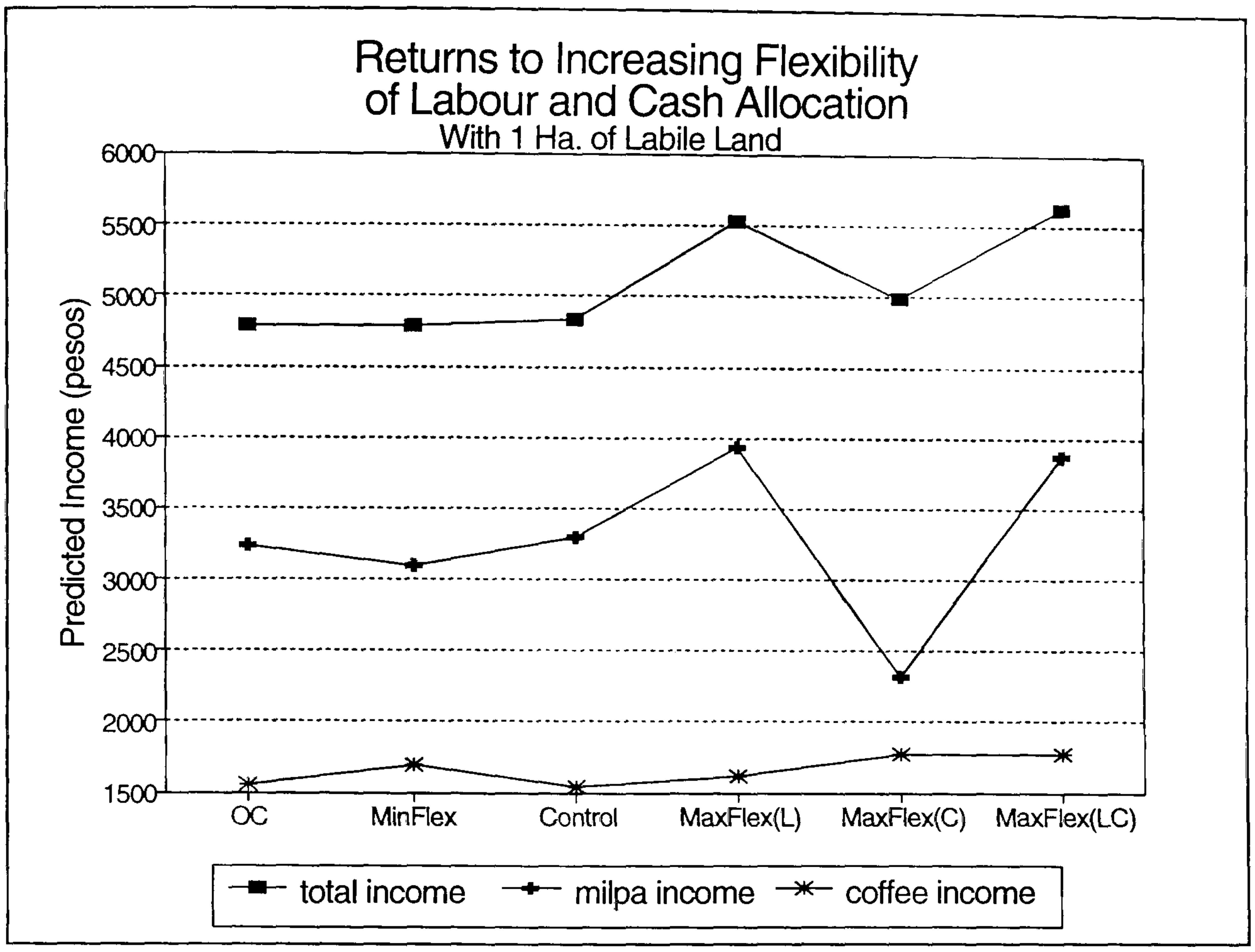
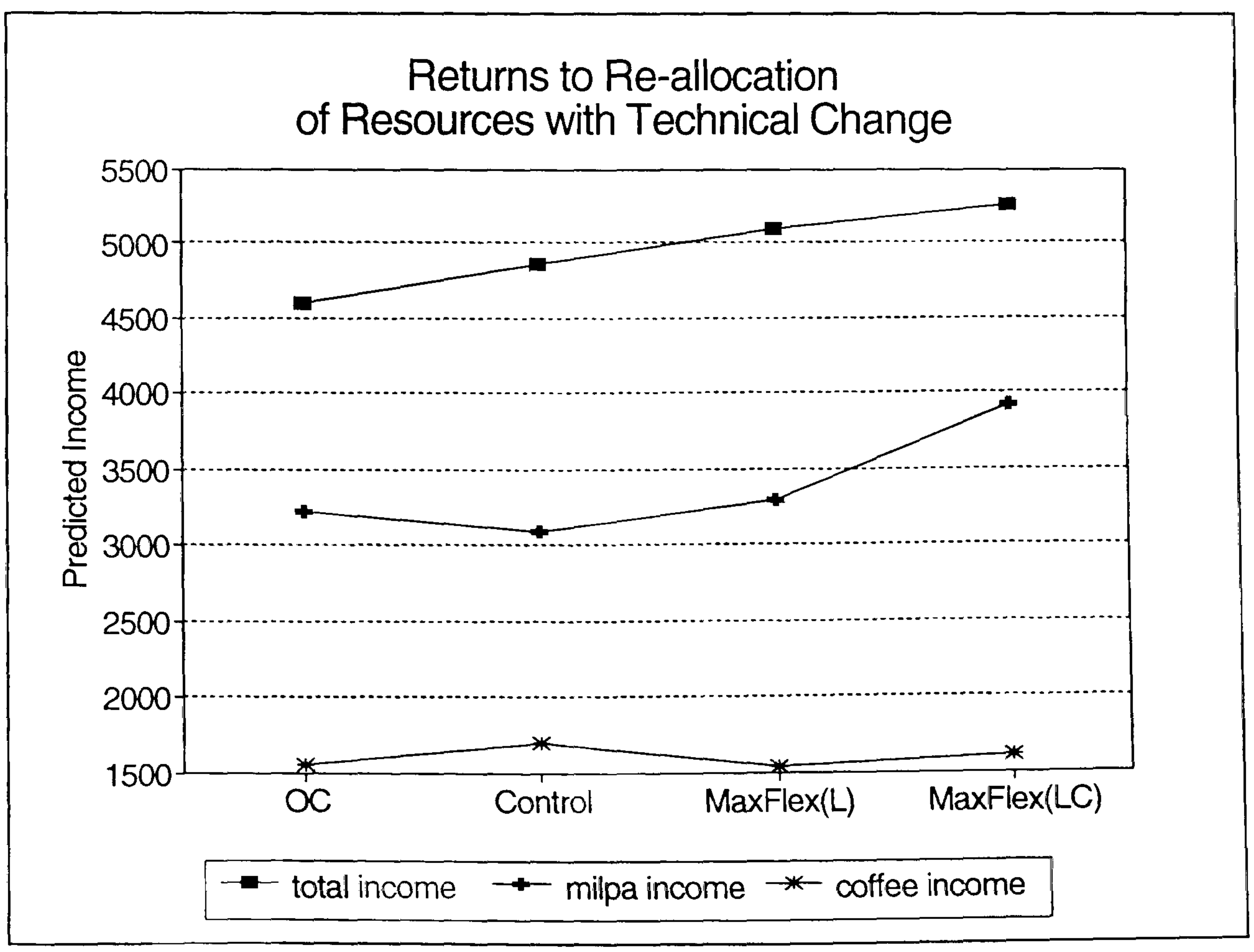



**Figure 6.vi.**




Ctrl=control, Minflex=minimum flexibility, Maxflex=maximum flexibility, (L)labour, (C)cash, (LC) labour and cash.

# 7 Discussion of Modelling Results

## 7.1 Discussion of *Milpa* System Model Results

The results of the modelling exercise of the *milpa* system (6.1), are interpreted in this section. Output from the models included the predicted "decision-paths"[1] of farmers using the specified decision-making criteria (3.4.5), and the expected effective income from the *milpa* system, over five year periods, under a number of scenarios. Firstly, the probable effects of varying cash availability for subsistence agricultural production on the cultivation method chosen are discussed. Secondly, the effects of restricting the options for cultivation methods to those that did not cause significant decline in soil fertility are assessed.

### 7.1.1 Technical Stagnation and Proletarianisation

The output from the first scenario examined with the model (6.1.1), demonstrated some of the important effects of decision-making in subsistence agriculture, using short-term criteria combined with lack of investment in fertiliser or non-burning cultivation methods. Firstly, the lack of cash, did not permit a technical response to increasing land scarcity. More intensive methods of cultivation are clearly not an option for farmers who are not able to purchase the required inputs. Secondly, the model predicted an increasing dependence upon the external labour market, despite the low prevailing wages. As the available land area for cultivation was reduced in successive years, the model indicated that the "short-term optimising farmer" would tend to divert resources away from *milpa* production and into earning cash by selling labour. This effect, known as the "proletarianisation" of peasants, has been observed by Collier (1990) in the Central highlands of Chiapas. However, Collier also pointed out, it is possible that earnings from wage labour to be subsequently invested in *milpa* production, in later years. The model also illustrated this possibility in the output for the final year of the first scenario. The

[1] The term "Short-term optimiser" is used to describe the decision-path predicted by the model on the basis of maximum effective income for the current year (without consideration of long-term effects). "Sustainable land user" is used to describe the decision-path taken by the model when restricted to non-soil degrading cultivation options.

similarity of the outcome of this modelling scenario to the effects observed in the location case studies of Chamula and Zinacantán (4.1.8) were noted.

### 7.1.2 Cash Availability and Land Degradation

The output from the model with scenarios 2 and 3 illustrated that the loss of soil fertility associated with burning short-rotation *milpas* could be exacerbated by increased cash investment in the subsistence system. This was attributed to two causal factors: (1) The short-term response to fertilisers was greater in short-rotation *milpa*s than in long- and medium-rotation *milpas*. Short rotations were therefore favoured by the short-term optimiser, even when slack land was available, (2) Investment in herbicides allowed an increased area to be cultivated (and thus burned) each year. Consequently, while initial returns from capital investment in *milpa* production were high (especially for small amounts of capital), these returns declined rapidly over the five year period, and more rapidly when larger amounts were invested.

Examples of this type of agricultural decision-making and similar effects on the agro-ecosystem were also found in the central highlands of Chiapas (4.1.8). A local agronomist (Short, 1990) estimated that maize yields in the municipalities of Chamula and Zinacantán had fallen from above 1,500 kg / ha to below 800 kg / ha despite substantial increases in the levels of chemical inputs applied.

### 7.1.3 The Effect of Sustainable Land Use Constraints

The model predicted that the adoption of exclusively sustainable production methods (either non-burning land preparation at short and medium length rotations, or long rotations with burning would lead to lead to a loss in total income, over the 5 year period. The amount of income foregone by eliminating non-sustainable cultivation techniques was dependent upon the amount of cash available for production (Table 7.1).

**Table 7.1 Income Foregone over 5 years as a result of the adoption of sustainable methods.**

| **Capital Input to *milpa* ($ / year)** | **Income Foregone ($ / year)** |
|---|---|
| 0 | 2200 |
| 200 | 1318 |
| 800 | 798 |

The farm with high levels available cash was predicted to forego the least income over the five year period, in comparison with the farms where the cultivation options were not restricted. This could be attributed to two factors: (1) The capital intensive farm, using non-sustainable production methods was predicted to become more rapidly less productive than the farm with moderate levels of cash input, (2) increased cash availability on the sustainably managed farm allowed the transition from non-burning to conventionally cultivated, long-rotation methods, to proceed more rapidly. This resulted in a substantial improvement of soil fertility and higher productivity.

Apart from the capital available for production the main obstacles to the adoption of non-burning methods were technical: (1) Low initial yields and, (2) high initial labour requirement for weeding and land preparation. The second point was particularly important as it reduced the area that could be cultivated with the limited labour resources.

### 7.1.4 Summary of Further Hypotheses Generated from Modelling

(1) As land becomes increasingly scarce, farmers making decisions on the basis of short-term (1-2 years) advantage will tend to choose non-sustainable combinations of short rotation lengths and land clearance by burning.

(2) Farms with scarce cash resources, using non-sustainable farming techniques will become increasingly dependent upon the wage labour market.

(3) Farms with relatively large cash resources for subsistence agriculture that use non-sustainable farming techniques will tend to degrade the soil on their land more rapidly than farmers with more limited cash resources, using the same techniques.

(4) The adoption of sustainable, or soil improving cultivation techniques entails a reduction in effective income from *milpa* farming over the first 2-3 years.

(5) Farms with relatively large cash resources will tend to benefit from the adoption of sustainable

production techniques more rapidly than farmers with more limited cash resources.

(6) The most important technical obstacles to the adoption of sustainable production techniques are (i) the additional labour requirement for land preparation in the first 2-3 years and (ii) the low yields expected, over the same period. Both these factors can be attributed to problems with weed control and crop / weed competition.

## 7.2 Discussion of Coffee System Model Results

The results of the exercise of modelling the coffee system (6.2), are discussed in this section. Output from the models included estimates of the expected net present values of production from coffee plantations under a number of different improvement plans, over periods of six years. The effects of varying the availability of resources for coffee production and of different rates of interest were examined. The net benefits (and costs) of coffee improvement were found to depend upon a number of variables: (1) The improvement plan implemented (both the techniques used and the area covered), (2) the characteristics of the adopting farm (as measured by the availability of different inputs) and, (3) the discount rate. The effect of diminishing marginal returns to inputs in the coffee system had an effect on the optimum allocation of inputs between different types of plantation within the categories of farms considered.

### 7.2.1 Effects of Plantation Improvement on Expected Income from Coffee

<u>The Choice of Improvement Techniques</u>

Whilst the rustic method of plantation improvement[2] was the most widely used by farmers in the northern highlands of Chiapas, the model based analysis (as simulated by the 1st improvement plan) found it to be only marginally profitable. However, this method has probably been favoured because of the relatively small short term cost (investment) required and the low level of risk entailed. The further development of intermediate plantations to advanced levels appeared to be unprofitable in nearly all of the scenarios examined. This may explain the small number of farmers who have gone on to develop advanced plantations in this way. The only improvement method that yielded substantial benefits was the one that had been recommended by the INMECAFE and other cooperatives in the region. However, this method also appeared to be a high risk option, with high losses expected at discount rates above 10% and with profitability showing a high degree of sensitivity to the scale of the improvement operation, due to the high level of resources diverted from annual cultivation activities.

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2 Improvement Method 1. The gradual, *ad-hoc* improvement of rustic plantation to an intermediate state.

The Area Allocated to Improvement

The profitability of improvement plans were found to be highly dependent upon the area of plantation allocated for development. In general, it was found that only small areas (less than 0.4ha) could be developed profitably at any one time. If larger areas were subject to improvement, the short term costs (land taken out of production and labour and capital diverted to this activity) would outweigh the long term gains. The effect of the scale of the improvement operation on the productivity of the coffee system in any given year was related to the degree of saturation of the annual production curves. If labour and cash inputs were to be diverted from the upper portion of the production curve the cost of improvement, in terms of production foregone, would be less than if inputs were diverted from the lower portion of the production curve (where marginal productivity is higher). Naturally, the position of any farm on its production curve would be dependent upon the ratios of available labour, cash and land resources.

