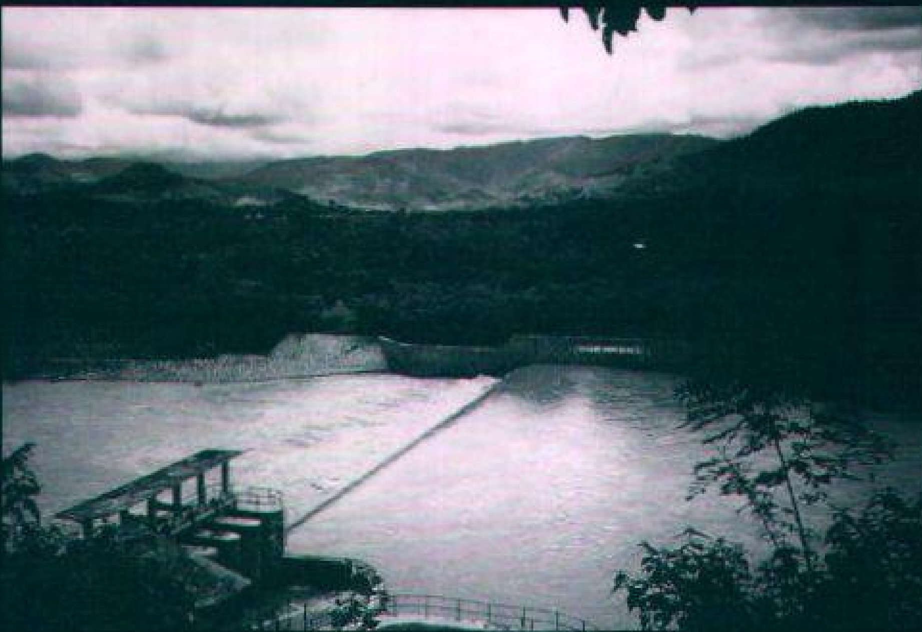
FACTORS INFLUENCING SMALLHOLDER COCOA PRODUCTION

a management analysis of behavioural decision-making processes of technology adoption and application



Salam Taher

PROPOSITIONS

1 The influence of individuals in the process of technological change which follows from their degree of freedom to make interpretation and act (Stein, 1995) may be not valid for farmers who live in a traditional community where farmers have a high dependency on community leaders and/or have a copying behaviour in an adoption decision.
Johan R.Stein (1995), Towards a socio-economic framework on technological change, International Journal of Social Economics, Vo 22 No. 6, MCB University Press.

2 The propositions of Berry (1975) that (a) cocoa was adopted more rapidly in some communities because there were individuals there whose personal backgrounds and experiences led them to be more willing to experiment with new productive activities than were the majority of their compatriots, and (b) cocoa was adopted sooner in some areas because local circumstances fostered greater incentives to exploit new economic opportunities than did those in other areas, remain relevant in early cocoa development in South-Sulawesi.
Sarah S. Berry (1975), Cocoa, Custom, and Socio-Economic Change in Rural Western Nigeria, Clarendon Press, Oxford.

3 Since cocoa has various advantages in terms of (a) agronomic, such as more rapid to harvesting, easier in maintenance, can be cultivated with other crops as mixcropping; (b) economic, such as harvesting can be performed periodically over a long period which can improve a farmer's cash flow and can produce a higher revenue compared to other tree crops, (c) social, such as can involve a higher number family workforce and other actors, and (d) environmental perspectives which can conserve environmental condition, compared to other tree crops, cocoa crop is one of the most prospective tropical perennial crops for increasing farmer's smallholder revenues as well regional development.
(This thesis).

4 In a suitable condition, the strategy of cocoa (or other perennial crops) smallholders is directed to complementary activities and balance achievement of long term and short term farm objectives by cultivating diversified cocoa, other perennial and annual crops.
(This thesis).

5 Once cocoa and related technology have been adopted by farmers, the origin of farmers does not influence technical efficiency of cocoa production anymore.
(This thesis).

6 By making optimally use of land and family workforces owned in both on-farm and off-farm activities, and introducing a more appropriate technology, cocoa smallholder has a wide opportunity to optimize their gross margin.
(This thesis).

7 As far, price differentials between fermented and unfermented cocoa are insignificant to compensate fermentation costs, and markets for unfermented cocoa are still available, there are impossible to expect farmers producing fermented cocoa.
(This thesis).

8 No substance which gives the characteristic 'chocolate flavour' has been found in the unfermented cocoa bean.
Guy Mossu (1995), Cocoa, MacMillan Education Ltd, London.

9 The conclusion made Geertz (1963) "as the bulk of the Javanese peasants (have small areas, more diversified farming and cultivating food crops as the main crop) moved toward agricultural involution, shared poverty, social elasticity, and cultural vagueness, a small minority of the Outer Island peasants moved toward agricultural specialization; the second course was the more perilous, and to some minds it may seem both less defensible morally and less attractive aesthically; but at least it did not foredoom the future", is not valid anymore because the latter cultivated perennial crops as a main crop, generally, diversified their farming with annual food crops, this pattern resembles farming on Java due to population growth and the increase of land scarcity.
Clifford Geertz (1963), Agricultural Involution, The process of ecological change in Indonesia, University of California Press.

10 Poverty is inversely related to the land and human capital (*i.g.* educational) endowment of the households.
Erik Thorbecke and Theodore van der Pluijm (1993), Rural Indonesia: Socio-economic Development in a Changing Environment, IFAD - New York University Press.

11 Tree crops' project development requires farmer household development in the first place.

12 Development that places farmers as a subject rather than an object of development could reinforce and motivate farmers' participation and responsibility in development process.

Salam Taher

Factors Influencing Smallholder Cocoa Production
Ph.D Thesis,
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FACTORS INFLUENCING SMALLHOLDER COCOA PRODUCTION

a management analysis of behavioural decision-making processes of technology adoption and application

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PREFACE AND ACKNOWLEDGEMENTS

For developing countries, the efforts in improving farmers' household and regional development can be an interesting subject for study. Selecting farmers' behavioural decision-making in technology adoption and application as a theme of the study was one of strategic alternatives to apprehend more profoundly a part of real farmer conditions and problems. Expanding knowledge about technology adoption and application for cocoa smallholder could give us a better understanding of various changes in conducting the cocoa business. In this respect, I have no a pretension to claim that by the results of study, the study could assist in explaining entirely cocoa smallholder's phenomena related to technology adoption and application. It is, however, expected that the study could contribute in grasping the perspectives of cocoa development, in both present and future, from a smallholder point of view.

To realize this study, I have obtained many contributions from many people both in the university and the field. I wish to thank all of them. I wish to express my appreciation to my supervisors, prof.dr.ir. J.A.Renkema, prof.dr.ir. L.O. Fresco, dr. P.J.P. Zuurbier for their professional and constructive support during the realizing this study. I would like to thank prof.dr. A.T.J.Nooij, dr.ir. C.E.M.J. van Dijk, dr.ir. Erick van Heck, ir. W.Gerritsma, ir. G.W.J. Giesen, Drs R. Ruben and M. van den Berg MSc. for their discussions and comments to the content and realization of this study. I am also indebted to many other persons in the Departements of Agronomy, Farm Management and Management Studies who are imposible to be mentioned all for their help.

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CHAPTER 1 GENERAL INTRODUCTION

1.1 Background

Cocoa is one of the tropical agriculture commodities to be traded worldwide. Although cocoa is produced in the tropics it is mainly consumed in the developed countries. The cocoa crop or *Theobroma cacao* (Braudrau, 1969; Wood and Lass, 1985; Wessel and Toxopeus, 1989; Mossu, 1992) is a tree crop that produces cocoa beans which grow in pods on the tree and take about six months to reach full maturity. Once the fruits are ripe, the pods are broken open and the beans are fermented and dried. Cocoa needs certain agro-climatic conditions (Braudrau, 1969; Wood, 1985). These conditions are: (a) rainfall of 1,250-3,000 mm per annum and preferably a level at between 1,500-2,000 mm, with a dry season of no more than three months and less than 100 mm rain per month; (b) temperatures varying between 30-32°C mean maximum and 18-21°C mean minimum and an absolute minimum of 10°C; (c) no persistent strong winds; (d) pH of soil within the range of 6.0-7.5 with a depth of soil no less than 1.5 m (Wood, 1985).

Like many other tree crops that are exploited commercially, cocoa crops are grown on large estates and smallholdings. A cocoa estate provides a large area for cultivation and it is operated by a planter or manager commanding a large number of paid workers. It usually uses production inputs intensively and the plantation area is served by road infrastructures and processing and post-harvest activity facilities. Cocoa estate production is practiced mainly in Brazil and Malaysia. More important than estate production is smallholding production. The cocoa smallholder exploits a small-scale area, generally less than 5 ha, worked by the farmer and his family. Cocoa smallholders are numerous in West Africa, Indonesia and certain other producing countries.

Production handling consists of three main activities, carried out pre-harvest, during harvest and post-harvest. Pre-harvest activities cover land preparation, the selection and preparation of plant materials, cultivation, and plant treatment that consists of weeding and clearing, fertilizing, pests and disease control, pruning of both cocoa and shade trees. Fertilizing, weeding and pests and disease control require specific production inputs which involves the investment of additional capital. Post-harvest activities consist of fermentation processing, drying, packing and storage.

If the cocoa quality is to achieve a certain standard of acceptability, processing in the form of fermentation is very important. The fermentation treatment is quite simple and it does not require a high level of investment. It involves placing the cocoa beans into closed wooden boxes or baskets for three to seven days after the beans have been removed from their pods. The number of days varies from one variety to another. Every 24 hours the beans are turned over to obtain evenly fermented cocoa. Three of the main objectives in a fermentation operation are (i) to separate the placenta from the beans, (ii) to kill micro-organisms by the generated heat, (iii) to remove the bitterness of the unfermented bean and in doing so, to produce the characteristic, sweeter, chocolate-like flavour.

To establish a new plantation both a large estate owner and a smallholder need, for the first three years of exploitation, a certain amount of investment for (1) land procurement and preparation; (2) procurement of materials such as plant materials both cocoa and shade trees, fertilizer, pesticide, and herbicide; and (3) workforce expenditure. The level of investment per hectare is usually different between large estates and smallholdings since (a) smallholders do not usually use fertilizer and only use production inputs in limited amounts during the period when the cocoa is immature, and (b) smallholders do not invest into plantation infrastructure such as roads. Excluding the cost of land procurement, the investment needed for the workforce in Indonesia during this period is approximately 60 to 70% of the total investment. During the mature cocoa period the cost of the workforce to produce 1,000 kg cocoa beans per hectare is about 50 to 60% of the total annual exploitation costs (DGE, 1992). In Brazil, the proportion of the production cost devoted to the workforce to produce 750 kg beans per hectare in both the establishment and operation phases is more than 60%, excluding fixed capital costs (ICCO, 1993; *see* Heijbroek and Konijn, 1995).

1.1.1 Worldwide cocoa development

During the last three decades worldwide cocoa supply and demand have increased (*Appendix 1.1*). However, supply and demand have not always been equally balanced. In a certain period, 1984/1985 to 1991/1992 for instance, the supply increased much faster than the demand. These imbalances are caused by several factors. Factors, apart from agro-climatic conditions, that influence the cocoa supply are:

(1) The price of cocoa, which affects the cocoa supply both in the short term and the long term. If prices rise in the short term farmers can increase productivity by applying fertilizer, spraying with pesticides or by maintaining their crop more intensively. In the long term farmers can increase production by new planting. However, it could take more than five to seven years for the trees to achieve a significant yield. By using newer hybrid varieties this period can be reduced to three to four years. However, prices actually received by farmers differ greatly from country to country. In Brazil, Malaysia and Indonesia where a free market mechanism exists internal prices are in line with the world price. In these countries world market prices are reflected in producer prices. In Africa, prices are generally lower, reflecting higher levels of government control over prices paid to farmers. The first visible increases in production of Indonesian cocoa in 1980/1981 correspond to the creation of plantations in 1977/1978, a response by the public and private sectors to the rocketing prices on the international market (Ruf, 1993). The launching of cocoa cultivation in Ghana at the beginning of the century (Gunnarsson, 1978) is also a result of the farmers' anticipation of better prices. Trivedi (1988) also showed that a rise in price enhanced new planting but delayed replanting decisions.

(2) Costs of inputs, such as workforces, fertilizers and pesticides, can influence the cocoa supply. Since the workforce forms the largest part of the production costs, a change in the price of the workforce will have a significant effect on supply. Compared with other perennial crop activities, the annual labour demand for adult cocoa plants per hectare which is about 235 man-days, is higher than coconut, rubber, oil-palm and coffee crops for example, requiring about 125, 190 and 195 and 225 man-days respectively (DGE, 1993). This highlights a subsequent implication that the annual exploitation costs for the workforce

of cocoa crops are higher than the other perennial crops mentioned. In Brazil, for example, labour accounts for more than 60% of production costs in both the establishment and operation phases (ICCO, 1993; *see* Heijbroek and Konijn, 1995). Obviously, countries with low labour costs have a comparative advantage in developing the cocoa area and in production levels. Smallholder with high labour availability, particularly in cases for low external opportunity of off-farm activities, has opportunity costs lower than larger farms. However, the low labour cost is not the sole factor in supporting cocoa expansion. Ruf (1993) stated that the recent expansion of cocoa areas in Indonesia, the Ivory Coast and Ghana were mainly the result of virgin land being available for exploitation by smallholders and their families. Indonesian smallholders are amongst the lowest cost producers in the world (Ruf, 1993) in terms of low labour costs. The increased production that has taken place since the 50s is largely the result of the use of pesticides to fight diseases (Heijbroek and Konijn, 1995). Since the cost of fertilizer is usually high, the use of fertilizer is less widespread amongst smallholders. It results in lower productivity than larger estates. The rising cost of imported inputs could act as a disincentive for farmers to invest in capital inputs (Asante, 1993), which in turn could affect the cocoa supply.

(3) The application of production technology has had a considerable effect on cocoa production. Modern hybrids produce more pods, which of course means higher yields, and are able to withstand adverse weather conditions, pests and diseases. Because of their compact, regular shape, more hybrids can be planted (2,500 to 3,000 trees per hectare), compared to only 1,000 trees per hectare for traditional varieties. The high yield produced by hybrids takes its toll on the soil, particularly when replanting, as the remaining soil nutrients have to be paid special attention and additional fertilization is needed.

(4) Damage caused by pests, diseases, droughts and floods could affect the yield per hectare, and on some occasions, may even affect the area planted. Although these are usually incidental set backs, they can influence the level of production significantly and, in turn, influence supply.

(5) Competitiveness with other crops can affect the cocoa supply. Climate and land which is suitable for cocoa can also be used to cultivate other crops such as coffee, rubber, coconut, palm oil and pepper. The relative returns produced by other crops is an important influence on the initial decision to grow cocoa, and may encourage moves away from cocoa to other crops. In Ghana, for example, in recent years the expansion of palm oil crops has encroached upon the cocoa area.

(6) Government regulations and services have had an important influence on the farmer's decision to exploit cocoa. The provision of facilities for the occupation of new land and forest may provide for the establishment of new farms. In these circumstances the role of migrant farmers becomes significant. Also cheap loans, subsidy inputs, improvement of infrastructures, extension services, research and education can influence the expansion of cocoa exploitation.

In 1992/1993, the total world supply was almost 2.4 million tonnes which was highly concentrated on the five largest producers that hold a combined market share of 75%

(Heijbroek and Konijn, 1995). These producer countries are the Ivory Coast (37%), Ghana (13.6%), Indonesia (12.6%), Malaysia (7.1%) and Nigeria (6.8%). So, compared to the world market share in 1987/1988, when the Ivory Coast, Malaysia, Ghana, Nigeria, Brazil and Cameroon contributed respectively 27.5, 13.7, 11.3, 10.3, 10.1 and 8.0% of the world market supply (ICCO, 1994), the world cocoa market has changed considerably. Indonesia became a large producer, the Ivory Coast has increased its production remarkably, while Brazil, Malaysia, Ghana, Nigeria and Cameroon have tended to decrease their share.

In producing countries, three types of marketing systems can be distinguished based on a descending scale of government intervention (Ruf, 1993): viz. Marketing Boards, Caisse de Stabilization and Free market systems. Marketing Boards provide state level management of the entire marketing process from purchasing from the producer to selling to traders and processors. Guaranteed prices protect farmers from fluctuations in world prices. This system is found in Ghana and, until 1986, Nigeria. A Caisse de Stabilisation system also guarantees a certain producer price but leaves the whole marketing process at home and abroad to the private sector. The producer price is laid down by official order. This system has been in operation on the Ivory Coast and Cameroon. Free market systems, in which the price received by producers is determined by world prices rather than by initiatives at administration level, have existed in Nigeria since 1986 and also exist in Malaysia, Indonesia and Brazil.

The cocoa-bean trade is confronted with many difficulties. On the supply side, beans are of differing quality and come from many farmers and the supply is irregular. On the demand side, standard quality and on-time delivery is required, large quantities are needed and consumption is highly concentrated (Heijbroek and Konijn, 1995).

The earliest stage in the processing of cocoa is fermentation. The European market generally requires cocoa to be fermented. However, the American market can receive cocoa unfermented. In Indonesia most of the cocoa exported is unfermented. Cocoa beans are processed into a number of intermediate cocoa products such as cocoa liquor, cocoa butter and cocoa powder. Chocolate is made using these intermediate products. About 30% of all cocoa produced is processed in producer countries such as Brazil, Malaysia and the Ivory Coast. The United States and the Netherlands are the largest processing countries in the world with a market share of 13%; 30% of all exported beans pass through Amsterdam.

Heijbroek and Konijn (1995) mentioned several factors that influence cocoa demand such as (1) the cocoa price: a rise in cocoa prices leads to a fall in demand, (2) income: this has a significantly larger effect on demand than prices. There is a positive relationship between final consumption of cocoa and the level of Gross Domestic Product per capita. Countries with the highest cocoa consumption per capita also have high Gross Domestic Products per capita, (3) increasing population and a change in population structure may have even greater effects on cocoa consumption, (4) different pattern of tastes and preference have a significant impact on the demand for cocoa; climatic and cultural differences are also relevant factors that influence cocoa demand, and (5) substitutes, have become a major issue in the cocoa industry recently. The most important substitutes contain vegetable fats which could also influence cocoa demand.

The total final world consumption of cocoa in 1982/1983 was 1.7 million tonnes which increased to 2.2 and 2.4 million tonnes in 1991/1992 and 1992/1993. If final consumptions per region are compared the changes were remarkable. Western Europe, America, and Asia and Oceania increased their consumption from 40, 34.8 and 9.1% in 1982/1983 to 44.2, 37.6 and 11.1% in 1991/1992, in the same period Eastern European and African consumption decreased from 14.9 and 1.3% to 6.0 and 1.0% (*Appendix 1.2*).

Several general problems in cocoa development that are related to the involvement of smallholder farmers as the principal producer are the following:
(1) Cocoa is a long term investment crop. Cocoa is subject to a time lag of at least three to four years for new cocoa hybrids and five to seven years for traditional cocoa to give a stable production. During that period farmers are limited in their spending capacity.
(2) Cocoa has a high dependency on world market prices, particularly for producer countries with free market systems. This means farmers must compete with other producers in producing cocoa according to market requirements.
(3) The specific implication for smallholder levels is that under the constraints of their production capacity farmers must adjust their farm activities to meet every change on the global market. The instability and variability of world cocoa prices lead to farmers experiencing income uncertainty. In general, small farmers still find it difficult to predict the changes in cocoa prices on the global market, and their risk-bearing capacity is limited.
(4) Smallholder farmers have difficulty in acquiring new technologies since their price is usually high. Moreover, smallholder farmers may have limited abilities such as limited knowledge, limited access to the source of technology and a lack of capital to purchase the technologies.