Effect of Input Factor Scarcities

Different improvement plans represented different levels of risk for different types of farm. The adaptive improvement of rustic plantation (tested in the Ist improvement plan scenario) was the least sensitive improvement method to changes in relative resource scarcity on farms. In contrast, the improvement methods promoted by INMECAFE programme (tested in the 3rd improvement plan scenario) gave the high expected NPVs for farmers with scarce land and labour resources, but also highly negative NPVs for farmers with scarce cash resources. In general, coffee improvement did not appear to be a viable option for farms with cash scarcity, as any diversion of this factor from annual cultivation efforts caused a disproportionate loss in short term productivity. The expected effect of credit was that, mainly those families with relatively scarce cash resources would benefit, after repayment.

Sensitivity to Discount Rate

As expected, the NPVs of coffee improvement plans, which all entail the investment of labour, land and cash resources over several years before substantial increases in plantation productivity occur, were found to be sensitive to discount rates. The adaptive improvement of rustic plantation (1st improvement plan) was the least sensitive to increases in the discount rate, and could be undertaken profitably, on farms without particular scarcity of cash, at discount rates of up to 15%. This emphasises the low risk nature of the rustic (and most commonly used option). In contrast, the NPV of the promoted methods was sensitive to high discount rates. Only when a discount rate of 5% or below was available, would this method become profitable. As a result, the availability of interest free credit for coffee production would be most valuable to farmers adopting the recommended improvement methods.

### 7.2.2 Allocation Choices Between Plantations Types

The occurrence of more than one type of plantation on many small farms gave farmers a number of options for allocating resources spatially and temporally. Areas of plantation that were at relatively greater distance from the homestead, or on steep or difficult terrain could be allocated a low level of inputs, and kept at a rustic level (with high levels of shade and therefore slow growth of weeds). While the production from these areas would be low, in terms of yield per hectare, the farmer could expect a good return for each peso and labour day invested. Conversely, convenient areas of fertile land could be more intensively used. If these areas were maintained in a rustic state the production curve would become rapidly saturated and returns to further inputs would fall. However, if these "high potential" areas of plantation were developed, then they could be allocated larger amounts of inputs without diminishing productive efficiency. In these cases, farmers must make strategic decisions about which areas of plantation land should be developed, by what means and over what period.

### 7.2.3 Summary of Hypotheses Generated from Modelling

(1) The improvement of rustic coffee plantations by the adaptive methods widely used in the northern highlands of Chiapas, is a viable, low risk means of developing intermediate level plantations but further improvement of these intermediate plantations is not profitable.

(2) The development of advanced plantations from rustic plantations can be profitable but only at low levels of discount rate and for farmers without particularly scarce cash resources.

(3) The overall benefits of plantation improvement are particularly sensitive to the scale of improvement operations. In general, only small areas can be developed profitably at any given time. The methods of plantation improvement advocated by INMECAFE are more sensitive to scale than the adaptive

methods of improvement that have been more widely practised.

(4) The optimum plan for coffee improvement on any given farm will depend upon the relative availability of productive resources available. Farms with scarce cash cannot develop coffee plantations profitably by any of the methods currently available in the northern highlands. Farms with relatively plentiful land would benefit most from the adaptive improvement of rustic plantations. Farms with scarce land and labour will benefit most from the methods advocated by INMECAFE.

(5) The occurrence of several plantation types on the same farm will allow a more efficient allocation of the household's productive resources between different land types and micro-sites than a uniform stand of coffee and by allowing greater flexibility in response to changing prices and availability's of inputs.

## 7.3 Discussion of the Farm Resource Allocation Results

Unfortunately, due to constraints on the length of time in the field it was not possible to derive a model of household resource allocation from observations of the actual decision-making processes of farmers in the region. Instead, this model was based upon the theoretical notion that the productive inputs might be efficiently allocated between the *milpa* and coffee sub-systems by consideration of the shadow price of each input factor (within each sub-system). Conclusions based on the results of this modelling exercise must, therefore, be tentative, bearing in mind the following assumptions, that were included in the model: (1) Farmers could "sense" the relative opportunity costs of resources applied to each of the production sub-systems, (2) as a result of tradition and experience farmers have learnt to avoid risk and have already achieved a reasonably efficient balance between the two sub-systems. So, farmers will only be willing to re-allocate a certain fraction (labile fraction) of the available resources each year.

### 7.3.1 Benefits from Re-allocation of Household Resources

Low Levels of Labile Resources

On the base case farm, with low levels of labile resources, it was predicted that re-allocation would yield only small benefits (in the order of 1-5% of the total, effective, annual income). This level of improvement would be too small to be noticeable or accurately measured, due to the larger background levels of variations in performance, from year to year, due to weather and economic fluctuations. It is reasonable to identify conservative farmers with modelled-farms that had low levels of labile resources. Conversely, farmers who are more innovative and flexible could be associated with model scenarios where the levels of labile resources were greater. These are discussed in the following paragraphs.

High Levels of Labile Resources

When the levels of labile resources were increased, the expected benefits from re-allocation were greater. It was also found that the effect of increasing the labile fractions of different input factors was complimentary. Thus, a farmer who might be conservative with regard to allocation of labour but more flexible and responsive, with regard to allocation of cash would benefit less than a farmer who was prepared to re-allocate larger fractions of both factors. It should also be noted that it would be possible to over-allocate resources to one sub-system as a result of comparing relative shadow prices. This would result in an inefficient allocation of resources and a reduction in the total output from the system. The maximum increase in efficiency that could be achieved on the base case farm was estimated at 18%. Unfortunately, there was insufficient time in the field to test whether this figure might be true for the farms in the region.

Effect of Technological Change and Price Changes

As technological change on any farm involves the investment of resources, it could be expected that this would lead to changes in the shadow prices of inputs and, subsequently, to the re-allocation of inputs between the production sub-systems. The results of the model analysis reflected this expectation, by predicting greater benefits from re-allocation of inputs when an plan of plantation improvement was executed in the coffee sub-system. Similar responses would be expected from changes in the relatives prices of agricultural products. As predicted by the neo-classical theory of enterprise choice, one would expect the optimum ratio of outputs from sub-systems to be determined by the point of tangency between the production possibility frontier and an iso-revenue line.

### 7.3.2 Summary of Hypotheses Generated from Modelling

(1) Innovative farmers (as defined as those who are willing to consider the re-allocation of a larger fraction of total farm resources between enterprises) are more likely to be more efficient, as they will respond more quickly to changing prices and input costs.

(2) Innovative farmers must be able to sense the opportunity costs of resource allocation between production sub-systems.

(3) Increased benefits from the re-allocation of resources can be expected during times of technical change. Innovative farmers, as defined above, will therefore gain most from change.

# 8 Concluding Discussion and Recommendations

## 8.1 Assessment of the Methods Used

In the following sections, the adequacy of the methods used to address the problems of technological change, in the context of peasant farming systems in southern Mexico, are discussed. In particular, the effectiveness of the "action research" approach to fieldwork and the use of spreadsheet modelling within a Soft System Methodology framework, to generate hypotheses about farming systems are assessed. As resources for the study of problems of social and economic importance are usually limited, the research methods employed are judged in terms of their efficiency and effectiveness in providing potential agricultural improvements as well as their scientific validity. Future improvements to modelling and fieldwork methods are suggested.

### 8.1.1 Fieldwork Methods

The investigative approach used in the study could be viewed as an extension of the traditional anthropological method of participant observation of groups or societies. In this case, the researcher's interaction with the subjects was extended to participation in directed (mutually agreed) actions, designed to provide solutions to problems identified by the subjects.

Implicit in this arrangement is a transaction between the researcher and the subject group. The researcher applies effort and skills towards the resolution of a problem identified by the group, and in return, expects cooperation through the supply of relevant information and data. The validity of extending the anthropological approach in this way depends, to a large extent, upon the reactions of the investigator and the subject group to this added "action" dimension of the research, and also, the effect of the transaction on the relationships between subjects and the researcher. Indeed, these factors tend to obscure the distinction between researcher and subjects - who become co-researchers (nevertheless they remain the "owners" of the problem under scrutiny).

It may be argued that, by focusing the investigation on problems identified by subjects (farmers), rather than hypotheses derived from the deductive processes of detached observers, and by engaging subjects as co-researchers, the validity of results will be limited to the extent of technical recommendations, of specific but not general relevance. Indeed, much action research is confined to this area (IIED, 1989-93)[1]. This may be true if the investigator does not employ a periodic (or parallel), detached, critical appraisal of the research as it progresses. In the case of this study, the evolution of "action research" activities must be viewed as partly determined by the rural system itself. With this in mind, the "general" value of results derived from "action research" becomes apparent when they are contextualised, by reference to places and situations, and a body of theory, as was attempted with the parallel observations of the economic systems in four highland locations (4.1).

A second criticism of this mode of investigation concerns the representativeness of the subjects with whom the researcher interacted, either as co-problem solvers, or interviewees (despite a genuine attempt to obtain reasonably "typical", or at least non-extreme cases for each community). The following areas where important biases may have occurred are readily identifiable:

a) By concentrating much of the fieldwork effort upon the coffee "problem system" the researcher made contact with many farmers who were keen or potentially keen coffee farmers.

b) Landless peasants, women, children and the elderly were unfortunately excluded from the study (see recommended further work. It is therefore recognised that the application of the study's conclusions to these important groups must be tentative.

While the study's recommendations (8.4) should be reviewed, in relation to any excluded groups, before and during the implementation of the proposed interventions, it is suggested that the general conclusion, that technical support services should made much more responsive to the diversity of needs of peasant families, can only be positive. It is also asserted that the above limitations of the "action

1 "Participatory Rural Appraisal Notes" are published by the International Institute for Environment and Development. They give descriptions of the application of participatory field techniques in rural development.

research" mode are more than compensated for by three important advantages:

a) The researcher's involvement in activities of direct relevance to farmers is rewarded with far greater access to information, than the "unconnected" researcher.

b) The interests of farmers in the process and results of this type of study increases the motivation to speak the truth.

c) The participation of farmers and extension workers in the "research group" can provide a framework for preliminary action, through implementation or testing of conclusions.

In conclusion, it is considered that, "action research" is both a valid and efficient method of conducting investigative fieldwork in the context of improving peasant farming systems.

Suggested Improvements to Fieldwork Methods

The action reset approach could be made more effective if some farmers could be trained in practical data gathering and analytical techniques. Farmers themselves would then be seen as the problem solvers and the role of the researcher would be one of an adviser or catalyst. The training of farmers in these skills should be an important component of the recommended programme.

### 8.1.2 Modelling Methods

The use of a Soft System (SSM) framework for spreadsheets to modelling of agro-systems enabled the modeller to keep a broader systems perspective of the peasant farm than might have been possible with hard modelling techniques alone. From the scenarios chosen in the modelling exercises, hypothetical behaviour patterns for the operational sub-system of the peasant farm *holon* were generated. In particular, the modelling exercises revealed the inherent tensions within the system between short-term and long-term production goals, and how these could vary from farm to farm. While hard modelling techniques alone might not have contributed so much to the new conceptual model of the peasant farm, SSM alone would not have yielded the insights into the scale and relative importance of the system's crucial physical and biological parameters. Indeed as SSM assisted with the design and use of the models, and with the interpretation of the output, the two methods were found to be highly complimentary.

As well as providing insight into the general behaviour of peasant farm systems, the modelling of data from the field surveys also affirmed and helped to explain some of the empirical observations made in the descriptive sections of the thesis. The construction of a model can be justified if it provides information about a system, or problem that would not be readily apparent from scrutiny of the input data alone. This information should also be testable so that the model can be evaluated, adjusted (either structurally or by changing the coefficients), or discarded in favour of a replacement.

In the cases of the models applied to the maize and coffee systems of the northern highlands, information about the costs and benefits of technical change to various groups of farmers under a variety of conditions was yielded. Many of these relationships would not have been readily deducible from the input data alone. This type of output could be fairly easily verified / falsified by field surveys, or the model could be gradually improved through application to specific problems (see further work (8.4.2).

In the context of action research, the information provided by the models should also be relevant to the problem solving process. As previously mentioned (1.3.4), an important part of the process of technological improvement in agriculture consists of combining specific technical expertise with local knowledge to determine the necessary conditions and possible benefits from particular innovations. The models developed could provide a practical framework for this communication. The most useful capability provided by these tools is the ability to evaluate the potential of a given innovation in terms of its likely effect upon whole production systems (Jacques & Tipper, 1993). Used in this way, the models have the potential to increase the efficiency of adaptive agricultural research (see recommendations (8.4).

Further Development of the Models

A significant limitation of the spreadsheet format of the models (as with several other types of model) is the lack of immediate clarity of structure and function to the unguided user. Recent advances in modelling and graphics software should allow a more user friendly interface and greater transparency of the modelling process (see recommendations (8.4).

## 8.2 Technological Change as an Economic Process

It was shown that the effects of markets on the technical development of agriculture found by Collier, in Chamula and Zinacantán (Collier, 1990) have not been reproduced in other peasant communities in the state of Chiapas. This was due to the widely differing local circumstances of each community. Important variations in the market systems found between communities were: the relative isolation or integration of communities relative to external markets; the type of markets with which communities were integrated; the nature of transactions within each market; and the response of the community to external pressures. The response to external markets was found to depend greatly upon the internal structure and stratification of the community, as observed by Stavenhagen (1979).

Are markets necessary for the development of agricultural technology, and are they sufficient? The first conclusion from the above case studies is that, strictly speaking, markets are neither necessary nor sufficient for the development of agricultural technology. This was demonstrated by the farmers of Coquija, whom, while relatively isolated from both agricultural input and product markets improved both their milpa and cash crop techniques. The case of Yaluma highlighted the insufficiency of markets alone, to stimulate development.

Despite the finding that markets are not always sufficient to stimulate technological change, much of the evidence from these communities substantiates the Hayami and Ruttan's principal hypothesis (Hayami & Ruttan, 1971): that increasing scarcity of a given factor tends to stimulate innovations that will save that resource. This was demonstrated, even in cases where the factor scarcity was not reflected in a market price, for example, the investment in land improving (saving) non-burning cultivation techniques despite the effective absence of a land market. The evidence for market-led innovation was also strong; hence the general trend towards cash crop production in several communities as a result of increasing demand for capital and consumer goods.

Grabowski's (1979) implications of induced innovation, though supported by the evidence from Chamula and Zinacantán, appear to be oversimplifications when viewed in the context of the complex interactions within the various market structures that were observed. These cases demonstrated the necessity of considering the combined effects of components within the rural market system. Chamula and Zinacantán demonstrated how the presence of strong markets of agricultural inputs, credit, labour and produce combined to stimulate the development of relatively high technology cash crop production. The year round availability, in markets, of basic foodstuffs at competitive prices appears to have contributed to the stagnation of self-sufficiency technology. In contrast, San Miguel farmers managed to develop their coffee production technology, (despite problems in the agricultural supply markets) in order to take advantage of opportunities in the coffee market. However, the inadequacy of markets supplying basic foods ensured that interest in *milpa* technology was maintained.

In addition to leading and inducing innovation it was also shown that markets or market imperfections can effectively constrain technological change. The weakness of external market links in Coquija, due mainly to its isolation meant that innovation was concentrated on self-sufficiency and low cost methods, requiring few external inputs. Finally, in Yaluma it appears that earning opportunities in the external labour market have outweighed the perceived profitability of cash-crop production, where attempts at innovation failed due to market constraints. The labour market has not, however, provided enough security for farmers to lose interest in their maize production.

Problems with Theories of Allocation

It was demonstrated that peasant farmers not only make allocation decisions between different crops, but they also make allocation decisions about the labours within the same crop during the growing season. The fragmentation of the decision-making process means that, ultimately, combinatorial or method decisions cannot be meaningfully separated from input level decisions.