1.1.2 Indonesian cocoa development

Amongst the main world cocoa producing countries, Indonesia has lately become significantly involved in the international cocoa business. Statistical data shows that Indonesian cocoa production rose from about 10,000 tonnes in 1980 to about 50,000 tonnes in 1987 (Anonymous, 1991) and later to 260,000 tonnes in 1993/1994 (ICCO, 1995). Amongst the various tree crops that are exploited by smallholder farmers in Indonesia, the cocoa crop is showing an increase in cultivation area and production, particularly in the last two decades. When it is compared with the other main tree crops (*Appendix 1.3*) during this period, the average annual area growth and production growth for cocoa show the highest increase of about 16% and 23% respectively.

In earlier years, until the seventies, the cocoa crop was cultivated in a limited area and was mainly exploited by only a certain number of government and private estates. Although this crop was known and had been developing well in certain regions of Indonesia, such as Northern-Sulawesi and Maluku since the beginning of the 17th century [1], the farmers' interest in cocoa really began in the 1970's, in the wake of the successful results obtained on

[1] *The detailed information of the history of cocoa in Indonesia could be referred to the Archieves of Cocoa Research Vol.2, Cocoa Research in Indonesia 1900-1950, edited by H.Toxopeus and P.C. Wessel, published by American Cocoa Research Institute and International Office of Cocoa and Chocolate, 1983.*

Malaysia cocoa plantations (Durand, 1993). This interest was reinforced by the distribution of a new hybrid whose performance was promising.

Currently, the cocoa crop is widely cultivated almost throughout the entire country. As a result, in the last five years the share of Indonesian cocoa in the world market has risen from 3.3% in 1977/1978 to 12.6% in 1992/1993 (*Appendix 1.4*). Compared with cocoa development in Malaysia, for instance, which also shows a fast growth performance in the same period, Indonesian cocoa shows a higher average production growth. In Malaysia, the annual growth rate of production and hectare is about 14% and 16% respectively, whereas the Indonesian annual rate attains 23% for production and 16% for hectare in the same period.

Another factor that differentiates Indonesian and Malaysian cocoa development is that Malaysian cocoa is exploited mainly by private estates, while Indonesian cocoa is cultivated mainly by smallholder farmers. The improvement of cocoa production in Indonesia is particularly important from a social-economic point of view because of the involvement of large numbers of farm households. The area of smallholder cocoa farms accounted for 67% (over 95% in Sulawesi) of the total area in 1990. Statistics show (DGE, 1991) that in 1990 about 650,000 farmers and their families earned their livelihoods from this crop. The number of households involved tends to increase continuously.

The agro-climatic conditions of Indonesia allow cocoa to be cultivated in almost every region of the country. At the end of the 80s the production of Indonesian cocoa took place mainly in three large regions: East Java which is exploited by state plantations, North Sumatra, which is dominated by private plantations and the Eastern zone of the archipelago, which is mostly exploited by farm smallholders. Currently, although cocoa may be grown in almost all regions of the country, cocoa smallholders are concentrated in a few regions. In 1990, the main cocoa producers were South Sulawesi (20% of total area), South-East Sulawesi (14%), North Sumatra (13.7%), East Kalimantan (8%), and East Java (6%).

During the last two decades national cocoa production has shown an increase (*Appendix 1.5*) of about 1,700 tonnes in 1970 to about 113,800 tonnes of cocoa beans in 1990. Recently, in 1993/1994 the production has risen to about 260,000 tonnes. The average yield per hectare is still low, only about 920 kg/ha or about 60% of the average potential yield that is 1600 kg/ha (Napitupulu and Pamin, 1993). This yield is lower than the yield of the main producer regions, like South Sulawesi, South-East Sulawesi or North Sulawesi. In the same year, the three regions had average yields of about 935 kg/ha; 940 kg/ha and 1,053 kg/ha respectively. Sartono (1991) reported in his survey on the *Bupon* regency, South Sulawesi, an average production for smallholders of about 1,387 kg/ha for cocoa intercropped with coconuts and 1,109 kg/ha for sole cropping cocoa. This difference may be explained by the different fertility levels of the soil: sole cropping cocoa is grown on the uplands with a lower soil fertility, whereas intercropping is practiced on the alluvial soils in the plains.

Besides the different soil fertility, as described above, other factors such as the different ability of farmers to appreciate the opportunity offered by cocoa crop could provoke the differences in cocoa development from one region to another. In certain regions the majority of the cocoa farmers have been successful in cocoa exploitations, due to the application of technological innovations such as using plant materials recommended, technical cultivation and chemical production inputs. Other farmers exploit cocoa under difficult conditions that impede a higher performance. It seems that cocoa expansion is determined by a different social environment, a dynamic effort and different attitudes amongst farmers in deciding to adopt and apply cocoa technology. For the latter, notwithstanding a lack of capital, limited knowledge and a traditional attitude, and even various environmental constraints, farmers have succeeded in developing cocoa crops as a source of their livelihood. The development of the cocoa crop and the important implications for both the farmers' households and their contribution to national economic development merit more study. The results of decisions to adopt or reject technologies deserve to be studied in more detail to explain a question that often emerges at farm management level, particularly on smallholder farmers: how do the decision-making processes of technology adoption and use take place in practice, and what are the factors associated with these processes?

1.2 Farmer adoption and use of tree crop technology with special reference to cocoa

Empirical studies concerning the farmers' technology adoption and application of tree crops, with special reference to cocoa, are reviewed in order to gain an overall insight into cocoa farmers in technology adoption and application. Different characteristics are to be found between, on the one hand, annual food cropping with the demand for renewed investment every season and, on the other, perennial crop farms with a long gestation period. Tree crop exploitation involves a number of farm management characteristics that can in many ways be regarded as advantages compared to the characteristics of arable farming (Ruthenberg, 1976), leading to different decision-making in terms of technology adoption and application. Various empirical studies of tree crop smallholders have been conducted to obtain a firm grasp on the behaviour of farmer smallholders with regard to technology adoption and application. The general inference of various previous studies indicates that although the technology adoption process occurs in different perennial crops, the adoptions of technology by farmer smallholders is determined by farmers' ability and the availability of resources, the available technology in the surrounding area and other external factors. The results of several previous studies of cocoa technology adoption apparently pointed out similar conditions of technology adoption at a smallholders' level.

The studies of farmers' behaviour in terms of technology adoption and application that have been carried out in many tropical countries were frequently focused on annual crops or on farming systems that are dominated by annual crops. Less frequently, studies were conducted on the cocoa crop, or at least, cocoa in comparison to other tree crops. However, previous studies, both annual and tree crops' studies, can lead to a comprehensive understanding of technology adoption and application by smallholders. Several preceding studies showed the diversity of farmers' behaviour, the characteristics and prerequisite of technology adoption and application, and problems and constraints which farmers faced in the technology adoption process.

Tree crops, in particular, show similar characteristics to cocoa exploitation, at least in terms of the common perennial exploitation system, and show many similarities in terms of farmers' behaviour, as they conduct their activities to make the best use of available technology and resources. Inferences and results of many tree crop studies could be considered important reference material in arriving at an understanding of smallholder attitudes towards the development of their farm activities. Several studies concerning technological innovation to various tree crops that have been carried out recently in different countries, which will be presented later, show the different factors associated with technology adoption.

(1) Shree and Siddaramaiah (1993) in their study examining the extent of the adoption of improved cultural practices by small and large coffee planters in Karnataka, India, found that the adoption level of small planters was generally lower than that of the large planters. The small planters lagged behind the large ones in following recommendations related to levels of farmyard manure, lime and pesticide. The main constraints were shortage of finance and non-availability of labour and fertilizer.

(2) A study of this same crop was conducted by Nyoro and Whitaker (1988) to determine the factors influencing the adoption of coffee management practices by smallholder coffee farmers in Kenya. The study was aimed at obtaining information related to farmers' attitudes towards uses of fertilizers, fungicides and services provided by local cooperative societies. In this study a number of factors and constraints were identified.

(3) A study on the use of indigenous technology by coffee-growing smallholders has been conducted by Tomich *et al.* (1993) on Jarat, South Sumatra, Indonesia. They found that local coffee farmers were replanting and even innovating on their own. The farmers' experience with an indigenous high-yielding coffee variety shows that productivity increases are possible through the incremental adoption of new tree-crop varieties, without the need for expensive public replanting projects.

(4) Arganosa and Gomez (1991) in their study subjecting various socio-economic variables to factor analysis on attitudes towards improved cultivation techniques in the coconut-based farming system programme in the Philippines, found that education, tenure status, farm size, farming experience, income, membership of organizations, attending seminars, radio and magazines as media sources and media exposure were significantly associated with perceptions of innovative cultivation options.

(5) Nyoku (1991) in his study to determine the levels and rates of adoption of improved oil-palm production technology amongst small farmers cultivating oil-palm, used six parameters of recommended technology which are: improved varieties, fertilizers, insecticides, herbicides, triangular spacing and pruning. He found that pruning had the highest adoption rate, followed by triangular spacing and the use of improved varieties. Then, slightly over half of the farmers used fertilizer but many farmers did not believe that fertilizer was necessary after the trees were 2 to 3 years old. Since fertilizer application is labour intensive, its use was constrained by the acute labour shortage in the area. Few farmers used pesticides because they were expensive. The greatest constraint to the adoption of improved technologies was the farmers' perception that using pesticides was complex. Small farmers did not know what type of insecticides and pesticides to use, how much to use, or how to

apply them. Another set of constraints was the high cost of labour and of pesticides. Many of the new technologies require intensive labour use, which contrasts greatly with the limited amount of labour expended in the traditional, wild oil-palm groves.

(6) Mandac and Velasco (1991) in their study about cropping patterns on upland farms in Northen Mindanao, the Philippines, showed many factors significantly associated with cropping pattern choice such as: tenure status, number of work animals, available farm labour, field slops, proportion of crops sold, gross margin of the cropping patterns, farmer's assets, age of farmer, non-farm income and year to year variability. They concluded that it is feasible to increase cropping intensity and the growing of perennial crops in the uplands through a combination of policies that increase security of land tenure and improve access to work animals.

Although still limited in certain areas, the number of studies on cocoa smallholders have increased, particularly in the domains of technical production and post-harvest activities. Many of the studies concerned the effort to improve technical culture treatment and quality of cocoa production. In comparison with the sort of cocoa studies carried out previously, the studies of cocoa farmer smallholders' behaviour in technology adoption and application, which can be a significant factor in cocoa development at smallholder level, have lagged behind and are badly needed to reveal various aspects in the process of smallholder development. Compared to studies on annual crops in many developing countries, where almost all aspects concerning development of these crops have been the subject of research development, studies of cocoa smallholders' behaviour in technology adoption and application, particularly socio-economical factors of technology adoption and application, are still carried out less frequently. Several studies of technology adoption and use with reference to tree crops and cocoa smallholders that have been conducted recently were more focused on cocoa crop adoption. However, the interest in a more profound understanding of the phenomena relevant to the socio-economic aspects of technology adoption and use by farmer smallholders is increasing. Studies conducted in various regions indicate the variability of farmers' behaviour in cocoa technology adoption and use. Several recent studies of technology adoption and use amongst cocoa farmers show the variability of the findings, which can be presented as follows:

(1) Berry (1975) in her profound study of cocoa, custom and socio-economic change in rural western Nigeria presented how traditional institutions facilitated the rapid adoption and development of cocoa production in the small-farm sector of Western Nigeria. Institutions which fostered reciprocal responsibilities for services and support amongst members of kin groups and communities provided the means for small-farmers to mobilize capital and incur the risks of moving to uninhabited forest lands distant from their communities and investing in an unfamiliar crop with a long gestation period. The conclusion of the study is that information on market costs and returns cannot be expected to fully explain patterns of investment and output in the small-farm sector.

(2) Hill (1970) in her study of migrant cocoa farmers of Southern Ghana reveals the most important role of farmer migrants of South Ghana as 'real innovators' in the development of the cocoa area in Ghana. The study dispels the myth of the 'traditional' farmer or small-

farmer being backward and resistant to change. In order to finance the long-term capital investment required to buy suitable lands distant from their communities and bring the cocoa trees into production, small-farmer households formed corporations based on kin groups.

(3) Clark and Akinbode (1968) in their study of factors associated with the adoption of three farm practices in the Western State of Nigeria summarized in their finding that the use of mass communication media, size of family, size of farms, value of products sold, knowledge heard about recommended practices, frequency of agents' contacts, economic feasibility and village factors, were the significant factors associated with recommended pesticide application for the cocoa crop. They concluded that economic gain was a major reason for adopting and continuing to follow the cocoa spraying programme, which specified that (i) they received the necessary detailed information from persons in whom they had confidence, (ii) they saw a neighbour and/or friend follow the practice successfully, (iii) they were encouraged by a salesman or dealer, and (iv) they thought they could make more mony. Farmers' reasons for not adopting the prescribed practices were the lack of specific information about practices, credit facilities, necessary equipment and knowledge and skills required to follow the advice received.

(4) Anthony and Uchendu (1968) in their study on the effort made to continue to find techniques for controlling pests and diseases, and raising productivity (which is affected by the farmer's ability and willingness to utilize proven technical innovation which can increase yield and control pest and disease) found that: (i) farmers who are expanding their cocoa farms tend to plant whatever varieties are easily accessible to them, therefore they tend to get seeds from their own farms or they might buy them from neighbours; (ii) although the number of farmers that used insecticides was high (about 80 percent), the use of insecticide depended on its availability; (iii) lack of fertilizer was not seen by farmers as limiting their yield therefore about 80 percent of the farmers had never used fertilizer.

(5) In the study on the innovation adoption behaviour of Ghanian cocoa farmers, Opare (1980) tried to find, (i) the extent to which cocoa farmers have adopted recommended cocoa practices, (ii) whether correct knowledge of recommended practices leads to adoption, and (iii) whether the source of information affects the adoption process. His findings show that, on average, cocoa farmers have adopted part of the innovation and have almost correct knowledge of recommended practices. Farmers do not necessarily adopt the innovations on which they receive correct information. Farmers use the formal institution as the source of information for more technical recommendations, while they depend mostly on friends and relatives for information on less complex innovations.

(6) Monu (1982) in his study of acceptance of farm technology amongst peasant cocoa farmers in Nigeria showed that farmers who adopted pest and disease controls had more frequent contacts with extension agents and external sources of information and came from specific regions and owned larger farms. Farmers who adopted fermentation technology were younger and had more frequent contacts with extension agents. However, the number of farmers that adopted the fermentation technology recommended was only about 10 percent.

(7) Kehnert (1988) in his study of institutions and technical change in the development of

smallholder agriculture viewed the wide adoption of coffee and cocoa by Cameroonian farmers as a successful innovation in traditional agriculture. He concluded further that technical change is possible. Investment models for innovations in coffee and cocoa show the profitability of adopting technical change at farm level. As crop specific innovations have to be analyzed in a farming system, farm models in different agro-ecological zones are presented which highlight important resource constraints on farmers and alternative production opportunities. Nevertheless, coffee and cocoa production are common to most competitive farm enterprises and innovations have been partially adopted. It is therefore concluded that innovations for coffee and cocoa will be profitable investments for farmers.

(8) In the study of the genesis of the pioneering cocoa front in Indonesia, Durand (1991) concluded that copying the previous success of cocoa development in Malaysia was the important factor that determined cocoa expansion in Southeast-Sulawesi. This factor was accompanied by the arrival of *Bugis* migrants who choose cocoa because of the large amounts of available land and because this crop has a considerable number of comparative advantages both in terms of required labour and market price: A regular cash income, with two or three harvests per month. Amongst several characteristics of farmers that are involved in cocoa development, he mentioned the farmer's willingness to take risks, as he is ready to invest all his labour and income on a single crop, even though there are non-negligeable dangers such as a prolonged drop in the world market prices or the development of a serious parasite like the pod borer. He also found that the farmers see no advantage in fermentation since the price offered by the collectors does not take into account the extra work this process would require.

(9) Pomp (1992, 1994) in the case study of cocoa adoption by smallholders in South Sulawesi tried to express several aspects that relate to cocoa adoption by smallholders in the region. Those aspects are the different scale and speed of adoption, assessing the relative profitability of cocoa in comparison with other crops, and assessing the extent to which copying behaviour explains the diffusion of cocoa. Several conclusions from the study were that compared to non-*sawah* food crops and coconut, cocoa is a profitable crop, thus household income may be increased by planting cocoa trees. Differences in the scale at which households adopt cocoa are only related to the amount of non-*sawah* land they own. One hectare of land owned by farmers allows them to adopt cocoa. The study also pointed out large differences in adoption across villages which may be explained by the land quality of each village. With respect to the information diffusion process, it showed that other farmers constitute the most important source of information. Information conveyed is not about the financial returns from cocoa. Farmers seem to infer that cocoa is profitable from the fact that others adopt it.

(10) A study with a similar subject to the previous study looked at smallholder adoption of tree crops in South Sulawesi, however, in a different region, and was conducted by Jamal and Pomp (1993). This study concluded that the factors that determine a farmer smallholder's adoption of the cocoa crop were farmers' levels of education, land ownership and information received about this crop.

(11) Ruf (1993) in an economic study through his several years of research in Ivory Coast

and Indonesia and periodic observations in certain other cocoa producing countries has attempted to develop a 'model' that explains the process of shifting production centres at farm, region, country and continent scale. His model was heavily centred on production dynamics and was based on concepts of forest rent, tree-capital, non-tree capital, migration and labour rent, life cycles, establishment of private property and the duality of family plantations and capitalist plantations. He concluded that with regard to the model, each of the factors, relations and concepts acquires a real dimension as a component in the overall process of supply and demand cycles. All the observations lead to technical and social change, which are sometimes sudden in the ecological and technical fields. He further concluded that these changes demonstrate the futility and scientific erroneousness of claiming to establish 'production costs' and drawing up 'comparative and competitive advantages' without in-depth study of farming systems and their dynamics.

(12) Boahene (1995) in his study of innovation adoption in cocoa production in Ghana found several factors which influenced cocoa farmers in adopting hybrid cocoa. In his study several sets of factors were presented as predictors of hybrid cocoa adoption. Those factors were (i) individual characteristics, such as age, education, family size, years of farming experience; (ii) social variables, *i.e.* network of relations and social status; and (iii) the institutional condition in which the farmers operate such as the system of land tenure and the system of acquisition of credit, chemical inputs, labour and information. The conclusion of the study was that information accumulation was important for farmers' choosing hybrid cocoa. Farmers with increased access to the extension services, or who had more successful adopters in their networks, accumulate higher levels of knowledge and hence adopt the innovation earlier compared to others. The use of credit and hired, cooperative labour and younger farmers are also the factors that influenced adoption, meanwhile the level of farmer education had a non-significant impact, and family size and output were not important in the adoption decision either.

(13) Several studies emphasized more technical aspects for explaining farmers' behaviour in technical culture application of cocoa. Oladucon (1990), in his study of tree crops based on agroforestry in Nigeria, found that almost all farmers in the region studied practiced intercropping other crops with cocoa. Meanwhile, Kolade (1991) found that the low level of maintenance influenced the agronomic practices of cocoa. The most important factors that contributed to smallholder cocoa production have been studied by Noormamat and Shahar (1989) in Malaysia. They concluded that the most important contributory factor to cocoa production was land, followed by labour input and fertilizer application. They also found that pesticide application did not affect production. Studies concerning to the technical aspects of cocoa production that have taken place for last several decades in Indonesia indicated the effort to maintain the production both quantity and quality. It should be noted several publications concerning to the biological method control (Zehntner, 1901-1906; Roepke, 1911-1917; Levert and Giesberger, 1930; see Toxopeus and Wessel, 1983), fermentation (Giesberger, 1953), and the improvement of plant materials (van Hall, 1910's; Wellensiek and Toxopeus, 1930's; van der Knaap, 1950's) are some studies that were focused to technical aspects. Apparently, the studies of crop protection placed the main focus of many cocoa researchers in Indonesia for a long time which could indicate the important effect of certain pests and diseases in reducing the cocoa production.