Implications for Risk Aversion Theories

The study did support the theory that farmers respond to risk by adopting lower intensity, safer or more conservative methods of production. Advanced plantations did seem to involve greater financial risk and some farmers mentioned this as an important factor. However, risk was only one of the factors that discouraged farmers from improving their plantations. The availability of cash inputs and seasonal labour constraints were probably more important.

Chyanovian based Household Theories

The study showed clear the linkages between production and consumption aspects of farm households: consumption requirements were obviously important considerations for farmers deciding how much cash and labour could be allocated to plantation improvement. The data for coffee production agreed with Chayanov's prediction (Durrenberger, 1984) that the amount of labour supplied by each worker depended on the ratio of workers to consumers. As the ratio of consumers to workers increases, so the labour supplied by each worker must increase.

## 8.3 Technological Development, the Opportunities and Obstacles

Both subsistence and cash cropping systems appear to present considerable opportunities for improvement, both in terms of area and labour productivity, and in long-term sustainability. However, the cost of making improvements (in terms of loss of effective income) for peasant farms is often greater than has previously been suggested.

As peasant enterprises survive by the careful and continuous allocation of (relatively) scarce resources to both cost saving and revenue earning activities the impact of interventions, such as credit programmes, will depend on the balance of resources in each household. Therefore, the very assistance that will enable one farmer to modernise effectively will lead another into indebtedness.

### 8.3.1 Subsistence Agriculture

The study of change in subsistence agriculture among the Tzeltals showed that most of those innovative farmers who adopted non-burning *milpa* succeeded in establishing a secure, sustainable subsistence base for their families. This was confirmed during a brief visit to the Tzeltal region in 1993; several of the farmers who had adopted this method during the study period were contacted, and all reported continued improvements in soil fertility and *milpa* productivity.

The need for accelerating the adoption of sustainable production methods, of the type described (4.2), is clearly demonstrated by the study. In practice however, there are definite obstacles that need to be addressed: (1) the low yields obtained during the first two to three years of non-burning; (2) low initial labour productivity due to increased weeding and land preparation and (3) the lack of confidence in the recommendations of external agencies, particularly government extension agents.

The hypotheses about technical change in milpa cultivation, generated by the modelling exercise, identified poorer farmers as a group facing particular economic barriers to the adoption of sustainable subsistence agriculture:

The tension between sustainable and non-sustainable methods of maize production in the Tzeltal area is dependent upon income. Farmers with sufficient cash available for investment in *milpa* (800 pesos per year) will lose very little income over the 5 year transition period by adopting sustainable methods. However, farmers with no capital to invest in fertilisers or herbicides are likely to lose "effective income" of over 2000 pesos over the same period. Poorer farmers are therefore much less likely to adopt non-burning production. Unless some form of financial assistance is given to poorer farmers, it is likely that the processes of land degradation and proletarianisation will accelerate, leading to further reductions in the incomes of this group.

Projects designed to make improvements to the *milpa* systems in this area have not taken sufficient account of the variations in financial and labour resources of farm families, or the attitudes of farmers towards external information sources. Native Tzeltal fieldworkers, who have themselves experienced the adoption of new techniques, would make the most convincing change agents and local organisations rather than government agencies are more likely to understand the particular constraints and obstacles to improvement that occur in each location. Unfortunately, however, most of these local organisations are currently under resourced and struggling to survive (Harvey, 1990).

### 8.3.2 Cash Crop Production

It was shown that the benefits of adopting the "modern practices" recommended in recent government programmes such as INMECAFE's Programa Naciónal de la Roya, were not as clear cut as has been suggested by the promoters of the new technology.

Differential Benefits of Modernisation

Output from the coffee model suggested that the benefits of intensification of the coffee system would be small for farmers who were allocating small absolute levels of inputs to their plantations (they will be in the lower portion of the production curve and returns to increased labour input in cultivation may be greater than returns from improvement). In contrast, those farmers who were applying large amounts of labour per hectare and for whom the marginal returns to labour had declined would benefit most from modernisation.

Furthermore, the modelling exercise suggested that, for many farmers, adoption of the promoted coffee improvement programme would be likely to lead to losses rather than gains, particularly if real interest rates are above 10% (as was the case). At this level of interest only farmers with scarce labour resources were predicted to gain significantly, and those with "typical" levels of resources or scarce cash were likely to lose significant income over 10 years. Farmers with scarce cash resources appear to be likely to incur losses on attempts to improve perennial cash crop systems by any of the observed methods, unless assisted with credit.

The Choice of Coffee Improvement Methods

The modelling exercise suggested that the farmers faced a "Hobsons Choice" between alternative methods of plantation development:

> Adaptive methods of plantation improvement were attractive to farmers with rustic plantations because of the low level of investment required and the low risk (as reflected in the low sensitivity to changes in the discount rate). Unfortunately the resulting intermediate plantations represented a technological "dead end", as it was not profitable to invest further inputs in the development of an advanced level plantation. Alternatively, the promoted methods of improvement offered a viable means of transforming rustic plantation to an advanced level, however, they were costly and also more risky (with profitability particularly sensitive to the discount rate, the scale of the improvement operation, and the resources available for coffee production).

Time-Preference, Performance and Qualitative Decisions

As coffee plantation improvement is a process that takes several years, all farmers have to consider the difficult question, whether to try to maximise their earnings in the short-term or whether to invest for the future. These considerations do not only apply to the major decisions such as "whether or not to modernise", but also to the "How", "When" and "Where" decisions taken daily, throughout the agricultural year. Once a farmer has decided to modernise his plantation the method of improvement must be chosen. If the farmer does this by a cheaper, more *ad-hoc* methods then the improvement will be slow but the loss of earnings in the meantime will also be less. If a more input intensive method of improvement is pursued then the improvement will be greater and more secure but the demands of this method may force the farmer to minimise expenditure on household goods. Thus, this strategy may require a shift in the allocation of labour towards subsistence production. The inevitable fragmentation of the decision-making processes described above, provides an explanation for the uneven pattern of plantation development that was observed in the region.

In conclusion, coffee farmers of the northern highlands have adapted promoted methods of plantation improvement to suit their own convenience and individual circumstances. However, the promotion of a single technological package over an area where the agricultural potential varies greatly has hindered the efficient exploitation of the natural resource base. A more effective strategy would be to encourage farmers to execute (after developing their own plans for) the selective intensification of areas of high productive potential, and diversification in areas where this is not viable. This approach would take advantage of the innate capacity for peasant farmers to micro-manage their resources (see recommendations 8.4.2).

## 8.4 Recommendations for The Northern Highlands

### 8.4.1 The Principles for Action

With the prospect of increasingly open markets influencing the economic environment of rural Mexico, peasant farmers must exploit their potential competitive strengths more effectively in order to thrive. The areas of potential advantage of the peasant mode of production (as compared with the large scale agro-sector) are its flexibility, durability, the ability to efficiently manage "marginal[2]" resources (particularly fragile and mountainous lands), and the ability to provide a vast array of products with particular special qualities. The value of these attributes (particularly the last two) appears to have been overlooked by economists and planners. However, it is essential that any effort to intervene is based on an understanding of these principles.

### 8.4.2 Technical and Research Recommendations

Before providing technical recommendations it should be emphasised that new technology itself will not provide solutions to the problems of peasant farmers, but it may furnish those who are problem solvers with better tools. The acquisition of a new technique may offer fresh opportunities but success will depend upon the time, place and measure of its application. Despite this qualification, a number of areas for potential improvements in both *milpa* and coffee production systems were identified by the study, and consequential recommendations are outlined in the following paragraphs.

<u>Subsistence Production Systems</u>

The most important technical obstacles to the adoption of non-burning milpa farming are the low initial yields and the increased labour requirement during the first 2 - 3 years of implementation. Both of these factors are related to the control of weeds in unburned *milpas*. Technical efforts should therefore focus upon cheap methods of overcoming the weed problem.

a) The improvement and promotion of cover crops (and green manures). Leguminous vines such as *Vigna unguiculata* and *Mucna spp.* can be used to smother weeds and also build up

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2 Marginal is used in both a quantitative sense (small quantities, eg. micro-plots of land) and a qualitative sense (these resources are often dispersed in time and space, and inaccessible).

nitrogen rich mulch. These methods were used extensively by the pre-colonial Maya but largely fell into disuse during the colonial period. The main technical requirement for re-applying this method is the development of reliable sources of locally adapted seeds.

Investigation of cover crops could justify the re-direction of some of the national research funding currently spent on high technology maize production, which will only be applicable to a small section of the agricultural sector. A small amount of extra funding would be required to improve the links between research and extension (see programme recommendations (8.4.3).

b) Improvement of ultra low volume herbicide application technology for backpack sprayers would benefit smallholder farmers around the world. The main limiting factor in the effective application of herbicides by this means is the labour required to carry water from springs or rivers to the fields (clean water is a necessity as the efficacy of several herbicides is impaired by organic impurities). ICI have developed a potentially useful electrostatic sprayer but, at present, its use is limited to the application of specially designed pesticide formulations.

Technical research and development in this area would be most effectively carried out by the chemical industries. Whilst these multi-nationals may not view the investment as profitable, the World Bank or FAO should consider appropriate financial incentives.

Cash Cropping Systems

A two-fold strategy is advocated: firstly development of appropriate technology for small-scale intensive systems that will be applicable to selected locations where the necessary inputs are available and land is suitable; secondly development of low intensity agroforestry systems yielding a diversity of products such as timber, fruits, spices and medicinal plants, as well as coffee.

Intensive System Technology:

Priority should be given to finding methods of decreasing the costs of plantation improvement. There are several possibilities: (1) The introduction of other crops, such as annuals between the rows of coffee. This has been done successfully with squash in the Cho'l region. As well as producing a nutritious and saleable crop, the squash plants also reduce the weed competition. (2) Technology to reduce the labour requirement for coffee plant propagation and transplanting. There appears to be considerable potential for the development of new hand tools for land preparation. (3) Appropriate plant propagation technology, such as non-mist propagators could be established at village level to provide high quality material for transplanting at relatively low cost.

Extensive System Technology:

The main constraint for the introduction of diverse but high value timber and fruit trees into coffee plantations is the availability of genetic material of sufficient quality. A national programme of tree improvement could be enhanced by identification, selection and propagation of local provenances (again this is another area where local action research could be integrated with conventional research programmes). Low cost plant propagation technology, mentioned above, would be a valuable aid to this effort. Another important area of practical research for this extensive agro-forestry system would be to develop timber harvesting techniques that would minimise the damage to surrounding cash crops.

Credit and Advisory Services

Current credit and advice schemes provided by the State should either be abandoned altogether or else radically restructured. The ultimate aim should be to provide a framework that will serve each rural enterprise according to its individual requirements. Two basic measures are advocated: (1) The decentralisation (managed privatisation) of most credit and advisory operations to farmers' organisations, co-operatives and other non-government institutions, and (2) A shift of emphasis away from the promotion of pre-formulated technical packages towards the promotion of (and training of farmers and their representatives in) the processes vital for agricultural improvement: rural appraisal, innovation and planning. This should include assisting groups of farmers to identify the potential opportunities and constraints within their existing farming systems, the establishment of a farmers' network for exchanging information about on-farm trials, assisting truly innovative farmers[3] by teaching them better experimental techniques, and offering training in enterprise planning and management.

Particular attention should also be given to the processing and marketing of products other than coffee. The marketing of products within the region of southern Mexico offers considerable potential. Information about prices (and quality specifications) of produce in key markets (San Cristóbal, Tuxtla Gutierrez, Mérida and México D.F.) could be disseminated at low cost by public radio. The service would also assist the development of off-farm economic activities such as tourism and small-scale rural industries. An initial investment (8.4.3) would be required to transform the current extension system, in the long term, the system should be able to function effectively with similar levels of resources currently applied to agricultural extension.

Appraisal of Natural Resources

While the study focused on the technological and economic aspects of rural development it is recognised that there is a vital need for more information about the related ecological systems.

Data relating to the state of soil and forest resources in the region should be gathered using conventional and remote sensing methods, and this should be compiled and held on a geographical information system for the region. This would provide the basis for the development of a regional strategy for conservation and resource management, identifying areas with special biological characteristics that merit preservation and areas at risk of environmental degradation. As the system would also enable the determination of appropriate ecological constraints for agricultural development, it should be closely integrated with the provision of agricultural advice. An outline of the programme required to initiate this activity is given below. The permanent operation of a facility of this type, covering the whole of Chiapas, could cost anything between $ 0.5 - 3 million (US) per year depending on the level of sophistication of the computer hardware. Given the unique importance of Chiapas within Mexico, as a centre of biodiversity and agricultural production, this level of expenditure should be easily

[3] Descriptions of some "truly innovative" farmers are given in Apendix 8. This definition of innovative differs from the conventional one assigned by extension researchers.

justified.

Research into the Mobilisation of Indigenous Knowledge

Investigations of "indigenous knowledge" about agriculture, medicinal plants and natural ecosystems are currently fashionable research areas. However, studies have concentrated on the formalisation and documentation of knowledge, so that it may be readily accessed by the scientific community, rather than understanding the processes behind the development and use of agricultural, ecological and medicinal knowledge within rural societies. Furthermore, studies have been biased towards distinct social groups and practices that are identifiably "indigenous"; in Latin America this implies the neglect of large sections of the (*mestizo*) rural population that may hold equally valuable pools of expertise.

It is therefore recommended that research be carried out into the mobilisation or application of popular, indigenous or local knowledge within the context of agricultural improvement[4]. Within the proposed study, the utilisation of software tools, such as those that were developed during the course of this investigation, could be extended. This would involve construction of a user-friendly interface for the models and the training of extension workers in their use. The research could be executed as a doctoral or post-doctoral study (within an action research framework).

Research into the Micro-Management of Resources

Richards (1989) has referred to the cumulative effect of micro-decisions during the agricultural cycle as the "performance factor". The results of this study concurred with Richards' conclusions, that performance is important in determining final productivity of small farm enterprises and also highly variable between individual farmers.

The fact that many production decisions relating to agricultural improvement can be (and usually are) broken down into sequential components has either been ignored or forgotten by programme planners and technicians. To some extent effective planning requires the hardening-up of decision-making by

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4 The application of indigenous, popular or local knowledge to the resolution of a particular problem in a given location implies either the mobilisation of the knowledge within the local population (perhaps by a trained advisor acting as a catalyst), or the transfer of indigenous knowledge from another location.

specifying sets of operations to be carried out at given times, over given areas; on the other hand advantage can be taken of micro-opportunities, by "adding value" to existing patterns of work:

> in a recent example of a successful tree planting project in the northern highlands, farmers were encouraged to take two or three trees to plant each time they went to work in their fields. This was much more successful than attempts to mobilise whole communities in nearby areas to plant large numbers of trees on certain pre-planned days.

The coffee study indicated that diversity of production systems within the same farm (even though the end product may be identical) allowed farmers to utilise scarce resources more effectively and to reduce the inherent risks of cash crop cultivation. Further research into the value of heterogeneity of cultivation systems at the level of the individual smallholding could yield valuable information on "good management" practices. This would be an appropriate subject for a doctoral thesis (again, to be carried out in the action research framework).

Investigation of Livelihood Systems of Groups not Included

The probable impact of the recommendations advocated in this section upon women and landless families have not been fully considered. Possible additions or modifications to the proposed interventions in the light of the problems and choices faced by these groups should be considered. An applied study of 6-9 months duration should commence as early as possible.

### 8.4.3 Project and Programme Recommendations

It is recommended that the technical changes and further investigations, proposed in the previous section, should be carried out within a strategic framework aimed at improving agriculture and conserving the natural resource base within the northern highlands of Chiapas. A proposal for a programme to establish a regional strategy for natural resource management has been prepared (Bubb & Tipper 1993), and is currently being considered by the Overseas Development Administration of the British Government, after initial funding for a feasibility study was provided by the British Council, Mexico.