From the various studies presented above, several points can be underlined concerning the process of technology adoption and application by cocoa farmers. *Firstly*, although the studies started from different points of elaboration and analysis, seemingly they arrived at the similar finding that cocoa is a profitable crop, particularly in comparison with certain other crops. This crop can provide a great opportunity to improve farmers' household income and economic development in the region. *Secondly*, the role of migrants in cocoa development in certain regions is one of the main factors that determine the development of cocoa in the region. *Thirdly*, farmer ability that could be identified as farm and farmer characteristics and farm community elements, *i.e.* farm size, education, the availability of family labour, origin and ethnicity, play important roles in association with cocoa technology adoption and application. *Fourthly*, access to sources of information is the most powerful factor that influences the farmer's ability to adopt the cocoa crop. *Fifthly*, recommended fermentation technology was apparently less adopted by farmers, since the prices offered by collectors and traders do not take into account the extra work this process would require.

1.3 Research problems and objectives

1.3.1 Research problems

The problems faced by cocoa farmers are low yields and an enormous variation in yield per hectare. In relatively similar agro-ecological conditions in the Sulawesi region, certain regions, like North Sulawesi, showed higher yields per hectare and others showed the reverse. According to Ruthenberg (1985) crop yields depend to a high degree on environmental factors, technology and price relation. Thus, it can be assumed that under the same environmental and price conditions, the main dependent factor affecting the different levels of yield per hectare, may be the farmers' different technology adoption and/or application. Indonesian cocoa development varies in terms of technological adoption, both differences in the adopting of technology and in copying patterns. This diversity can be assumed to be related to the conditions and characteristics of small-farmers as decision makers in meeting their subsistence requirements, in striking a balance between labour and leisure, in choosing between consumption and saving, and in coping with risk and uncertainty (Ruthenberg, 1985).

Another problem with cocoa development in Indonesia is the low quality of the crop which contributes to its low price on the local and international markets. The price of Sulawesi's cocoa, for example, is always lower than the world market price for cocoa. *Figure 1.1* compares the situation of South Sulawesi's cocoa price with the international market price. South Sulawesi cocoa has always received lower prices than the average cocoa price on the world market. This deals mainly with Indonesian cocoa quality that has always been lower than the international quality grades. Apparently price premiums for well-fermented cocoa on the world market remain unfavourable for Indonesian cocoa producers. This price apparently is still not enough to compensate for costs and time spent by farmers on fermentation.

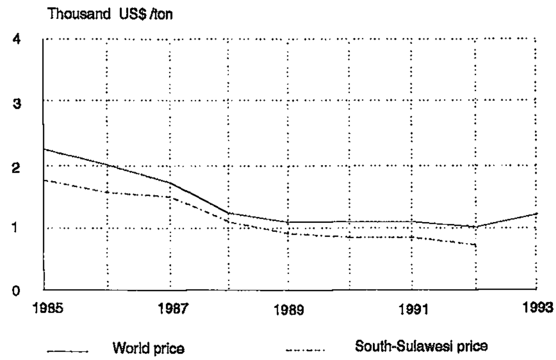

Figure 1.1 Comparison between South Sulawesi cocoa and the world cocoa price during 1985-1993 (Source: ICCO and Directorate General of Estates).

Over three quarters of Sulawesi's cocoa and two thirds of Indonesia's cocoa production, may be Fair-Average-Quality (FAQ) with relatively high levels of unfermented or slate beans (Bennet and Hasan, 1993). Exports of such low quality cocoa are cited as constraints on raising export revenue and farm income, and are detrimental to Indonesia's export image (Siswoputranto, 1992). Farmers seem not to be interested in adopting fermentation processing technology, although this technology is quite simple and, theoretically, could be performed by all farmers since technically it does not need advanced knowledge to adopt the technology.

According to Simmonds (1985), the farmers are economically rational but not necessarily profit-maximizing because they have their own scales of utility, or they are conscious of uncertain environments, of cash shortage, and of family responsibilities and therefore they are averse to risk. They often suffer cyclical labour shortages and under-employment too. Despite certain necessary technologies available, which would presumably allow for an increase in farmer's profits, the limitations that Simmonds mentioned, in capital or otherwise, has led to some farmers not adopting the technology, or adopting it only in part.

Given these problems it appears urgent to focus on behavioural adoption and application of technology at farm household level. Several questions can be submitted such as (1) to what extent do farmers utilize the technologies of production inputs and fermentation processing?; (2) what are the farmers' strategies and how does the farmers' environment affect the decision-making for technology adoption and application?; (3) how do farmers decide to adopt or not adopt and to apply or not to apply the available technology in both pre-harvest (fertilizer, pesticide and herbicide) and post-harvest (fermentation) technology?; and (4) under what conditions would adoption and application be profitable?. These questions would lead to greater insight into technology adoption and use amongst on cocoa farmers.

1.3.2 Research objectives

There is limited information about the pattern of smallholder decision-making in adopting and applying technology, particularly the technology adoption and application of the cocoa smallholder. The research objectives are to expand present knowledge on the technology adoption and application of production inputs and fermentation processing related to farmers' decision-making, and to formulate an optimal technology application particularly for smallholder cocoa farmers. To achieve these objectives it is necessary to understand factors that are associated with farmers' decision-making in adopting and applying these technologies and problems related to them. Given the two objectives, the study will develop and test (1) a model that assesses factors which explain cocoa farmers' technology adoption and application, and (2) a model that presents the optimization of cocoa farmers' activities both at the cocoa farmer and regional level.

1.4 Thesis outline

The thesis consists of four main parts and seven chapters. The initial part is composed of chapter 1 and chapter 2. Chapter 2, the theoretical framework, consists of the literature reviews of theoretical aspects. The review of technology adoption and application at small-scale farmer level is presented in section 2.2, where behaviour and characteristics of smallholders dealing with technology adoption and application are described. In the theoretical review that is presented in section 2.3 the main concepts of management, decision-making and technology are described in chronological order to clarify the concepts and their relations. Various concepts are discussed such as decision-making in the management process, decision-making at farmer's level, and adoption of technology. Section 2.4 presents the conclusion of the theoretical framework.

The second part of the study is covered in chapter 3 and chapter 4. Chapter 3, the research model and hypotheses, consists of the description of the research region, a general model, a research model and hypotheses developed, which are presented in sections 3.2, 3.3, 3.4 and 3.5. Chapter 4, research design and its implementation, consists of the research design and methodology used, and research organization, which are presented in sections 4.2 and 4.3; data collected and characteristics of variables which are presented in sections 4.4 and 4.5; and the technical methods used which are presented in section 4.6.

The third part is the research analysis, which examines all relevant data and information collected through two approaches: the positive and normative. The two analyses are presented in chapter 5 and chapter 6. Chapter 5, factors explaining technology adoption and application, presents the positive approach, where production function approach are used as tools of analysis. In section 5.2 the findings of empirical model of technology adoption presented and section 5.3 the results with regard to the factors that influence technology application are described in detail. Section 5.4, conclusions, terminates this chapter.

Chapter 6 presents the normative approach by analysing the opportunity of optimizing the application of technology in cocoa development. In section 6.2 the technical method of linear programming is presented. Then, follows section 6.3 describing the linear programming model. Section 6.4 presents the application of the model and the steps of its implementation.

The final part is the conclusion and discussion, which is presented in chapter 7. To start the chapter, in section 7.2 the discussion of results, describes technology adoption and application in recent years and relations of factors significantly associated with cocoa technology adoption and application. Section 7.3 presents the conclusion of findings. Section 7.4 discusses the subsequent research implications and suggestions in various domains of cocoa and regional development.

CHAPTER 2 THEORETICAL FRAMEWORK

2.1 Introduction

This chapter will discuss the theoretical framework of the study and present those elements that are related to technology adoption on the part of smallholder farmers. To initiate the discussion, section 2.2 will present small-scale farmers dealing with technology adoption. Various factors of technology which may be stimulants or constraints to adoption will be described in this part. Farms and farmers' activities and attributes associated with small farmers' technology adoption are described by referring to various empirical studies over time and will complete this section.

Section 2.3 will place adoption of technology within a particular decision-making process, refer to basic concepts of decision-making in the management process, decision-making at farmer's level and adoption of technological innovation. Decision-making and the process of technology adoption and application at farm level, more particularly at smallholder level, are part of the management processes. Technology adoption and utilization by farm smallholders are the result of the decision-making by the farmers. This decision-making process is embedded in the overall management concept at farm level. This is why the theory of decision-making presented is based on management theory and concepts, and factors that are related to these. In this part, management and decision-making at farmer level is also presented, describing its characteristics and the underlying problems that usually have to be faced. Conclusions and results from various other studies dealing with tendencies in technology adoption by cocoa smallholder farmers are presented at the end of this chapter in section 2.4.

2.2 Small-scale farmers dealing with technology adoption

Technology adoption has taken place amongst farmers since 5,000 years B.C. While the empirical evidence shows that in many developing countries technology adoption of chemical production inputs has taken place widely amongst small farmers, at least since 'the green revolution era'. The adoption occurs at various levels as does the kinds of technology adopted. The differences in adoption have occurred due to the different abilities and conditions of farmers and other external factors, even due to different specific conditions that are needed for technology to be adopted, *i.e.* their technical conditions and technology availability in the surrounding farms. Frequently technology is available but it is not suitable or appropriate for the conditions under which the farmer operates (Beets, 1990). However, certain technology can be adopted by farmers, not only because of its appropriateness to farmers' needs, but certain conditions may facilitate the processes of adoption. Nweke and Akorhe (1983) in their study of determinants of adoption of new technology amongst smallholders concluded that technology is adopted if the technology is profitable and the material components of the technology are available under acceptable conditions. The necessity to design agri-support services specifically and exclusively for small farmers or to take steps to improve agri-support services for all farmers in a region in such a way that small farmers are fully serviced by them (Mosher, 1979) is a way to facilitate technology adoption. Evidently, many of the failures of technology adoption are due to the lack of supporting facilities for the technology either due to lack of information, appropriate conditions or to a lack of extension institutions. In other cases, many successful adoptions occurred where the farmers had easy access to various available supporting infrastructures of technology, such as adequate extension assistance.