The proposed programme includes integrated research and intervention sub-projects, as follows:

Research into (1) the state of the natural resource base and the effects of farming and forestry on forests, soils and watercourses, and (2) the methods of agricultural assistance and technical advice most appropriate for given locations within the northern highlands.

Intervention to (1) strengthen the institutions and organisations of the rural sector by offering information, training and advice, (2) establish specific examples of appropriate intervention (focused on stimulating innovation and local planning for conservation and resource use) in selected communities. These cases will be used as training centres and act as nuclei for the expansion of this style of intervention.

The programme will be carried out by a consortium of non-government and government institutions in Chiapas, with the assistance of a British centre of expertise, over 5 years and the expected cost will be approximately £350,000. The recommended doctoral research projects are not included in this programme.

### 8.4.4 Policy Recommendations

It must be emphasised that the effectiveness of any projects or programmes will be highly dependent upon the attitude and policies of both State and Federal governments. The modernisation of government institutions concerned with agriculture and natural resources, with the goal of providing high quality services for long term benefits, is imperative. Until recently the suggestion of collaboration between independent and state organisations, and the trimming and decentralisation of state intervention, would have been implausible. Indeed, it is easy to argue that the clientelistic structures of Mexican politics are being adjusted rather than dismantled, and in many places, the public perception of government is still one of a negative coercive force. However, the efforts of the Salinas regime to modernise the public bureaucracies has already resulted in a number of promising collaborative efforts between these sectors. Whether this trend is continued will depend, to a great extent, upon the policies adopted by the next presidency.

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# Appendix 1

**Key to Mexican Institutions and Abbreviations**

**BANRURAL**
- Rural development bank

**CONAFRUT** Confederación Naciónal Fruticola
- Promotion of fruit growing
- Nurseries of fruit trees

**CNC** Confederación Naciónal Campesina
- Representation of farmers to government

**CONASUPO**
- Distribution of subsistence foods and household goods
- Storage and cooperative shops

**DIF** Desarrollo Integral de la Familia
- Small scale projects invloving women and children
- Counselling for problems such as drugs and alcohol

**FERTIMEX** Fertilisantes de México
- Manufacture and distribution of fertilisers

**INEGI** Instituto Naciónal de Estadisticas Geographicas y Información
- National census information
- Mapping

**INI** Instituto Naciónal Indigena
- Small scale projects in indian communities
- Community health and midwives
- Training courses
- Marketing of artesan products

**INMECAFE** Instituto Méxican de Cafe
- Development of new coffee technology
- Marketing and processing coffee
- Credit to coffee producers
- International representation

**PESCA** - Development of fish farming

**PRONASOL** Programa Naciónal de Solidaridad

- Diverse range of small to large scale public works

**Reforma Agraria**

- Land expropriation and distribution
- Land title records, administration and arbitration

**SARH** Secretaria de Agricultura y Recursos Hidraulicos

- Ministry of agriculture
- Agricultural development programmes
- Programme for high technology maize production
- Forestry regulation

**SDR** Secretaria de Desarollo Rural

- Rural development credits
- Tree nurseries

**SPP** Secretaria de Programas and Presupuestos

- Control of government funds and auditing government projects

# Appendix 2

## List of Communities and Farmers Included in Study Surveys

### CHOL ZONE

| Community | Sample No. | Name |
|---|---|---|
| UNION JUAREZ | 1 | ANTONIO MARTINEZ ORTIZ |
| | 2 | MATEO MARTINEZ LOPEZ |
| PETALCINGO | 3 | ALEJANDRO MENDEZ OLETA |
| COQUIJA | 4 | MANUEL RAMIREZ LOPEZ |
| | 5 | PEDRO RAMIREZ LOPEZ |
| | 6 | ALBERTO HERNANDEZ LOPEZ |
| OCOTAL | 7 | HERMELINDO JIMENEZ LOPEZ |
| | 8 | CRISTOBAL PEREZ PEREZ |
| | 9 | GERMAN LOPEZ JIMENEZ |
| SHUSHUPA | 10 | MANUEL PEREZ CRUZ |
| | 11 | MATEO JUAREZ PEREZ |
| | 12 | DOMINGO PEREZ PEREZ |
| PROP. PALMAS | 13 | ALEJANDRO PEREZ RAMIREZ |
| | 14 | GERMAN PEREZ RAMIREZ |
| | 15 | MANUEL PEREZ DIAZ |
| PARAISO | 16 | GREGORIO LOPEZ SANCHEZ |
| | 17 | ARMANDO LOPEZ PEREZ |
| | 18 | MANUEL TORRES PEREZ |
| MARISCAL | 19 | ANTONIO PENATE VAZQUEZ |
| | 20 | NICOLAS DIAZ ARCOS |
| | 21 | PASCUAL MENDEZ CRUZ |
| SHOCTIC | 22 | SEBASTIAN LOPEZ GUTIERREZ |
| | 23 | MATEO VAZQUEZ RAMIREZ |
| | 24 | PASCUAL PARCERO |
| MONTERREY | 25 | JUAN SANCHEZ ALVAREZ |
| JOLSIVAQUIL | 26 | MATEO PARCERO ALVAREZ |
| | 27 | ROSENDO CRUZ JIMENEZ |
| | 28 | ASUNCION CRUZ |
| CHININTIE | 29 | SEBASTIAN LOPEZ MARTINEZ |
| | 30 | MANUEL LOPEZ CRUZ |

| | | |
|---|---|---|
| | 31 | BENITO LOPEZ CRUZ |
| V GUERRERO | 32 | SEBASTIAN JIMENEZ MARTINEZ |
| | 33 | CARMELINO LOPEZ GOMEZ |
| | 34 | BENITO CRUZ HERNANDEZ |
| N ESPERANZA | 35 | FERNANDO SANCHEZ PEREZ |
| | 36 | MATEO GOMEZ PEREZ |
| | 37 | JOAQUIN MARTINEZ PARCERO |
| TIONTIEPA | 38 | CRISTOBAL RAMIREZ PEREZ |
| | 39 | ANDREZ MERTINEZ PEREZ |
| | 40 | MANUEL RAMIREZ PEREZ |
| J TIONTIEPA | 41 | FRANCISCO GOMEZ VAZQUEZ |
| | 42 | JOSE ALVAREZ LOPEZ |
| | 43 | FCO.GALLARDO LOPEZ GOMEZ |
| CH PALMAS | 44 | MANUEL LOPEZ MARTINEZ |
| | 45 | MATEO JIMENEZ PEREZ |
| | 46 | FERNANDO LOPEZ MARTINEZ |
| CH JUAREZ | 47 | FERNANDO GUTIERREZ VAZQUEZ |
| | 48 | RAFAEL LOPEZ VAZQUEZ |
| | 49 | DOMINGO GOMEZ VAZQUEZ |
| PANSUSTEOL | 50 | JULIO PEREZ PEREZ |
| | 51 | JOSE FRANCISCO RAMIREZ |
| | 52 | ABELARDO GUTIERREZ LOPEZ |
| WILLIS 1 | 53 | JUAN LOPEZ VAZQUEZ |
| | 54 | DOMINGO LOPEZ PEREZ |
| | 55 | ANTONIO LOPEZ MARTINEZ |
| WILLIS 2 | 56 | ANTONIO LOPEZ MARTINEZ |
| | 57 | ROBERTO GARCIA LOPEZ |
| | 58 | ABRHAM LOPEZ LOPEZ |
| JOLHUITZ | 59 | ANTONIO LOPEZ LOPEZ |

**Tzeltal Zone**

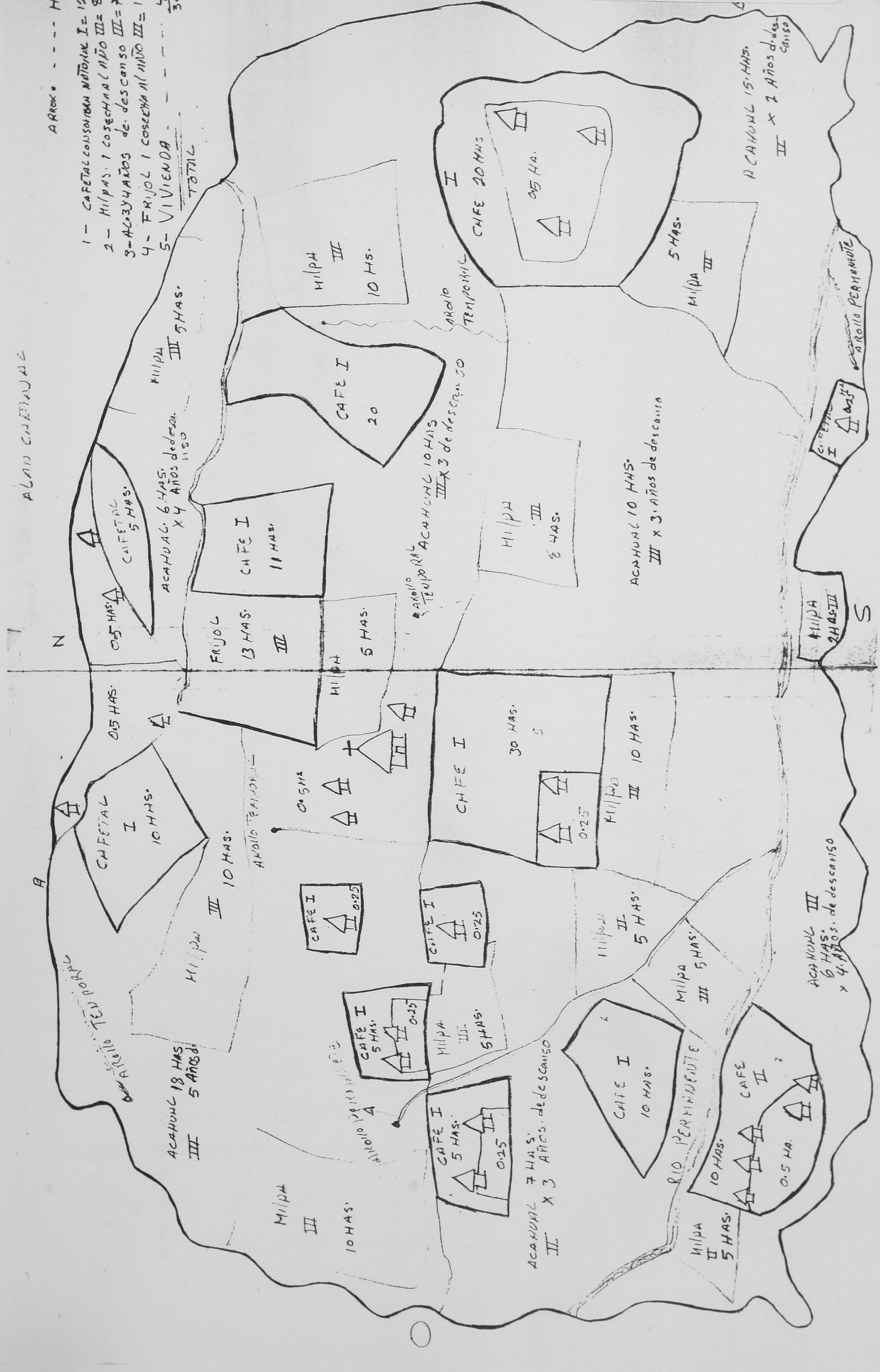
| Community | Sample No. | Name |
|---|---|---|
| CHICH | 1 | JUAN DEMESA GARCIA |
| | 2 | NICOLAS ALVAREZ MORALEZ |
| | 3 | FRANCISCO DEMESA |
| TIAQUIL | 4 | FRANCISCO DEMESA |
| | 5 | MARIANO PEREZ GOMEZ |
| | 6 | MARIANO MORENO DE ARA |
| A CANTAJ | 7 | MANUEL GOMEZ PEREZ |
| | 8 | MIGUEL CRUZ MENDEZ |
| | 9 | JERONIMO LOPEZ GOMEZ |
| CHALPUL | 10 | MANUEL GOMEZ CRUZ |
| | 11 | PEDRO GOMEZ LOPEZ |
| JOLCACUALA | 12 | MARCOS M PEREZ |
| | 13 | JUAN M GOMEZ |
| | 14 | MANUEL M PEREZ |
| TIANCHIBIL | 15 | DOMINGO MIRANDA LOPEZ |
| | 16 | MANUEL LOPEZ MIRANDA |
| | 17 | DOMINGO LOPEZ HERNANDEZ |
| ALAN CACUALA | 18 | MANUEL MORENO HERNANDEZ |
| | 19 | PEDRO JIMENEZ GOMEZ |
| MANG LIM | 20 | MIGUEL HERNANDEZ GOMEZ |
| | 21 | JUAN MORENO GOMEZ |
| | 22 | SEBASTIAN PEREZ MORENO |
| GPE PAXILA | 23 | JULIAN HERNANDEZ MORENO |
| | 24 | MANUEL MORALES GOMEZ |
| | 25 | MIGUEL RUIZ MORALES |

**The Tzotzil Zone**

| Community | Sample No. | Name |
|---|---|---|
| EL ROSARIO | 1 | Manuel Lopez Diaz |
| EL ROSARIO | 2 | Enrique Lopez Diaz |
| EL ROSARIO | 3 | Miguel Lopez Diaz |
| FCO MADERO | 4 | Andres Perez Perez |
| FCO MADERO | 5 | Miguel Perez Gomez |

| | | |
|---|---|---|
| FCO MADERO | 6 | Felix Diaz Diaz |
| EJIDO CALIDO | 7 | Carmen Rojas Hernandez |
| EJIDO CALIDO | 8 | Damacio Rojas Gutierrez |
| EJIDO CALIDO | 9 | Margarito Hernandez Sanchez |
| ALTAGRACIA | 10 | Filemon Gonzalez Hernandez |
| ALTAGRACIA | 11 | Pedro Sanchez Diaz |
| ALTAGRACIA | 12 | Juan Sanchez Gomez |
| ALV OBREGON | 13 | Miguel Perez Hernandez |
| ALV OBREGON | 14 | Alfredo Gomez Hernandez |
| ALV OBREGON | 15 | Anastacio Gomez Hernandez |
| CHOYO | 16 | Andres Lopez Gomez |
| CHOYO | 17 | Miguel Lopez Gomez |
| CHOYO | 18 | Agustin Lopez Perez |
| A L MATEOS | 19 | Marcos Perez Diaz |
| A L MATEOS | 20 | Andres Perez Hernandez |
| A L MATEOS | 21 | Andres Gonzalez Hernandez |
| JARDIN | 22 | Jose Molina Gomez |
| JARDIN | 23 | Mariano Perez Hernandez |
| JARDIN | 24 | Sebastian Cruz Perez |

## Appendix 3 Example of Map and Transect from Land Use Survey




Map of Alan Cantajal, hand drawn by Nicolas Hernadez Diaz

...sect of Tiaquil, hand drawn by Nicolas Hernadez Diaz

# Appendix 4

## Systems Of Coffee Production and Their Development

Despite a distinctly uniform model of coffee production that was introduced to Mexico by colonial landowners, it is now possible to see several distinct systems of cultivation within the state of Chiapas. Indeed, even within the peasant communities of the northern highlands a number of different systems were detected during fieldwork.

These systems have been classified (by the author) according to the following characteristics;

Shade

Shade is a critical factor in the classification of coffee systems, as increasing exposure to sunlight increases the rate of photosynthesis, and hence the yield of coffee obtained. However, as coffee is naturally an understory plant it is stressed by exposure to direct sunlight. Thus as shade is reduced, so the plants require increasing amounts of nutrients, in order to maintain a balanced metabolism. Shade also has the physiological effect of lengthening the internodes. Thus heavily shaded coffee produces long, straggling secondary branches with only a few fruit bearing nodes. Unshaded coffee, on the other hand, yields heavily but requires high levels of fertiliser and is more susceptible to stresses such as cold and drought.

The species used to shade the coffee crop is also an important variable. Coffee may be planted in a natural forest, in which case the shade is likely to be dense, non-uniform and difficult to regulate. Artificially sown shade trees vary in their characteristics; some such as bananas and citrus trees are not ideally suitable as shade providers, as their canopies are upright or compact and they compete with coffee for water and nutrients, Despite these disadvantages, they are often used as they yield crops of their own. Others, such as the Chalum (Inga spp.) fix nitrogen and provide a very even level of shade but serve no other purpose (apart from firewood and a rather poor source of nectar for honey bees).

Another factor affected by the level of shade is the amount of weeding required. Obviously, in unshaded conditions the rate of weed growth is higher and this is compounded by the amounts of fertiliser used in these circumstances. Furthermore, the types of weeds that grow in unshaded conditions (tough runner grasses) tend to be harder to control. However, the weed problem is usually ameliorated in densely planted stands of mature coffee by the compact nature of the unshaded bushes which in themselves may provide a fairly dense ground cover.

The Logic Of Production, Or System Management.

While it is assumed that the overall objective of any cash crop grower is to maximise long term earnings from the plantation, (albeit subject to various constraints) producers take different approaches to achieving this aim. In the case of a landowner employing hired labour to produce coffee, a uniform system of plantation management is required. Each task is carried out uniformly over a block on the plantation, one task at a time. The key variables of productivity are areas, and the man-days required to complete the necessary labours. Productivity is raised by increasing the yield, relative to costs over a whole area, by a general improvement in technique.

The small producer is much more flexible. Each coffee plant is tended individually and some parts of the *plantation may be more intensively worked than others.* When an old bush begins to decline in productivity a new one is planted beneath it; leading to a mixture of different ages (and sometimes different varieties) of plant in the same area. Household labour is not allocated on a pre-planned basis but switched from one activity to another according to immediate requirements or the most promising perceived outcome. For example, weeding, pruning and shade control over a single coffee bush may be carried out concurrently. Furthermore coffee production may not be the most important farm activity, particularly when a farmer's priority is to assure the self sufficiency of the household.

As well as different approaches to the management of the production system there are also several possible production strategies. Coffee may be the only crop harvested or it may be one of a polyculture of different fruits, tubers, woods and gums. The grower may concentrate on elevating yields, or aim for one of the expanding niche markets for high quality or organically grown coffees.

Variety

Old varieties of coffee such as Typica, Mondo Nuevo, Maragogipe and Bourbon are tall, with long internodes and bear few berries on each node. Modern varieties, such as Caturra, Catuai, Garnica, and Maracaturra are more compact, bearing more berries on closely spaced nodes. They also respond more to fertilisation. While the older varieties are now considered obsolete by most farmers, they retain some popularity as they are longer living and need only to be replaced every 20-30 years, compared with 15-20 years for the modern plants. Furthermore, some farmers contend that berries of the Bourbon variety weigh more than those of the modern plants, so picking becomes more efficient. This observation was not confirmed during the study, but it is true that if the modern varieties are left under -fertilised (particularly if potassium is lacking) then many poor quality, underweight beans can be produced.

The impact of the defoliating fungal disease known as leaf rust (*H. vastatrix*) in Chiapas has been variable. The worst affected producers are lowland coffee farmers in the west of Chiapas, where cafetals are unfertilised. Rust resistant varieties, produced by crossing commercial varieties with the resistant wild type know as "Timor", have been available since around 1987. However, they are low yielding and have a short productive life (around 12 years).

Intensity

Some coffee systems, such as those that are unshaded, automatically require a high intensity of labour and inputs, but most shaded coffee production can be carried out at varying intensities. The most common way of increasing the intensity of production is through the application of artificial fertilisers. Coffee also responds well to mulching, pruning, and weeding. Under all systems of management and shade types, all varieties are capable of doubling their yield in response to intensification.

The Colonial System

Coffee in the colonial *haciendas*, or *fincas* was grown under an artificially planted and maintained shade cover. The two main shade species used were of the *Inga* family, known as the Broad Leafed, and the Narrow Leafed Chalum. The varieties of coffee used were tall, with vigorous vegetative growth;

Typica, Borbon, Mondo Nuevo and Maragogipe. The bushes were uniformly spaced in rows, at densities of between 800 to 2000 plants per hectare.

The logic of this system was that it provided for the easy management of hired (or indentured) labour. Weeding and pruning and other labours were measured by area. The standard daily work unit, known as the *tarea* was generally $25m^2$. Harvesting was the only exception to this with workers being paid by volume of *cereza picked.*

One way of reducing the costs of establishing a plantation by taking advantage of the vegetative vigour of these early varieties was to create *agobios*. This was done by splitting the young bush three ways, bending the first three stems outwards, in a "Y" formation. From these primaries, fruit bearing secondaries would grow vertically upwards,(see figure). This method increased the productive area and consequently the yield of each plant. However, the requirement of a plant spacing of 3.5 - 4 $m^2$ for *agobios* meant that yield per hectare was probably lower. (This may not have been of overriding importance to landowners with more land than they were able to cultivate).

Under the colonial system of production, plantations were replanted or pruned block by block. Thus, within a large plantation there would be areas newly planted trees, (not yet in production) areas in full production and areas of declining production. When trees in an area became too old to renovate (usually between 25 to 40 years of age) they would be uprooted and new stock would be planted in its place.

Many different methods of pruning are described in manuals of coffee production (Villaseñor Luque, 1987), most of these were devised by colonial growers. The overall objective of pruning is to maintain a compact, healthy plant with as much fruit bearing potential as possible over a number of years. The difficulty with coffee is that berries are only produced on the vegetative growth of the previous year's secondary shoots. This means that pruning inevitably involves the loss of some of the current year's production.

Pruning methods can be divided into three groups. The first; removal of dead and diseased wood (*podas de sanitacion*), and non-bearing suckers (*deshije*) can be classed as sanitary pruning. This must be carried out to ensure that the plant remains healthy but does not change the morphology of the bush. The second; removal of apical buds (*recorte*) to stimulate the growth of new, fruit bearing secondary branches lower down the bush can be classed as compaction as it makes the bush grow denser, rather than taller, preventing berries being borne out of the reach of pickers. The third; rejuvenation, involves the cutting off of the plant about 30cm from the base (*recepa*), to allow a new bush to grow from selected shoots, which appear the following season. This is done when the bush is old but still has a good root stock.

The level of intensity of the colonial systems of coffee production was variable but mostly low, at below 15 qq (sacks) per hectare (Salazar Peralta, 1988). Artificial fertlisers were not available at this time and only a few *fincas* (such as the *finca Irlanda*) went to the trouble of using the coffee pulp as a mulch (yields around 15qq/ha).

Campesino Coffee Production 1930-1975

The production of coffee by peasant farmers on their own land in Chiapas is a relatively recent phenomenon. This is mainly due to the fact that the land reforms won in the 1910-1920 revolution only began to be enacted during the 1930's in Chiapas. Indeed, in the area of the northern highlands there were still some large fincas, controlling indentured labourers until the early 1980's, (notably El Trinidad, Mercedes and Caucalwitz in the Simojovel region). Finca Morelia in the Cho'l region still survives, but appears to be under pressure from the surrounding *ejidos*.

Campesino coffee production in the northern highlands received its first impulse in 1932, following a visit by President Lazaro Cardenas to Palenque. The national institution, Reforma Agraria was charged with promoting the crop, which it did by distributing coffee plants. At this time however, most of the Indian communities were still very isolated from the main routes of communication and closed to external markets.

Two peasant coffee systems developed during this period. The first of these was really a degenerate form of the colonial model, resulting from the take-over of old plantations, (usually abandoned, or semi-abandoned) or the copying of the plantation structure on a smaller scale by farmers who had experience of working as *peones* on the old *fincas*. The second involved the enrichment of natural forest areas by planting the new species under existing trees after clearing out some of the undergrowth.

The Post Colonial Peasant System

The structure of the post colonial peasant system of coffee production was found to be essentially the same as that of the colonial system; with Chalum shade trees over widely spaced rows of tall (old varieties) coffee bushes. Indeed, many of these *cafetales* were established on the sites of old plantations. The main differences to be found in these cases were the high density of the shade and the age of the coffee bushes; many of which were over 40 years old, some as much as 80, due to the slow rate of replanting. Consequently yields tended to be very low (5 - 10 sacks per hectare).

The slow rate of replanting of coffee bushes can be explained by several interrelated factors. Firstly, the total effort invested in coffee production by peasants was, until the late 70's, very little compared with maize production for self sufficiency. Low world prices, severe intermediarism and the isolation of the communities in the region from external markets meant that coffee production was far less attractive than it had been for the colonial *finca* owners, with their direct contacts in the consumer countries. Furthermore, the time of year for replanting coffee coincides with intense labour demand for weeding and sowing in the milpa system. With a high density of shade and little replanting, competition with maize production was reduced, as virtually the only input needed for the coffee was Winter labour for harvesting (not needed in the *milpa*).

The agrarian situation was another factor. Until the 1970's when there were still a large number plantations "waiting to be occupied" farmers were more interested in obtaining more land and harvesting, without having to cultivate, than in developing their production in a concentrated area.

Another explanation of the logic of this system was that the scarcity of cash in peasant households meant that farmers were reluctant to cut down the old coffee bushes to make way for new stock because this would cause a loss of income for the 3 - 4 years needed for a new bush to come into production. There is some validity in this point but it was found that farmers usually avoided this "production gap" by planting young bushes beneath the older ones, thus allowing the old bush to continue to produce, albeit feebly until the young plant became productive.

In summary the post colonial peasant system of coffee production was characterised as a heavily artificially shaded stand of old (tall, long living) varieties of low intensity.

The "Natural" or Peasant Coffee System

It was found that "natural" peasant coffee systems became established in virgin and secondary forest areas of the northern highlands where the colonial plantations were of little influence. Seedlings and young coffee bushes distributed by the *Reforma Agraria* were planted by farmers in forest areas adjacent to the *milpas, recreating, in a sense, the natural habitat of the coffee plant.*

*The disordered structure of the natural shade* meant that the *cafetales* were more irregular than colonial based systems, and although coffee was the main economic species it was usually just one of a number of useful trees and bushes, some naturally occurring, some introduced, in a given area. These included zapote, mango, avocado, cacate and lemon grass.

As with the post-colonial system the natural system was managed in a way that minimised the inputs of labour necessary at times when the *milpa* required work. The individual plants were not as old as those in the post-colonial system but as they tended to be spaced even further apart (rarely more than 1000 plants per hectare) yields per area were still very low (5-10 sacks per hectare).

Peasant Coffee Production 1975-1990.

In 1975 and '76 a series of severe frosts in the major coffee producing regions of Brazil, sent World prices skyward. From an average of around $65 US per sack (57.7 kg) in the early 70's the New York market price peaked at almost $325 US per sack in May 1977. Following this demonstration of the inelasticity of the World market the producer countries of the International Coffee Organisation (ICO) decided to fix new quotas, restricting the supply of coffee in order to maintain a high price. The quotas were maintained for just over 10 years, until the ICO agreement was broken, in 1989, following disagreements between Brazil and Columbia, the two largest producers. During this period the New York market price remained high, averaging around $140 US per sack. Since the breakdown of the ICO agreement prices have returned to pre-'76 levels.

Furthermore, a number of infrastructural projects undertaken in the oil boom years of the 70's had opened up communities in the northern highlands to new markets. Notably the construction of the roads from Tuxtla Gutierrez to Villahermosa, and Bochil to Simojovel, which opened up the Tzotzil coffee producing area, and the road from San Cristóbal to Palenque, with its branch to Yájalon, which opened up the Tzeltal and Cho'l coffee producing areas. (Plantation owners and coffee merchants in the Cho'l area had previously flown coffee out of the area from an airstrip in Yájalon). Subsidised fertiliser became available, albeit sporadically through the national fertiliser company FERTIMEX.

Producers in Mexico did not receive the full benefit of the increase in World prices. The State maintained a tight control over export licences, imposed heavy taxes on exporters and even controlled prices within Mexico through the coffee marketing board INMECAFE. Despite the dampening effect on the market of INMECAFE's intervention, the institution also mounted a major programme of coffee production improvement, which included the northern highlands of Chiapas. During the late 1970's and most of the 1980's farmers were encouraged to increase the density of plants in *cafetales* and to begin fertilising (PROGRAMA DE LA ROYA) and fumigating their coffee to combat the spread of coffee leaf rust which was arriving in Chiapas from Guatemala.

The INMECAFE System of Coffee Production

The main thrust of the INMECAFE programme was the introduction of new varieties and chemical inputs. The logic behind the system promoted was as follows: The defoliating fungal disease (H. vastatrix) known as *La Roya*, (leaf rust) had caused a considerable effect on yields in other coffee producing countries; (even decimating the Ceylon coffee industry in the 1920's, causing the colonial planters there to turn to tea) it was now advancing on Mexico from Central America, having spread northwards. The only effective means of control of this disease, it was reasoned, was through fumigation with either copper based or systemic fungicides. However, at this time, the productivity of most peasant coffee production was too low to justify the cost of fumigation, so in order to protect the coffee industry in Mexico it was seen to be necessary to intensify the whole system of production.

The new system of production proposed by INMECAFE during the 80's was still based on the colonial model: a regulated amount of shade was to be provided by artificially planted Chalum trees. The coffee varieties to be used were new, short stemmed plants, (*Caturra* and *Garnica*) with short internodes and a greater number of berries borne on each node. The density of coffee plants was to be higher; between 2000-2500 plants per hectare. Plants were to be fertilised annually following the harvest, and to be fumigated every two weeks during the rainy season, once signs of the *Roya* were detected. The recommended pruning regime included an annual sanitary pruning, one *recorte*, once the bush reaches a height of 2m (usually 8 or 9 years) followed by replacement or *recepa* after 12 to 15 years. It was envisaged that as in the old colonial systems operations would be carried out in blocks rather than the plant-by-plant procedure to be found in the post colonial and "natural" peasant systems. From the results of field trials at their experimental station in the Soconusco, INMECAFE suggested that yields from this system would be between 25 - 35 sacks per hectare.

INMECAFE hoped that the adoption of their system would turn the peasant farmers of Chiapas into small but efficient commercial cultivators of coffee rather than mainly unproductive coffee harvesters that they were seen as. Not only did this system require the additional labours of fertilising, fumigation, shade control and pruning, but as the amount of light reaching the ground was greater than in the low intensity systems, it was found that substantially more weeding was required (weeds also stimulated by fertilisation).

Apart from the increasing infrastructural and market development in Chiapas, the high price of coffee in the World market and the INMECAFE Programa de la Roya there were two other factors that may have increased peasant interest in coffee production development in the northern highlands in the '80's.

The first was a gradual cooling off of the "hot" agrarian situation as most of the remaining, large *haciendas* in the region sold-up or were abandoned and left undefended to be taken over, either by the surrounding ejidos or the resident peones. During the 60's and 70's Cho'l, Tzotzil and Tzeltal communities had been fighting (often literally) for control of these great holdings in partisan struggles that often involved invasion and counter-invasion of disputed territory. The uncertainty of tenancy of land at this time cannot have promoted the investment of effort in perennial crop systems. The relative stability of the '80's and the realisation by farmers that there was no more land for them to acquire must have stimulated the establishment of long-cycle farming systems. The second was the influence of a production oriented peasant organisations such as the *Union de Uniones*.