Besides the profitability of the technology, there are certain characteristics associated with the technology that are usually significant for the farmers. In general, new products and techniques are only adopted widely and rapidly if they are appropriate and attractive to farmers. In this respect, Jones (1963); Upton (1983), *see* Ruthenberg (1985),showed the characteristics that are likely to be important:
(1) the gain in income, or rate of return on the investment;
(2) the size of investment in relation to the current income level;
(3) the complexity of the innovation, its compatibility with existing farming systems, and farmers' attitude to work, to changes in diet and their way of life;
(4) the risk involved; and
(5) the conspicuousness of the innovations, both because the adopter may attain prestige from displaying his technical progress and because other farmers will become aware of its introduction into the area more quickly.

With regard to the importance of the gain in income, it can be argued that the new technique must promise quite a substantial increase in yield or a large reduction in costs to be acceptable to most farmers (Mosher, 1979; Upton, 1983). However, the gains are only likely to be substantial if the new technology increases the productivity of the most limiting resources (Ruthenberg, 1985). Level and size of investment, however, are important aspects that are usually considered by farmers in the use of technology. High necessary investment for large farmers may not be a large problem but for small farmers can be a serious constraint to adopting the technology. The characteristics of the technology, particularly biological technology such as fertilizer, pesticide and herbicide that can be dispersed in small quantities places these production inputs in a 'neutral' scale since they can be adopted as easily on small farms as on large ones. Not so in the case of adoption of mechanization which needs high investment and is difficult for small farmers to realize without the support of capital/credit and supervision by external institutions. This type of technology, as a less divisible technology, is likely to be less accessible to smallholders (Schutjer and Van der Veen, 1977).

The importance of fertilizer application lies in the fact that the use of mineral fertilizer increases yields and thereby also labour productivity (Ruthenberg and Jahnke, 1985). However, for the greater part of tropical agriculture the use of mineral fertilizers is still in one package with the use of high yield varieties (HYV). Therefore, chemical fertilizer still has to be regarded as a technical innovation. Since traditional crop varieties' response to fertilizer is often insufficient, and since modern varieties only developed their full yield potential with fertilizers, the introduction of additional plant nutrients must be seen as an important complement to the use of modern varieties. Now used more widely, chemical fertilizer is becoming the major monetary input for a growing number of farms, therefore economic considerations of production input uses have become important.

The attacks by pests, diseases and weeds on cocoa crops can not be ignored. They can influence the level of cocoa production in both quality and quantity. An integrated pest management control system has been the conceptual basis for most of modern plant protection (Teng and Heong, 1988), and has been recommended for the last few decades. This method integrates several kinds of controls (Entwistle, 1972; DGE, 1992) like cultural, biological, mechanical and chemical controls in order to achieve an optimal result in terms of pest and disease controls. The chemical or pesticide control is recommended as the last option. Pesticides must be applied prudently to minimize the risk of emergent insect resistance, and for them to have little or no side effect on non-target animals or plants and environment (Oka, 1988; DGE, 1992). The implementation of integrated pest management control on estate crops in Indonesia, for instance, is still in its initial stages with limited supporting components (Wirjosuhardjo, 1988).

The integrated pest management control system has already been recommended as the best pest and disease control method for a long time, however pesticide application is becoming more and more important since pesticide application has become one of the easier ways for farmers to protect their harvests. The application of pesticides is not only for maintaining production levels, this also leads to increased yields with low inputs of money and energy, it reduces yield fluctuations, it increases workforce productivity with growing workforce inputs per unit of area and it contributes to the creation of a dense crop vegetation with the resulting beneficial effects on erosion control, water retention, and preservation of soil fertility (Ruthenberg, 1985).

Herbicides are workforce-saving innovations that have their origin in chemical and agronomic rather than in mechanical technology. They are almost perfectly divisible and have low capital requirements, both properties being significant for smallholders in developing countries. Herbicides can be seen as substitutes for a hand workforce. Workforce capacities are usually insufficient for the weeding requirements. Even in densely populated areas with smallholder agriculture and significant rural underemployment and unemployment, only some of the fields are hoed in time and hoed frequently enough (Binswanger and Shetty, 1977). Particularly for rainfed agriculture in sub-humid climates, weed growth is one of the most important yield-depressing factors in the production process (Allan, 1968). Consequently the use of herbicides has not only a workforce-saving effect but also a yield-increasing effect.

The using of herbicides is still sometimes regarded and judged from a different point of view. At low wage levels and in the context of traditional rainfed agriculture, the use of herbicides is often uneconomic (Binswanger and Shetty, 1977). Despite low wage levels, in certain specific situations herbicides still prove economically attractive for the farmer (Franke, 1979; *see* Ruthenberg, 1985). Some of the situations in which small scale-cocoa farmers usually operate with the frequent use of herbicides are described as being (1) for the clearing and the establishment of cocoa on virgin land without the use of tractors, particularly in the control of *Imperata cylindrica*; (2) for minimum tillage systems of annual crops amongst immature cocoa, where the use of herbicides serves as a substitute for land cultivation practice; (3) for the control of perennial weeds amongst the rows of mature cocoa.

The economic problem of herbicide application lies in the conflict between farmers and the need for employment for many other family members who need work and income. However, in certain cases farmers used herbicides even though the number of family workers available was sufficient for hand-weeding their plots. Usually, practicality and time efficiency are considered to be the explanation for this preference. Moreover, many farmers used herbicide to overcome the shortage of workforces in the time the weeding had to be performed. It is common knowledge that tropical rainfed agriculture tends to be characterized by extreme seasonality of labour requirements and by labour peaks (MacArthur, 1980). Typically labour shortages arise at the stages of land preparation, weeding and harvesting. With the given traditional technology land cannot be cleared before the onset of the rains. Once the rains sets in, the time required for land preparation is time lost for the growing period of the crops, so a workforce may be the most binding constraint at this stage. But with the onset of rains in a warm climate the growing conditions become ideal, not only for crops but also for weeds, and the weeding requirements may again lead to excessive workforce demands (Ruthenberg, 1985). At that time family-workforces owned by farmers are sometimes not sufficient to fulfil farm workforce requirements. Consequently, farmers might use herbicides for weeding control. In the context of a smallholder economy, herbicides would normally be expected to be complementary to hand workforces (Baker and Cordova, 1978).

The involvement of risk in technology adoption is another aspect that farmers usually consider. The extent to which risk factors cause the relative riskiness of the use of particular inputs (Huijsman, 1986) depends on: (1) The type and the degree of interaction between input factors and risk factors. In this respect, a distinction can be made between protective and non-protective farm input. Protective inputs, such as pesticides and herbicides, are aimed at reducing the likelihood of low production outcomes without necessarily the potential yield of an activity. Non-protective inputs, such as fertilizer, are primarily meant to increase the potential yield without necessarily reducing the probability of low returns. (2) The extent to which risk situations occur prior to the time input decisions have to be made. Timing of input application will become a factor in the risk taking process. A possible decline in the response to inputs should be weighed against a possible increase in the efficiency with which decision can be made. (3) The ability of farmers to protect their crops from the influence of risk factors through adequate crop management practices (risk control). Effective risk control depends to a certain extent on the resources available to the farmers as the decision makers. Input response risk and farmers' perception of such risk may be influenced by perceived cash or labour constraints (Huijsman, 1986).

The factors described above are the factors that concern the characteristics of technologies. Certain factors associated with farms and farmers' activities will also influence farmers in technology adoption. The empirical studies concerning technology adoption showed the large variability of farmers' ability and behaviour in using the available technology. A number of limited ability and behaviour that accumulates in the similar time may have become constraints for farmers to adopt technologies. Schutjer and Van der Veen (1977) summarized a number of economic constraints as potential barriers to technology adoption by small farmers. According to them, within the context of a farm unit, resource availability and risk absorption capacity are the major constraints. In general, the evidence regarding a gross correlation between farm size and technology adoption is mixed. However, the preceding studies did not indicate a consistent pattern of size of holding *per se* as a barrier to technology adoption by farmers in the developing countries. Several studies (Kumar and Wasink, 1989; Chandra and Singh, 1992; Shree and Siddaraman, 1993) reported that farmers who exploited a larger area are more adoptive in using fertilizer, however, certain others (Van der Veen, 1975; Rawal and Noraula, 1988; Onte, 1988) found an inverse relationship between farm size and the amount of fertilizer and labour used and productivity per unit of land. Van der Veen (*see* Schutjer and Van der Veen, 1977) attributed the inverse relationship to: (1) the possibility that small farmers farm their land more intensively to meet subsistence needs; (2) the possibility that smaller farms had better irrigation, and (3) the possibility that more low-cost farm family labour per unit area is available on smaller farms. Rawal and Noraula concluded that small farmers have advantages over big farmers, they employ more labour and produce more on a unit of land. A similar finding has been reported by Onte, that small farmers were quicker to adopt new technology and used more labour than big farmers.

Another aspect of land size is fragmentation of land that is generally pointed out as an obstacle to the adoption of agricultural technology. Hodgdon (1966) reported the obstacle to making effective use of fertilizer, herbicide and insecticides namely fragmentation of land. It is also reported by Clay (1972), and Dobbs and Foster (1972) that fragmentation impedes the efficient utilization of tubewells.

Several studies showed farmers' education associated with farmers' technology adoption (Kumar and Wasink, 1989; Metzger, 1991; Doorman, 1991; Jamal and Pomp, 1993). In general, they reported that illiterate farmers are less adoptive than educated farmers. Nyoku (1991) and Kashem *et al.* (1993) concluded that the knowledge of farmers influences farmers' behaviour in crop technology and fertilizer application. The age of farmers is the factor that is associated with technology adoption by small farmers as reported by Kumar and Wasink (1989), Jha and Hojjati (1993); Zinyama (1992).