The Results Of The INMECAFE Programme and Regional Developments.

Despite extensive promotion of these techniques by INMECAFE technicians during the 80's, (nearly every community surveyed had been visited, and had been offered new coffee plants and backpack sprayers) adoption of the INMECAFE package was patchy. One reason was that the *Roya* turned out to be far less damaging in most parts of the northern highlands than was initially expected, (the only seriously affected region of Chiapas during the 1980's was the north-eastern lowlands - a marginal area for coffee production at the best of times due to its low altitude). Furthermore, when the disease did arrive peasant farmers found it far easier to control the damage by increased fertilisation, pruning and cutting back the shade. Fumigation proved to be unpopular because of the strenuous effort required to lug water in backpack sprayers up the often precipitous slope from the nearest stream to the *cafetales*. On the other hand, fertilisation combined with a reduction of the shade, resulting in improved aeration around coffee plants, had beneficial effects on both the spread and damage of the disease and the yield of coffee.

Contemporary Peasant Coffee Systems

The systems that developed as a result of the changes in markets, infrastructure, peasant organisation, the agrarian situation and the efforts of INMECAFE in the northern highlands during the early 80's varied considerably in intensity. A continuum of coffee systems, ranging from the unchanged "post colonial" and "natural" peasant models to highly intensive INMECAFE-like systems were found during the study. However, even the most intensive systems observed had important differences to the original INMECAFE system: Firstly, few of the naturally shaded *cafetales* had the original shade replaced by Chalum, the existing trees were merely thinned to give a light but patchy shade, which often left some areas exposed to direct sunlight. Secondly the management of the *cafetal* continued to be plant-by-plant, rather than in ordered blocks. The management of micro-variations in soil, shade and space was to be seen in the intercalated planting of modern varieties amongst older bushes in single areas, and in the establishment of virtually unshaded mini-intensive blocks of $25m^{2}$-$50m2$. As a result plant densities were found to vary from 1000 (3m X 3m) to 3000 (1.8m X 1.8m) plants per hectare. Thirdly, fertilisation rather than fumigation was relied upon to compensate for the effects of Coffee rust. The resulting productivity of these systems was, not surprisingly varied, ranging from 12 sacks per hectare to over 40 sacks per hectare in some exceptional cases.

Perhaps the most important development in coffee production during this time was the change in attitude of many peasants towards commercial production. Previously, the only time devoted to cash crops was outside the needs of *milpa* production for self-sufficiency. In the 80's farmers discovered that they could earn enough by growing coffee to supply the family food requirements and more. Although only a very few farmers actually abandoned their *milpas* there was a reduction in effort applied to their cultivation, especially the bean component (normally sown two weeks after the maize). Furthermore, the increased intensity of coffee cultivation meant that many farmers had to hire labour in order to harvest the greater production. For the first time peasant farmers in this region became hirers of labour.

Modern Commercial Coffee Systems

Since the 1950's, the production of coffee by commercial plantation growers has intensified considerably. Modern commercial systems are completely unshaded monocultures, of high plant density (4000 - 6000 plants per hectare). The coffee is not planted or cultivated as discrete bushes, but normally forms hedges that are often planted along contours, so as to prevent erosion. Labours are managed row-by-row and yields from 40 - 60 sacks per hectare are normal. These intensive systems now predominate in the Soconusco region of Chiapas and in areas of Puebla and Veracruz, where plantation owners have sufficient capital to invest in the chemical inputs and labour required. The main disadvantage of unshaded, intensive coffee production is its susceptibility to frost damage, (as occurred in Veracruz and Puebla in the Winter of 1990/91).

A few demonstration plots of intensive coffee were established by the Union de Uniones in the northern highlands in 1990/91 but these are not yet in production.

Peasant Coffee Production Since 1990.

Both producers and merchants of coffee were dealt a severe blow by the fall in the world price of coffee that occurred in 1989. Mexican merchants were hit even harder than those in other countries due to the Government's action of halting the decline of the Peso against the Dollar, as part of its new macroeconomic policy; the *Programa de Solidaridad* (many merchants had hoped to hold onto stocks until the following Summer, allowing devaluation of the Peso to effectively raise the price of coffee which is sold in Dollars).

In the northern highlands of Chiapas many producers who had obtained credit in order to buy fertiliser were unable to repay their debts. Lines of credit were discontinued and supplies of fertiliser dried up. Coffee production was hit by both low crop prices and lack of available credit and inputs.

The study found that, as a result of these pressures, farmers turned away from coffee production and in order to secure food supplies for their families concentrated on *milpa* agriculture. *Cafetales* were left unfertilised, unpruned and the shade was allowed to grow back, weeding was carried out just once or twice a year, instead of three times. In many cases the sudden loss of fertilisation had a severe impact on quality, this may have been caused by the initiation of too many fruits by bushes, which were not subsequently able to fill them. For many farmers the 1989 coffee crises meant a return to pre-1980 cultivation practices. However, some farmers capable of innovation and determined to continue producing for a cash crop markets began to look for new opportunities and ways of developing their coffee systems.

Innovative Peasant Coffee Systems

Two contrasting approaches to the development of future coffee systems were identified in the study. The first is in some ways retrospective in that it proposes to shade coffee with a variety of different trees and to produce with a low intensity of labour and inputs. Implementation of this type of system was observed in some Tzeltal communities in 1991. Fast growing cedar and *caobilla* were being planted in cafetales to replace the Chalum shade. Other species being used to enrich the shade canopy in the Cho'l region at this time were avocados and mangoes. The main difference between this potential agroforestry system and the old "natural" coffee systems is that the shade is artificially sown at more or less regular intervals and improved, selected (both fruit and timber) tree species are now available. The technique of grafting is also used.

The second approach identified was a more intensive type of cultivation that will require external inputs if it is to succeed. Coffee is grown in hedges, along contours, without shade but unlike the modern commercial system the hedges are interplanted with annual crops, mainly beans and squash. This means that when the stand is still too young to produce coffee it will yield annual harvests. Furthermore, weeding and fertilising labours can be done on several crops simultaneously.

**Appendix 5**

**Observations of Annual Cultivation Labours**

Weeding (*Limpia / Chaporeo*)

During the harvest months weed growth in most plantations is considerable, so once the last bushes have been picked clean farmers usually begin weeding. All the farmers in the survey used *machetes* for clearing weeds; a few had tried using herbicides but found them uneconomical. One farmer said "..if I could put the labour I saved by using herbicide into something valuable it would be worth buying but as things are it would only be laziness". Most farmers favoured short machetes rather than the long variety. Although the short machete cuts less with each stroke it is lighter and easier to manage around the bushes and especially on stony ground. Most farmers cut the herbage to within an inch of the soil; anything less thorough is considered a poor job. In most areas the weeds that grow beneath the shade of the plantation are broad-leaved and fairly easy to cut. In this case a healthy man can cover at least 1/16 hectare per day and sometimes double this. In some areas, particularly the Tzeltal zone there have been infestations of runner grasses, (Plectostachyum Spp.?) which are much more difficult to control and faster growing at the lower altitude. Where this occurs an area of 1/25 hectare represents a good day's work. In all but the most rustic of plantations weeding is repeated once or twice; in the Summer, (soon after the first rains following the dry season) and in the Autumn. A few keen farmers carried out a fourth weeding.

Fertilisation (*Fertilizacíon*)

Once weeding is completed at the end of March or in the first weeks of April, the farmer must decide whether or not to fertilise the coffee plantation. This is one of the key production decisions of the year. Often, due to lack of cash or credit the farmer may have no choice but to reject fertilising. In this case the farm household becomes more reliant on the production of maize and, for the rest of the year, the farmer's attention and efforts will be turned away from coffee towards basic subsistence crops. If fertiliser can be afforded and is available the farmer may choose to carry out one or two applications. (Most technicians recommended a third application of fertiliser in the Autumn to enhance fruit growth and prevent fruit-drop prior to harvest; however, this practice is almost unheard of as cash is always very scarce at that time of the agricultural year). The choice of fertiliser type is nearly always restricted; the most common compounds used are 17-17-17 and 18-12-06. Application rates are 8 - 12 sacks per hectare or 0.3 - 0.4 kg per coffee bush. A major consideration in the application of fertiliser is the carrying involved. Few farmers posses mules, so the sacks are carried on the back (with *mecana - a band that passes across the forehead and behind the back*), first from the place of purchase to the homestead and then to the coffee plantation: sometimes several hours walk in total.

Each coffee bush is fertilised individually. The farmer scrapes away the trash in a "half-moon" (*media luna*) on the uphill side of the bush, around 20cm from the base of the trunk, using a short-handled hoe (*asadon*). A scoop is usually used to sprinkle the fertiliser onto the exposed ground. There are some, minor variations in practice: some farmers distribute fertiliser in a complete ring around each plant; some farmers cut into the soil and the topmost roots of the bush before applying the fertiliser; some leave the fertiliser exposed on the surface to leach in while others cover the material with trash or soil. Once carrying is accounted for, most farmers cover 1/7 - 1/6 hectare per day.

Little use is made of organic amendments or methods of fertilising, though some farmers pile the residues from weeding around the bases of coffee plants. Organic methods of production are being promoted in other areas of Chiapas, such as the Comalapa region, along the frontier with Guatemala, by a Dutch organisation, and in the northern fringes of the Lacandón rainforest by the Quiptic Farmers' Union. The main drawback with these methods appears to be the amount of labour required to manufacture and spread good quality compost. The supply of good composting material is also a constraint. Organic production of coffee may be economically viable when linked to a marketing structure that can pay a premium for this specialist product. Of course many farmers are organic producers "by default"; they cannot afford or obtain chemical inputs and live with consequential low yields.

Annual Shade Control (*Desombre*)

Not all farmers cut back the shade trees above the coffee bushes every year. The objective of shade control is to provide the ideal micro-climate and light level for the growing coffee. Where shade is too heavy coffee bushes grow long internodes (and thus fewer fruits per unit of vegetative growth), photosynthesise less and are more prone to fungal leaf diseases, (which thrive in moist, still air). If left unshaded most coffee bushes suffer from stress due to excessive light levels and transpiration, they are also more susceptible to frost damage. There are strong relationships between the levels of fertilisation, plant variety and the optimum level of shade (See APPENDIX 4). The ease of controlling shade depends upon the type of shade trees and whether they have been artificially planted at regular spacings or whether they are the upper storey remnants of natural forest cover. Naturally occurring shade trees tend to be much higher, more irregularly branching, with more compact canopies. For these reasons, with natural shade, it is both difficult to reach the canopy branches and difficult to obtain an even level of shade at the bush level. Where artificially planted trees provide shade most farmers used *Chalum* or *Chaluhuite*, (Inga Spp.) of which there are several sub-types with different widths of leaf. These trees have naturally flat, evenly spreading canopies and are only 6-8 metres tall. They are easy to prune and the off-cuts are a useful source of firewood.

Most farmers spent 5-10 days per hectare per year on shade control; this work was often carried out in conjunction with pruning and sucker control. Machetes rather than saws were the preferred tool.

Pruning and Sucker Control: (*Podas y Deshije*)

If left untended for several years coffee bushes, (particularly the older varieties) become straggly, with much dead wood and diseased leaves, few fruiting nodes and branches that extend upwards, above 3 metres (beyond the reach of easy picking). This uncontrolled development is particularly marked in over-shaded plantations. The most rustic producers claimed that it was not worthwhile pruning their bushes: this may have been true for once a bush has been allowed to grow in this way for more than 8-10 years only replanting or rejuvenating pruning (which entails total loss of yield for 2-4 years) can re-establish a productive plant. The principles and methods of coffee pruning are explained in APPENDIX 4. It was found that most farmers considered how to prune each plant in turn rather than making systematic decisions about sections of the plantation on the basis of age or general condition. Only the more advanced producers took the approach of targeting specific areas of the plantation for different pruning treatments. The types of pruning used also varied between types of producers. The rustic and intermediate groups used only sanitary pruning (the elimination of dead and diseased wood) and the elimination of suckers. However, the more advanced producers also used some plant-forming methods, particularly the *recorte* and selection of stems. Nearly all producers used machetes for pruning, though sucker removal is usually done by hand. Only a few farmers claimed to use saws as recommended by technicians and nobody was ever observed using one. When pruning was carried out it usually took 6-10 days per hectare. (Rejuvenating pruning - *Recepa* is covered in the plantation improvement section).

Harvesting: (*Corte or Cosecha*)

The coffee harvesting season begins in mid-November and continues into late February or early March. Most farmers make 3 or 4 passes over their bushes, as berries ripen in flushes corresponding to the flushes of flowering. The whole family is involved in harvesting and many farmers hire extra labour. Often the first portion of the harvest is sold in advance or on the spot to travelling buyers from the towns at a low price in order to secure capital for paying labourers.

If picking is done properly only ripe fruits are picked. Unripened, green berries impart a thin, bitter taste to the final beverage. Each berry is grasped between the fingers and twisted or rolled as it is pulled. This leaves the fruit stalk intact on the branch, where it can develop into a flower the following season. Berries are usually picked into a *canasta* or small bag slung around the waist of the picker. Pickers work along rows or uphill (working downhill one is more likely to loose one's footing and drop the day's pickings!).

The quality of picking did vary between households; this appeared to depend upon the supply of labour available in relation to the abundance of berries to be picked. When farmers were in a hurry they would sometimes "Strip" branches; pulling leaves, fruits and fruit stalks from the branch in a single sweep of the hand. The efficiency of picking depended upon several factors: (1) The number of berries at each node; this can vary from 2 to 8 but the time taken to pick the cluster is only ever 1 to 3 seconds (2) The number of clusters on each branch; this varies from 1 to 6; so if the number is low the picker is constantly having to reach for new branches. (3) The accessibility of branches on the bush; if they are high up of tangled this obviously slows the picking. (4) The slope of the ground and (5) The distance of the plantation from the homestead. (6) As the harvest season progresses and the bulk of the crop has been picked so the remaining berries are slower to gather. Of course there is also variation in picking speed between individuals, with children usually but not always slower than adults. Typical picking rates in kg of parchment coffee are were found to be from 9 to 20 kg per day (See Table A10.1).

**Table A10.1. Typical Coffee Picking Rates in Different Conditions**

| | Poor Conditions/ Small Harvest | Average Conditions/ Average Harvest | Good Conditions/ Good Harvest |
|---|---|---|---|
| Kg Parchment Coffee Picked / Day | 9 | 15 | 20 |

Data source: field measurements during 1988-9 harvest.

Once the coffee berries have been harvested they must be de-pulped and dried. Most families had their own hand cranked depulpers which there are two basic types: drum and disk, the former being superior in speed and quality but slightly less durable and more expensive. Pulping was usually carried out in the evenings after the pickers returned home with the day's harvest. This fairly light chore usually took a couple of hours each evening and was often carried out by the children of the household. Once the coffee has been de-pulped there remains a mucilagenous coating which should be removed prior to drying if the flavour of the end product is not to be impaired. The method used by farmers was to stand the de-puled beans in a container (often a tub or a conctrete holding tank for 18-24 hours) during this time sufficient fermentaton occurs for the mucilage to be readily washed off. This task was done by most but not all farmers in the areas studied. A few farmers had no adequate means of holding the beans for fermentation or else the supply of water was inadequate for washing. The local price of unwashed coffee was between 20-50% below the full price for washed parchment.

After de-pulping and washing the beans must be dried. Many farmers did not have concrete patios and used plastic sheets of which to spread the beans. The Cho'l region is the most difficult area for drying as rains are both frequent and prolonged at the harvest time. Finally the dried parchment coffee is bagged before transport to the point of sale.