There is limited evidence to suggest that the availability of workforces on the farm will encourage the adoption of workforce intensive technology while a lack of workforces will discourage both adoption and efficient utilization (Schutjer and Van der Veen, 1977). However, certain studies showed the relation of the supply of family workforces to the adoption of technology. Hicks and Johnson (1974) reported that variations in areas planted with a new rice variety was related to increases in rural labour supply. Chandra and Singh (1992) reported the different use of workforces at the lower level of adoption and the higher level of adoption. The less adopting farmers had a higher workforce absorption compared to the farmers with higher level adoption. Caveness and Kurtz (1993) reported that labour availability contribute to adoption of agroforestry technology.

One aspect that closely relates to technology adoption is technical efficiency in which the maximum attainable level of output for a given level of production inputs. The willingness to be technically efficient is more important than the actual knowledge a person possesses about production process (Shapiro and Müller (1977). This willingness is associated with modernization, *i.e.* the extent to which the farmer has adopted modern items (possessions, practices, opinions or knowledge). Several studies reported the relation between farm and farmer household characteristics and technical efficiency, however the conclusions of different authors about the effect of these topics are not uniform (Ali and Byerlee). According to Yotopoulus and Lau (1973), small farms are relatively more technically efficient. However, Sidhu (1974) found that no differences in the technical efficiency on small and large farms. He further stated that smaller labour-surplus farms in traditional agriculture have a greater technical efficiency and if large farms have better access to research information, the equal technical efficiency of small and large farms found for the period just after the introduction of high-yielding varieties may well be explained by the more rapid assimilation of the new technology by larger farms.

Several other studies describe proxies for farmer's information and technical skills. Formal education, contact with extension services, experience (reflected by age, farming experience and/or off-farm employment) and gender are several interesting topics that were identified. An overview of studies of the effect of farmer's educational level and exposure to extension services on technical efficiency by Lockheed et al. (1980) and Jamison and Lau (1982) concluded that most studies find a positive and significant effect of education, while the effects of extension are much less clear.

The studies above, in general, mentioned that, (1) ability to mobilize production factors, (2) availability of capital, (3) access to production supply factors, (4) risk absorption capacity and (5) complexity of the technology are the main constraints stopping farmers adopting and applying certain technology. It can be summed up that empirical evidence highlighted many variances between factors that contribute to the process of technology adoption at a farmer smallholder level.

2.3 Decision-making and processes of technology adoption

After discussing the insight of farmer adoption of tree crop technology, and particularly cocoa technology, it is necessary to present an overview of decision-making and technology adoption-theories and concepts related to the framework of the farm management process. Decision-making on technology adoption activities is a part of operation of management activities. Decision-making has been studied frequently by many social scientists. There is a reason for this, because making decisions is surely ones of the most fundamental functions of management (Starr, 1971) and its business places it at the 'heart' of management (Castle *et al.*, 1972).

Management as a realm of social science has developed rapidly during the 20th century. Management can be approached through several concepts, such as a division of areas of responsibility; as coordinating a series of resource inputs; as obtaining desired results through the effective utilization of available resources - which is often called the six M concepts[2]; as the division into approaches or processes - which is the behavioural concept; and as a series of functions (Downey and Erickson, 1987). To formulate the definition of management, theorists have used different terminologies but have retained the same objectives: how to

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[2] *Management is viewed as coordinating a series of resource inputs, such as money, markets, material, machinery, methods, and manpower (Downey and Erickson, 1987).*

achieve the outcomes of management. Although they have different approaches in their concepts of management, similarity of thinking is still found, which is defined as management as a process to produce a certainty or outcome. It can be cited from various definitions, for example: "management is the process of getting things done by and through the efforts of other people" (Mondy *et al.*, 1988), and the simpler "management is about getting things done by and through people" (Smith, 1989), or according to Downey and Erickson (1987), management is "the art of successfully pursuing desired results with the resources available to the organization".

To understand decision-making it should be clear that the discussion is initiated by describing the decisions and the choices. MacKenzie (1975) identified a decision as a 'real choice', by which he means a choice about ends as well as a choice about the means to arrive at those ends, whether at an individual or collective level. Therefore his concept of a decision is one of a process: a cumulative sequence of stages of choice. At the same time Jabes (1978) described decisions as goal-directed behaviour shown by the individual, in response to a certain need, with the intention of satisfying the motive that the need occasioned. In a simple definition, Mondy *et al.* (1988) formulated that decision-making is a process of generating and evaluating alternatives and making a choice among them.

When discussing organization, Simon (1977) treats decision-making as synonymous with managing, For that, he underlines the fact that decision-making as a process should not be reduced simply to a choice amongst alternatives. This process involves a conceptualization of the problem to be solved and a description of how that final choice is made. Somewhat in accordance with Simon's statement is the more comprehensive definition of decision-making by Shull *et al.* (1970) "a conscious and human process, involving both individual and social phenomena, based upon actual and value premises, which concludes with a choice of one behavioural activity from among one or more alternatives with the intention of moving toward some desired state of affairs".

Decision-making theories can be viewed from various sides. Up to the early 70's, decision theorists distinguished between a discriminative decision theory and a normative decision theory. The discriminative decision theory is trying to establish rules and models to determine how a naive, unguided decision maker considers the different aspects of a decision problem in arriving at a decision. The normative decision theory develops models to be applied in certain situations when a given objective criterion is to be maximized.

A different approach from the classical decision-making theory is the administrative theory advanced by Simon in 1947. The classical theory of decision-making assumed that a decision is directed towards a single, unchanging goal and that a rational decision could be reached to meet that goal (Filley *et al.*, 1976). These assumptions where derived from the theory of the 'economic' individual. Economic individuals assumed that knew all the alternatives available in a given situation and the consequences of each. It is further assumed that they behave rationally, that is, they are able to order their preferences according to their own hierarchies of values, and they always seek to maximize some desired values (Filley *et al.*, 1976). The classical theory is criticized by modern management theorists and behavioural scientists for its assumption that once an imbalance has been resolved by an appropriate decision, the matter is settled once and for all. Modern theorists argue furthermore that goal stability and consensus can never be fully realized due to both environmental changes and individual differences.

The 'administrative' theory differs from the earlier classical theory in both its assumption and its prediction. Simon criticized the classical theory saying its assumption is invalid for real situations and that the question of values in decision-making must be decided by decision makers not by theoreticians. Simon (1957), see Filley *et al.* (1976) noticed two important differences between the artificial 'economic' individual and the decision-making, administrative individual. First, he rejected the notion that people can be fully informed about anything arguing that, since consequences always lie in the future, it is impossible for any person to know all potential alternatives, and future values can only be anticipated as projections of the imagination. Second, the administrative individual satisfies rather than optimizes when taking most decisions. 'Satisfying' means that when individuals are confronted with situations where a decision must be made, they begin by searching for possible alternatives and for information concerning the consequence of each alternative.

Kickert (1980) summarized several previous concepts (Simon, 1945; Luce and Raiffa, 1957; Taylor, 1965; Nutt, 1976; Meintzenberg *et al.*, 1976) which were cited. One can state that the concept of decision-making should at least consist of the following elements: (1) a choice between alternatives; (2) the conscious drawing of conclusions from premises; (3) a learning process of search, development, evaluation. etc.; and (4) an action commitment for implementation. Starr (1971) described the components of a generalized decision as the strategies and environments producing results. He detailed further that: (1) strategies are composed exclusively of controllable factors, that is, a strategy is an arrangement of those variables in the system that are entirely under the control of the manager; (2) environments are composed of uncontrollable factors in the system; and (3) results are an outcome; in certain cases several kinds of results must be considered in reaching a decision.

When this statement is formulated in an equal function, then:

$$R_{ij} = f\,(X_i,\ Y_j), \quad \text{where } R = \text{results}; \quad X_i = \text{strategy, number } i; \quad Y_j = \text{environment, number } j.$$

The environmental elements of a decision are not always known to people, because people are often forced to make decisions with limited information about the environmental condition of the decision. Available information is an essential factor which influences the completeness of decision-making. Understanding the information itself can not be let over without understanding knowledge. Knowledge and information are two central concepts of the knowledge and information perspective.

Röling and Engel (1991) stated that knowledge occurs between the ears, as a property of the mind, it cannot be transmitted directly. Knowledge is used to operate in the real world and its utilization is a mechanism for survival. Consideration of the knowledge - real world interface device - has an heuristic effect. And a crucial interface device is information which is defined as a sensory input that maintains or improves the goodness-of-fit between the knowledge and the real world. Information is explicit, visible, touchable, hearable and thus transferable. Furthermore, they specify that information is more than data or more sensory input but also implies an interpretable pattern and even to be informative. It must also anticipate the discrepancy which exists between the receiver's knowledge and the environment.

For knowledge to migrate quickly, four broad conditions must hold. First, the knowledge must be clearly articulated and reside in a 'package'. Second, a person or a group must be capable of opening the package, of understanding and of grasping the knowledge. Third, a person or a group must have a sufficient incentive to do so. And fourth, no barriers must stop them (Badaracco, 1991). To arrive reach the receivers, knowledge and information must be communicated. Rogers and Shoemaker (1971) defined communication as the process by which messages are transferred from a source to a receiver. Other explanations which detailed the messages that communication is the transfer of information, ideas, understanding, or feelings between people (Mondy *et al.*, 1988). One specific communication is the diffusion which is defined by Rogers and Schoemaker (1971) as the process by which innovations spread to the members of a social system. Further, they described the crucial elements in the diffusion of new ideas as (1) the innovation (2) communicated through certain channels (3) over time (4) amongst the members of a social system.

A communication channel is the means by which the message gets from the source to the receiver. The essence of the diffusion process is the human interaction by which one person communicates a new idea to one or several other persons. It can be differentiated into mass media channels and interpersonal channels.

As a process, decision-making consists of a number of steps. Castle *et al.* (1972) cited five steps in the decision-making process which are described by Bradford and Johnson (1953) such as (1) developing ideas and making observations; (2) analysis of observations, including formulation and reformulation of problems and ideas concerning their solution; (3) decision-making; (4) action; and (5) acceptance of responsibility for actions.