# Appendix 6

## Milpa Modelling

### Input Availability for Milpa Modelling Scenarios

**Table A6.1 Key to Tables A6.2 - 6.**

| | |
|---|---|
| LAND (hectares) | |
| E.SP.LAB (working days) | Early Spring Labour |
| L.SP.LAB (working days) | Late Spring Labour |
| SUM.LAB (working days) | Summer Labour |
| AUT.LAB (working days) | Autumn Labour |
| CAPITAL (New pesos) | Cash available |
| | |

**Table A6.2**

| RESOURCE AVAILABLITY 1ST SCENARIO | | | | | |
|---|---|---|---|---|---|
| LAND | YEAR0 | YEAR1 | YEAR2 | YEAR3 | YEAR4 |
| E.SP.LAB | 15 | 12 | 9 | 6 | 3 |
| L.SP.LAB | 40 | 40 | 40 | 40 | 40 |
| SUM.LAB | 40 | 40 | 40 | 40 | 40 |
| AUT.LAB | 50 | 50 | 50 | 50 | 50 |
| CAPITAL | 50 | 50 | 50 | 50 | 50 |
| | 0 | 0 | 0 | 0 | 0 |

**Table A6.3**

| RESOURCE AVAILABLITY 2ND SCENARIO | | | | | |
|---|---|---|---|---|---|
| | YEAR0 | YEAR1 | YEAR2 | YEAR3 | YEAR4 |
| LAND | 15 | 12 | 9 | 6 | 3 |
| E.SP.LAB | 40 | 40 | 40 | 40 | 40 |
| L.SP.LAB | 40 | 40 | 40 | 40 | 40 |
| SUM.LAB | 50 | 50 | 50 | 50 | 50 |
| AUT.LAB | 50 | 50 | 50 | 50 | 50 |
| CAPITAL | 200 | 200 | 200 | 200 | 200 |

**Table A6.4**

| RESOURCE AVAILABILITY 3RD SCENARIO | | | | | |
|---|---|---|---|---|---|
| | YEAR0 | YEAR1 | YEAR2 | YEAR3 | YEAR4 |
| LAND | 15 | 12 | 9 | 6 | 3 |
| E.SP.LAB | 40 | 40 | 40 | 40 | 40 |
| L.SP.LAB | 40 | 40 | 40 | 40 | 40 |
| SUM.LAB | 50 | 50 | 50 | 50 | 50 |
| AUT.LAB | 50 | 50 | 50 | 50 | 50 |
| CAPITAL | 800 | 800 | 800 | 800 | 800 |

**Table A6.5**

| RESOURCE AVAILABILITY 3RD SCENARIO | | | | | |
|---|---|---|---|---|---|
| | YEAR0 | YEAR1 | YEAR2 | YEAR3 | YEAR4 |
| LAND | 15 | 12 | 9 | 6 | 3 |
| E.SP.LAB | 40 | 40 | 40 | 40 | 40 |
| L.SP.LAB | 40 | 40 | 40 | 40 | 40 |
| SUM.LAB | 50 | 50 | 50 | 50 | 50 |
| AUT.LAB | 50 | 50 | 50 | 50 | 50 |
| CAPITAL | 200 | 200 | 200 | 200 | 200 |

**Table A6.6**

| RESOURCE AVAILABILITY 5TH SCENARIO | | | | | |
|---|---|---|---|---|---|
| | YEAR0 | YEAR1 | YEAR2 | YEAR3 | YEAR4 |
| LAND | 15 | 12 | 9 | 6 | 3 |
| E.SP.LAB | 40 | 40 | 40 | 40 | 40 |
| L.SP.LAB | 40 | 40 | 40 | 40 | 40 |
| SUM.LAB | 50 | 50 | 50 | 50 | 50 |
| AUT.LAB | 50 | 50 | 50 | 50 | 50 |
| CAPITAL | 800 | 800 | 800 | 800 | 800 |

**Coffee Modelling Results**

**Table A6.8 Output from model runs for farms with different factor shortages**

| | | Land scarcity | | | Lab scarcity | | | Cash scarcity | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Year | Incom | @L1 | @L2 | Incom | @L1 | @L2 | Inco | @L1 | @L2 |
| R to I | 0 | 1387 | 1.0 | 1.0 | 1072 | .39 | .50 | 1486 | .50 | .84 |
| | 1 | 1212 | 1.0 | 1.0 | 998 | .30 | .60 | 998 | .50 | .22 |
| | 2 | 1212 | 1.0 | 1.0 | 1022 | .30 | .50 | 1239 | .60 | .50 |
| | 3 | 1212 | 1.0 | 1.0 | 1013 | .30 | .50 | 1425 | .50 | .84 |
| | 4 | 1212 | 1.0 | 1.0 | 1024 | .30 | .50 | 1436 | .50 | .85 |
| | 5 | 1501 | .95 | 1.0 | 1159 | .30 | .50 | 1568 | .50 | .68 |
| | | | | | | | | | | |
| I to A | 0 | 1387 | 1.0 | 1.0 | 1072 | .39 | .50 | 1486 | .50 | .84 |
| | 1 | 1018 | 1.0 | 1.0 | 811 | .29 | 1.0 | 467 | .24 | 0.0 |
| | 2 | 1018 | 1.0 | 1.0 | 918 | .40 | .50 | 1005 | .51 | .20 |
| | 3 | 1018 | 1.0 | 1.0 | 894 | .40 | .50 | 1292 | .60 | 1.0 |
| | 4 | 1018 | 1.0 | 1.0 | 945 | .45 | .50 | 1333 | .60 | 1.0 |
| | 5 | 1597 | .95 | 1.0 | 1266 | .26 | .50 | 1690 | .48 | .50 |
| | | | | | | | | | | |
| R to A | 0 | 1387 | .90 | 1.0 | 1072 | .39 | .50 | 1486 | .50 | .83 |
| | 1 | 775 | .60 | .50 | 774 | .23 | .52 | 187 | .10 | 0.0 |
| | 2 | 1212 | .60 | .50 | 981 | .36 | .51 | 804 | .47 | 0.0 |
| | 3 | 1212 | .60 | .50 | 956 | .35 | .50 | 1366 | .51 | .75 |
| | 4 | 1212 | .60 | .50 | 953 | .36 | .50 | 1360 | .50 | .80 |
| | 5 | 1711 | .70 | 1.0 | 1347 | .28 | .50 | 1771 | .48 | .50 |

1. Low land availability = 1.5 ha rustic plantation, 0.35 ha intermediate plantation

2. Low Labour availability = 30 units spring labour, 36 units summer labour, 24 units autumn labour, 54 units winter labour

3. Low cash availability = $300k for coffee production

## Appendix 7

**Results of Correlation Tests for Average Yield versus Number of Labour Days Cultivation:**

### Cho'l Group 1: Rustic Producers

Simple Linear Regression and Pearson's Product Moment Correlation

Equation for straight line: Y = 0.1008734 x + 2.047395
Standard Error of the Slope = 0.033459
95.0% C.I. for population value for the slope = 0.032335 to 1.169412

Correlation Coefficient (r) = 0.4950348 ($r^2$= 0.2450595)
95.0% C.I. for r (Fisher's Z transformed)= 0.164017 tp 0.725852
t statistic with 28 d.f. = 3.014799
One tailed p = 0.002708
Two tailed p = 0.005415

This correlation coefficient is not significantly different from zero

Polynomial Regression Analysis

$Y = C + A1x + A2x^2$

Constant = -7.204909
1 Degree Coefficient = 0.7578148
2 Degree Coefficient = -1.081496E-02

Coefficient of determination (R sq) = 0.4433652
Correlation coefficient = 0.6658568
Standard error of estimate = 1.23421

### Cho'l Group 2: Ascending Intermediate Producers

Simple Linear Regression and Pearson's Product Moment Correlation

Equation for straight line: Y = 0.2540419 x + 5.320395
Standard Error of the Slope = 0.032582
95.0% C.I. for population value for the slope = 0.176999 to 0.331085

Correlation Coefficient (r) = .9469675 (r2 = 0.8967475)
95.0% C.I. for r (Fisher's Z transformed)= 0.762186 to 0.989065
t statistic with 7 d.f. = 7.797114
One tailed p = 0.000054

**Table A6.10 Estimated Net Present Values of Three Improvement Plans for Farms with Different Factor Scarcities at Discount Rates Between 0.5 and 0.25**

| Improvement Plan | Discount Rate | Land Scarcity | Labour Scarcity | Cash Scarcity | Control |
|---|---|---|---|---|---|
| Rustic to Intermed | 0.05 | -137 | 129 | -419 | 124 |
| | 0.10 | -196 | 53 | -439 | 48 |
| | 0.15 | -220 | 8 | -436 | 4 |
| | 0.20 | -225 | -18 | -421 | -22 |
| | 0.25 | -220 | -33 | -400 | -37 |
| | | | | | |
| Intermed to Advanced | 0.05 | -410 | 155 | -675 | -53 |
| | 0.10 | -495 | -7 | -778 | -200 |
| | 0.15 | -521 | -99 | -811 | -277 |
| | 0.20 | -515 | -148 | -805 | -312 |
| | 0.25 | -494 | -173 | -779 | -324 |
| | | | | | |
| Rustic to Advanced | 0.05 | 301 | 556 | -831 | 156 |
| | 0.10 | 11 | 275 | -975 | -97 |
| | 0.15 | -155 | 106 | -1025 | -239 |
| | 0.20 | -247 | 4 | -1024 | -316 |
| | 0.25 | -296 | -58 | -995 | -355 |

NPVs were calculated on a 10 year basis, using annual cash flows adjusted relative to the baseline income (baseline income = the income at year 0, before any improvements begin). For example, if the real cash flows for Year 0 and Year 1 were 1554 and 1020 repectively the adjusted cash flows would be 0 and -534 respectively. A scenario without any improvement would have a constant cash flow and therefore an NPV of zero.

# PAGINATION ERROR

P255

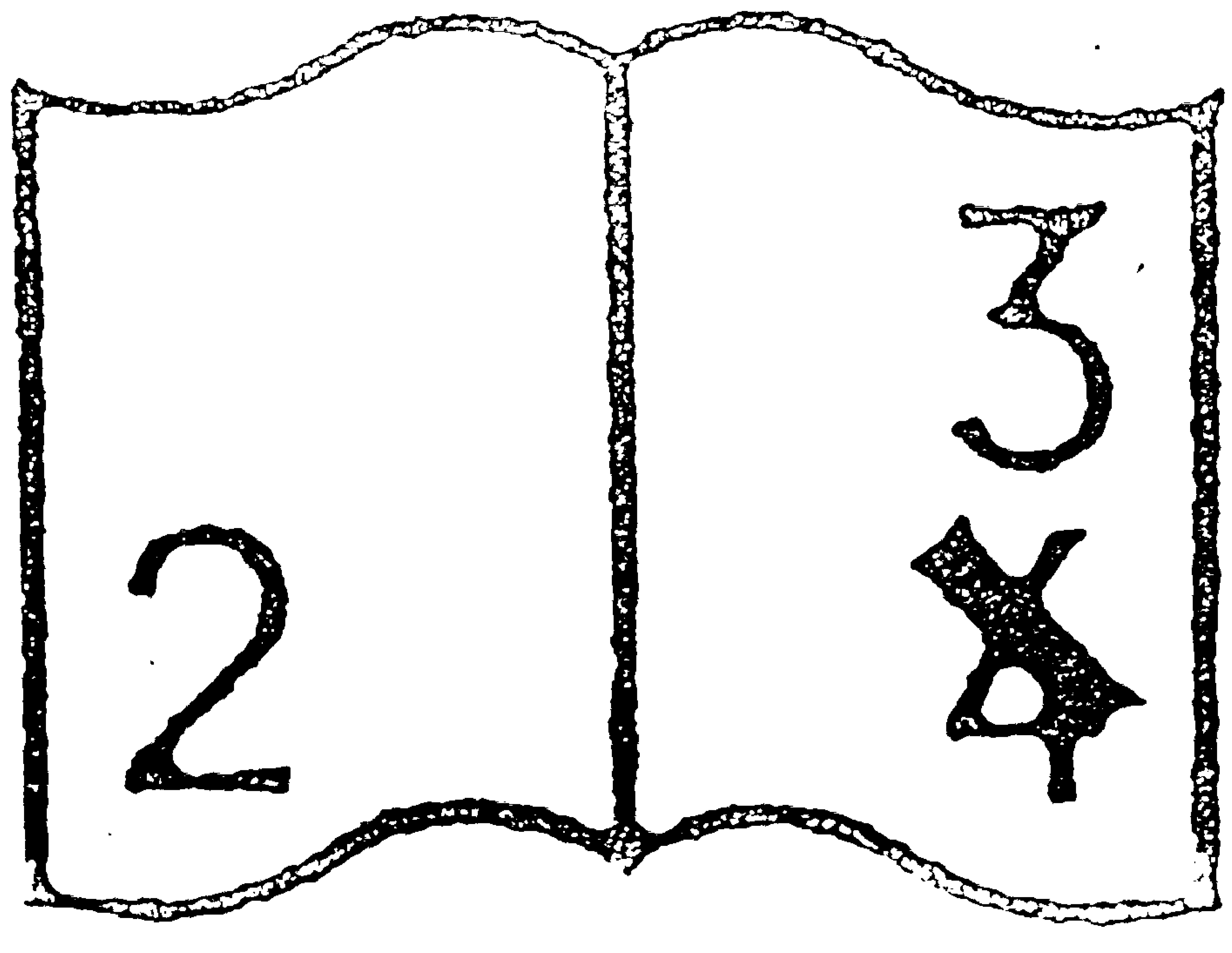


**Table A6.11 Estimated NPV of coffee improvement plans with proposed credit programme**

| Improvement Plan | Discount Rate | Scarce Land | Scarce Labour | Scarce Cash | Control |
|---|---|---|---|---|---|
| R to I | 0.1 | -195 | 294 | 270 | 254 |
| | 0.2 | -225 | 178 | 155 | 142 |
| I to A | 0.1 | -494 | 286 | 214 | 193 |
| | 0.2 | -515 | 89 | 26 | 10 |
| R to A | 0.1 | 373 | 650 | 670 | 662 |
| | 0.2 | 56 | 309 | 315 | 307 |
| | | | | | |
| | | | | | |
| | | | | | |

**Table A6.12 Change in expected NPV due to credit programme**

| Improvement Plan | Discount Rate | Scarce Land | Scarce Labour | Scarce Cash | Control |
|---|---|---|---|---|---|
| R to I | 0.1 | 0 | 245 | 710 | 206 |
| | 0.2 | 0 | 196 | 577 | 164 |
| I to A | 0.1 | 0 | 294 | 1093 | 394 |
| | 0.2 | 0 | 237 | 894 | 323 |
| R to A | 0.1 | 362 | 374 | 1645 | 758 |
| | 0.2 | 304 | 304 | 1340 | 623 |
| | | | | | |
| | | | | | |
| | | | | | |

Two tailed p = 0.000107

This correlation coefficient is significantly different from zero
Polynomial Regression Analysis

$Y = C + A1x + A2x^2$

Constant = 4.320662
1 Degree Coefficient = 0.3566006
2 Degree Coefficient = -2.310583E-03

Coefficient of determination (R sq) = 0.8997653
Correlation coefficient = 0.9485596
Standard error of estimate = 0.8044228

**Cho'l Group 3: Advanced Producers**

Simple Linear Regression and Pearson's Product Moment Correlation

Equation for straight line: Y = 0.2751907 x + 4.019549
Standard Error of the Slope = 0.142916
95.0% C.I. for population value for the slope = -0.043245 to 0.593527

Correlation Coefficient (r) = .5200811 (r2 = 0.270844)
95.0% C.I. for r (Fisher's Z transformed)= -0.076719 to 0.842513
t statistic with 10 d.f. = 1.925545
One tailed p = 0.041522
Two tailed p = 0.083044

This correlation coefficient is not significantly different from zero

Polynomial Regression Analysis

Y = C + A1x + A2x2

Constant = -5.766089
1 Degree Coefficient = 0.8210548
2 Degree Coefficient = -7.230093E-03

Coefficient of determination (R sq) = 0.289649
Correlation coefficient = 0.5381905
Standard error of estimate = 4.350947

**Cho'l Group 4: Declining Intermediate Producers**

Simple Linear Regression and Pearson's Product Moment Correlation

Equation for straight line: Y = 0.1629664 x + 3.2473
Standard Error of the Slope = 0.031447
95.0% C.I. for population value for the slope = 0.086018 to 0.239914

Correlation Coefficient (r) = 0.9040930 (r2 = 0.8173842)
95.0% C.I. for r (Fisher's Z transformed)= 0.549503 to 0.982699
t statistic with 6 d.f. = 5.18226
One tailed p = 0.001025
Two tailed p = 0.002050

This correlation coefficient is significantly different from zero

Polynomial Regression Analysis

$Y = C + A1x + A2x^2$

Constant = -3.9993
1 Degree Coefficient = 0.1106975
2 Degree Coefficient = 8.746248E-04

Coefficient of determination (R sq) = 0.8185331
Correlation coefficient = 0.9047282
Standard error of estimate = 0.5424187

**Tzeltal Group 1: Rustic Producers**

Simple Linear Regression and Pearson's Product Moment Correlation

Equation for straight line: Y = 6.082875E-02 x + 4.078093
Standard Error of the Slope = 0.021937
95.0% C.I. for population value for the slope = 0.013039 to 0.108618

Correlation Coefficient (r) = 0.6249720 (r2 = 0.3905901)
95.0% C.I. for r (Fisher's Z transformed)= 0.141221 to 0.867794
t statistic with 12 d.f. = 2.773297
One tailed p = 0.008429
Two tailed p = 0.016859

This correlation coefficient is not significantly different from zero

Polynomial Regression Analysis

$Y = C + A1x + A2x^2$

Constant = 5.85491
1 Degree Coefficient = -1.312347E-02
2 Degree Coefficient = 7.220341E-04

Coefficient of determination (R sq) = 0.4026141
Correlation coefficient = 0.6345188
Standard error of estimate = 1.079103

**Tzeltal Group 2: Intermediate Producers**

Simple Linear Regression and Pearson's Product Moment Correlation

Equation for straight line: Y = 8.769237E-02 x + 8.680696
Standard Error of the Slope = 0.021937
95.0% C.I. for population value for the slope = 0.023955 to 0.151430

Correlation Coefficient (r) = 0.7199828 (r2 = 0.5183752)
95.0% C.I. for r (Fisher's Z transformed)= 0.211420 to 0.921753
t statistic with 9 d.f. = 3.112354
One tailed p = 0.006236
Two tailed p = 0.012471

This correlation coefficient is not significantly different from zero

Polynomial Regression Analysis

$Y = C + A1x + A2x^2$

Constant = 4.027848
1 Degree Coefficient = 0.2920156
2 Degree Coefficient = -2.076389E-03

Coefficient of determination (R sq) = 0.5552368
Correlation coefficient = 0.7451422
Standard error of estimate = 1.334595

**Tzotzil Group 1: Rustic Producers**

Simple Linear Regression and Pearson's Product Moment Correlation

Equation for straight line: Y = 0.0336861 x + 6.044575
Standard Error of the Slope = 0.034812
95.0% C.I. for population value for the slope = -0.48631 to 0.820450

Correlation Coefficient (r) = 0.3434879 (r2 = 0.1179839)

95.0% C.I. for r (Fisher's Z transformed)= -0.415392 to .820450
t statistic with 7 d.f. = 0.9676586
One tailed p = 0.182725
Two tailed p = 0.36451

This correlation coefficient is not significantly different from zero

Polynomial Regression Analysis

$Y = C + A1x + A2x^2$

Constant = 3.681888
1 Degree Coefficient = 0.2269093
2 Degree Coefficient = -3.176087E-03

Coefficient of determination (R sq) = 0.2422483
Correlation coefficient = 0.4921873
Standard error of estimate = 1.225063

**Tzotzil Group 2: Intermediate Producers**

Simple Linear Regression and Pearson's Product Moment Correlation

Equation for straight line: Y = 0.1394891 x + 5.821937
Standard Error of the Slope = 0.085261
95.0% C.I. for population value for the slope = -0.079681 to 0.358659

Correlation Coefficient (r) = 0.5904818 (r2 = 0.3486688)
95.0% C.I. for r (Fisher's Z transformed)= -0.292755 to 0.93000
t statistic with 7 d.f. = 1.636027
One tailed p = 0.081380
Two tailed p = 0.162761

This correlation coefficient is not significantly different from zero

Polynomial Regression Analysis

$Y = C + A1x + A2x^2$

Constant = -10.29927
1 Degree Coefficient = 1.69237
2 Degree Coefficient = -3.58863E-02

Coefficient of determination (R sq) = 0.6338837
Correlation coefficient = 0.7961681
Standard error of estimate = 0.9255469

**Tzotzil Group 3: Advanced Producers**

Simple Linear Regression and Pearson's Product Moment Correlation
Equation for straight line: Y = 9.361479E-02 x + 7.109015
Standard Error of the Slope = 0.063857
95.0% C.I. for population value for the slope = -0.070535 to 0.257765

Correlation Coefficient (r) = 0.5482867 (r2 = 0.921051)
95.0% C.I. for r (Fisher's Z transformed)= -0.348780 to 0.921051
t statistic with 7 d.f. = 1.466006
One tailed p = 0.101275
Two tailed p = 0.202550

This correlation coefficient is significantly different from zero

Polynomial Regression Analysis

$Y = C + A1x + A2x^2$

Constant = -42.24415
1 Degree Coefficient = 1.748182
2 Degree Coefficient = -1.303278E-02

Coefficient of determination (R sq) = 0.629788
Correlation coefficient = 0.7935918
Standard error of estimate = 2.137546

# Appendix 8

## A. Cuestionario Individual (Family)

**1. Introducción**

Nombre:
Edad:
Numero de personas en la casa (edad y sexo):
Numero de personas quien trabaja (milpa, cafetal, otro):
Area total de tierra disponible para producción, inc. acahuales (dotacion, comunales, propiedad):
Estado de la casa (materiales de construcción, y condición):
Opinión sobre las condiciones de vida ahora en comparación con 10 años atras:

**2. Producción de Maiz**

Recursos para la Producción de Maiz

Area total dedicada a milpa (inc. Acahaules), y cambios en los utlimos 10 anos:

Area sembrada:
1989 1988 1987

Numero de años que se siembra la misma parte en secuencia:

Numero de años que se deja la tierra para decanzar:

Cambios en el tiempo que se ha dejado la tierra para descanzar durante los ultimos 10 años:

Cambios en la calidad del suelo durante los ultimos 10 años: 1984-86; 1987-89;

Numero de personas trabajando en la milpa:

Uso de fertilisante:
1984-86 1987-89
Nunca
A veces
Siempre

Uso de la quema:

Si (desde cuando)
No (desde cuando)

Uso de herbicida (tipo):
1984-86 1987-89

Estimacion de tiempo ahorrado por use de herbicida:

Dias dedicados a varios labores:

Preparación del terreno (roza)
Quema

La siembra
1er Limpia
1er Fertilización
2da Limpia
Dobla
Cosecha

Produccion de maiz (ammarillo / blanco) y de frijo (vaina / suelo):
1989 1988 1987

Opiniones sobre:

El apoyo estatal hacia la milpa
El apoyo de la union hacia la milpa
El estado de su terreno
El efecto de producción de milpa sin quemar

**3. Producción de Café**

Recursos para prod. de café

Area de cafetales (y fragmentacion):

| Variedad | Area | Densidad | Edad |
|---|---|---|---|
| Typica | | | |
| Bourbón | | | |
| Maragogipe | | | |
| Garnica | | | |
| Caturra | | | |
| Catuaii | | | |
| Otros | | | |

Tipo y nivel de sombra (natural, Inga, otro):
Otros arboles:

Equipo de Producción:

Aspersora manual
Aspersora motorizada
Fungicida
Herbicida
Insecticida
Despulpadora
Patio

Numero de personas (para labores / para la cosecha):

Salida de dinero en efectivo hacia produccion de café:

Creditos recibidos:

1989 1988 1987

Dias dedicados a varios labores:

1er Limpia
Podas
Recepas
Desombre
1er Fumigación
1er Fertilización
2da Limpia
Desmusge
Deshije
2da Fertilización
2da Fumigación
3ra Limpia
Control de plagas
Cosecha
Despulpado
Secado
Costalero

Nivel technologico asignado (rustico, transiciónal, avancado):

<u>Producto</u>

Producción (quintales):
1989/90 1988/89 1987/89

Opiniones sobre:

El apoyo estatal (creditos y asistencia técnica)
El apoyo de la Unión
El mercado de café
La broca
La roya.

## B. Three Cases of Innovative Farmers

In the studies of the spread of new agricultural technologies among peasant societies, social scientists (Rogers, 1971; Roling, 1988; and Hayami & Ruttan, 1971) have identified progressive farmers (particularly those with greater than average financial resources) as being more innovative. However, the term "innovative", in these cases, was used to describe those farmers who were early adopters of new (modern) technology.

The author prefers to use the term "innovative" to refer to farmers who have developed their own technical solutions, or responses, to certain problems. Innovative farmers of this type were to be found at all social, educational and economic levels, in northern Chiapas. Furthermore, this type of innovative behaviour was often associated with other personal characteristics, of a dynamic nature, such as: inquisitiveness, foresight, planning ability, acute observation and idealism.

**Case Studies**

Rogelio Martinez Martinez

Rogelio is a young farmer in the Cho'l community of Nueva Esperanza, of the Municipio of Tila. As one of four sons, he inherited only 0.5 ha of unbroken land on the edge of the ejido; about 2½ hours walk from the village. He hopes to inherit more land from his wife's family in the future but for now he must manage to keep his family through a combination of farming and other jobs.

Fortunately, Nueva Esperanza has one of the best village schools in the Cho'l area. Rogelio completed primary school and two years of secondary education. At the age of 18 he attended an three month INMECAFE course on coffee production. Later he worked for the Unión de Credito as an assistant extension agent. He attended courses at the union's small farmer training centre. And also visited various intensive coffee plantations and experimental stations in Chiapas and Guatemala. He currently is paying for himself to attend part-time courses in computing in the town of Yájalon.

Despite having only a tiny parcel of steeply sloping land Rogelio has made imaginative use of the small space. Most of the area is planted with unshaded Caturra and Garnica coffee bushes (modern varieties) currently between 3-5 years of age. The coffee plants are closely spaced along contour lines, with only a minimal amount of shade around the edges of the plot. Between the rows of younger coffee bushes, beans, squashes and tomatoes have been planted. The beans contribute to the fertility of the soil and the broad leaves of the squashes keep weed growth to a minimum. After weeding and pruning, the trash is piled around the bases of the coffee plants where it decomposes to form a mulch. As the coffee is planted in contour rows this process should, in the long term, lead to the development of small terraces.

Last year, Rogelio and two or three other farmers from the community made a trip to Guatemala in order to obtain seeds of a new variety: maracaturra. This variety is virtually unavailable in Mexico and combines the compact, high yielding form of the caturra with the high quality beans of the old maragogipe.

Rogelio is conscious of the problem of relying on coffee as the sole cash crop. He has tried growing grafted valencia oranges onto local citrus root-stock and has also planted several nut trees.

Apart from being technically ingenious Rogelio is also a dynamic member of the community and has helped to organise various community projects, including reforestation, the community clinic and a cooperative fertiliser store for the region.

Alberto

Alberto (c.55) is a member of the Spanish speaking (mestizo) community of Yaluma, on the Comiteca Plane. He recalled that the community had changed dramatically since he was child. Forty years ago, the land around the community was still wooded and the principal activity of villagers was charcoal production. Now only a few hilltop copses remain and the land is under almost continual cultivation for maize and beans.

While Alberto has only slightly more than the average area of land he is well known in Yaluma and the surrounding villages, as one of the best maize producers in the area. While he is willing to explain his methods to other farmers he never boasts about the remarkable results: In the past three years his average yields of maize have been around 4 tonnes per hectare (more than double the regional average of 1.8 tonnes per hectare for unfertilised maize). Rather than high levels of chemical inputs, this remarkable production was mainly attributed to the non-burning methods of cultivation that he adopted 6 years ago (he was the first farmer in the area to do so). He recalled that, at first, many of his neighbours laughed at him and agronomists from the bank of rural credit even refused to lend him money on the grounds that he was "not burning last year's trash out of sheer laziness". Nevertheless, after noticing improvements to the quality of the soil under non-burned "test" plots he extended the method to cover all his land (4.5 Ha).

Observations made of Alberto's and his neighbours' maize crops in June, after a dry Spring, showed some remarkable contrasts. Most of the neighbouring maize crops were retarded in their growth (only 0.8 - 1.2 metres tall), with a high number of failed plants (50-60%), whereas Alberto's was 1.5 - 2.5 metres tall, with very few failed plants (10 - 20%). The soil in Alberto's fields was still slightly moist to the touch at a depth of 35 cm but neighbouring fields tested in the same way were dry. Now that neighbouring farmers can see the results of non-burning with their own eyes they are beginning to adopt these methods.

Alberto is concerned to make further improvements in maize production. Following a workshop organised to bring together to farmers of various regions in Chiapas, with similar experiences of non-burning cultivation, he is keen to test new ideas (1) the use of leguminous break-crops to be sown in fallow periods and then ploughed in, or cut back to add further mulch to the soil and to retard weeds, (2) the weeding out of un-fertilised maize plants by hand before the grain filling stage, so that fertiliser is not wasted, (3) the selection of maize seed according to desirable characteristics, pre-harvest.

Alberto is not only an exceptional maize producer, he is also known as a talented builder. Four years ago he heard about methods of constructing walls from compacted soil and chalk mixture. He tested and refined the technique on his own house and has since built several sturdy buildings, for use as clinics and storehouses in several communities. In the places where he has worked he has passed this knowledge on to the local builders.

Nicolas Hernandez Diaz

Nicolas (c.40) is a Tzeltal farmer from the lowland village of Alan Cantajal. In this community the size of holdings are larger (typically c. 15 ha) than the average in the Cho'l and Tzotzil zones. However, the farm income from the coffee in this area have been severely hit by a combination coffee rust and low coffee prices. Farmers are therefore seeking alternative sources of cash.

In Alan Cantajal, Nicolas has pioneered a number of new techniques: (1) Bean production, in particular the cultivation of winter beans, which avoid the pests that arrive with the peak rains in June, (2) The planting of alternative woody species in coffee plantations such as high value timber species (cedar, caoba, and guanacastle) as well as fruits (mangoes, avocados, and zapotes), and (3) The adoption of non-burning *milpa*, as in the above case.

A particularly interesting traditional Mayan technique that has been revived by Nicolas and some of his neighbours is that of planting *Mucuna* spp., (known locally as Nescafé) a leguminous vine in the fallow milpa. To act as a blanket, smothering out the grassy weeds, a green manure and also a nitrogen fixer.