Meanwhile, Simon (1977) distinguished three phases within the decision-making process. First, the intelligence activity, the occasion for making a decision is considered. Second, the design activity, deals with inventing, developing and analyzing an alternative action course. Third, the choice activity - one particular alternative is selected. Generally, these activities are passed through in chronological order. However, it must be stressed that reality is often far more complex and cannot be described without understanding that each phase in making a particular decision is itself a complex decision-making process (Simon 1977).

The decision-making process often occurs between two or more decision-making units. In the case of the joint decision-making process, Tuite (1972) defined three comprising steps: (1) recognition that interdependencies exist between the decision units; (2) an intervention which facilitates consideration of these interdependencies in the decision-making process; (3) selection of technology for making the decision.

Decision-making necessitates model building. A 'model' is a simplification and abstraction of some aspect of the real world (MacGrew and Wilson, 1982). It is impossible to select those aspects of decisions which are significant without the concepts that define what should be observed. Jabes' aim of decision-making models is to describe how people make decisions. The models describing the decision-making process fit the data from the actual decision to the prescriptions of the model. The decision-making model can be a descriptive model and a normative model.

From several decision-making models developed, this study illustrates two of the dominant perspectives upon decision-making, namely the organizational and the rational decision-making perspectives.
(1) The organizational Process Model, emphasizes the centrality of routines and procedures in reducing the effect of uncertainty, and also emphasizes the management of information to protect individual and departmental interests in the organization. Jabes (1978) described three conditions in which a decision is made: certainty, risk and uncertainty. Starr (1971) detailed six conditions: ambiguity, instability, certainty, risk, partial uncertainty and uncertainty. Certainty, risk and uncertainty conditions were described by Jabes and Starr in a similar sense. According to Starr (1971), certainty occurs when there is only one environment that is relevant to the decision. Risk exists when there are several relevant environments which means that the results will vary according to which environment actually occurs. Uncertainty occurs when environments are known but nothing whatsoever about the probabilities associated with those environments. Thus forecast information has reached zero. As a result, many decision options are available. Decisions made 'under ambiguity' is when the decision maker in this condition lacks knowledge about the relevant environments. Decisions made 'under instability' is when the environment is not rendered stable but it is important to know what it might be in order to be able to have the appropriate corrective action available. And decision 'under partial uncertainty' is made when the shape of the distribution of probabilities is not known but some information is available about the parameters and/or character of the distributions - then a decision can be reached using only this partial knowledge. The description by Jabes (1978) is: certainty occurs when the outcomes of alternative actions can be accurately predicted; risk involves a state in which the possible outcomes of the alternative action can be specified and a probability assigned to the likelihood of the occurrence of each; and uncertainty exists when the probability of occurrence of the alternative outcomes is unknown.

(2) The Rational Decision-making Model; a model in which decisions are made systematically and based consistently on the principle of economic rationality. Economic rationality is the belief underlying the Rational Decision-making Models that states that people attempt to maximize their individual economic outcomes (Wagner and Hollenbeck, 1992; *see* Batelaan, 1992). Information about all possible alternatives, their outcomes and the preference of decision makers is assumed to be available. Furthermore, Batelaan (1992) mentioned two concepts which can restrict people in making decisions (a) bounded rationality as an outcome of cognitive limits, and (b) incrementalism, which is the empirical and theoretical restriction on functional rationality, *i.e.* interception by substantially rational elements.

The Bounded Rationality Model is the model enabling human beings to reduce the complexity of the objectives and to transform social reality into something that can be dealt with in the decision-making process. The Disjointed Incrementalism Model, developed by Lindblom (1959), *see* Batelaan (1992), is a theory in which the rational perspective is adjusted for cognitive limits and political considerations. Lindblom advocates that objectives are adjusted to means in the sense that what we establish as policy objectives we derive for a large part from an inspection of our means. The processes of policy (strategy) formulation and goal-setting interact and are characterized by reconstructive treatment data. Analysis and evaluation are serial, remedial-oriented and socially fragmented (Batelaan, 1992).

2.3.1 Decision-making about agricultural technology at farmer's level

It is necessary to describe the process and the state of decision-making concepts at farmers' management levels, in order to verify to what extent the previous management and decision-making concepts operate at farm level. Management methods, principles and functions prevail at farmers' management level. Considering the distinctions in the level of decision, the decision to adopt technology can be understood to contain strategic, tactical and operational factors. In the case of cocoa farm smallholders, when the level of the decision-making concepts distinguished previously by Simon (1977) are introduced in depicting the activity levels in decision-making, the different decisions taken in adopting or not adopting the pre-harvest and post-harvest technologies (*Figure 2.1*), can be seen, this is depicted in more detailed in *Figure 2.2.*

Level of decision	Pre-harvest technology	Post-harvest technology
	Fertilizerr/Pesticide/Herbicide application	Fermentation application
Strategic	* Adoption decision of cocoa * Investment	* Adoption decision of cocoa * Investment
Tactical	* Analyzing input and output prices * Analyzing available budget and workforce * Procurement	* Analyzing output prices * Analyzing available workforce
Operational	* Application decision	* Application decision

Figure 2.1 The distinction of decision between pre-harvest and post-harvest technologies.

The different adoption decisions in favour of pre-harvest and post-harvest technologies are taken mainly at the tactical level. At this stage, the adoption decision for pre-harvest technology is a procurement of production inputs preceded by the analyzing of inputs and output prices, availability of budget and workforce, and short term credit needed. All level decision adoptions of pre-harvest technology could be optimized to achieve optimal outcomes of exploitation. Whilst on the adoption decision for post-harvest technology, the analysis is focused on output prices and the availability of workforce, since this technology does not need a significant procurement. The optimization of the implementation decision is an important objective to achieving an optimal outcome.

Year	Strategic decision	Tactical decision	Operational decision
t - n	* Adoption of cocoa		
.	* Purchasing of land	* Choosing land clearing	* Land clearing operation
.	* Workforce, building,	system	
.	material and other capital		
t - 1	availability		
	* Long-term credit	* Self nursery/buying plant materials	
	* Selecting variety	* Number and time of planting	* Planting of shade trees
	* Adoption of shade trees	* Frequency of cultivation	* Planting of food crops
	* Adoption of food crops	* Procurement	* Herbicide application
t	* Cocoa planting	* Number and time of plant	* Plant replacing
	* Cocoa population	replaced	
t + 1		* Number and time of plant	* Plant replacing
		replaced	* Food crop cultivation
		* Analyzing input price	* Fertilizer application
		* Credit; Procurement	* Herbicide application
		* Time and system of pruning	* Cocoa and shade tree pruning
t + 2		* Analyzing input/output price,	* Fertilizer application
		available budget & workforce	* Pesticide application
		* Credit; Procurement	* Herbicide application
		* Time and system of pruning	* Cocoa and shade tree pruning
			* Food crop cultivation
t + 3		* Analyzing input/output price,	* Fertilizer application
		available budget & workforce	* Pesticide application
		* Credit; Procurement	* (Herbicide application)(*)
		* Time and system of pruning	* Cocoa and shade tree pruning
			* (Food crop cultivation)(*)
		* Analyzing cocoa price and	* Harvest (**)
		available workforce	* Fermentation application
t + 4		* Analyzing input/output price,	* Fertilizer application
		available budget & workforce	* Pesticide application
		* Credit; Procurement	
		* Time and system of pruning	* Cocoa and shade tree pruning
			* Plantation clearing
		* Analyzing cocoa price and	* Harvest
		available workforce	* Fermentation application
t + 5		* Analyzing input/output price,	* Fertilizer application
.		available budget & workforce	* Pesticide application
.		* Credit; Procurement	* (Herbicide application)(*)
.		* Time and system of pruning	* Cocoa pruning
t + n			* Plantation clearing
		* Analyzing cocoa price and	* Harvest (***)
		available workforce	* Fermentation application

Figure 2.2 The different adoption decision of cocoa technologies over time for each management level. Note: (*) Conditional; (**) Hybrid varieties; (***) Local varieties

The different characteristics and specific activities of farming units causes them to treat their applications differently. The characteristics of farmers' management are that in the operation of their activities of the natural environment needs to be taken into account (MacArthur, 1980) such as climatic influences and the biological environment. The other factors which characterize farmers' management activities are the influence of the socio-economical environment, the farmers' family and production factors such as land, workforce, capital, material. *etc.* (Dufumier, 1985).

It seems that for tropical farming such characteristics are still accumulated with some critical aspects such as the problem of soil fertility, coping with risk and uncertainty, low labour productivity and problems of seasonality (MacArthur, 1980). For some of the farmers, application management theories have been carried out traditionally and sometimes instinctively by considering these characteristics. They managed their available resources and based their choices on their experiences and knowledge. If some of the farmers changed slowly and inefficiently under certain limited conditions, this was another aspect of farmers' management. In rather technical terms, the definition of farm management was formulated by Yang (1971) as "farm management is a science which deals with the proper combination and operation of production factors, including land, labour and capital, and the choice of crop and livestock enterprises to bring about a maximum and continuous return to the most elementary operation units of farming".

To describe the characteristics of the farmers' decision-making, it is necessary to refer to the characteristics of farm management. Various statements identified the factors determining or influencing the decision-making process in farm management. Feil (1991) emphasized the community influence on the farmer. He argues that decisions in farming will be determined not only by the goal of maximizing the benefit or of reducing the risk, but also by willingness to accept criticism from the community (depending very much on a farmer's social position in different groups). According to Reijntjes *et al.* (1992), the decision-making process is influenced not only by the culture of the community to which the household belongs but also by other factors such as personality of the different household members, biophysical characteristics of the farm, the availability and quality of external inputs and services, and socio-economic and cultural processes within the community. More details about the characteristics of households that influence the farm household decision-making are: the number of men, women and children, their ages, state of health, abilities, desires, needs, farming experience, knowledge and skill, and the relations between household members. Those factors that influence the farmers' decision-making to achieve their outcomes can be systematized in physical environment, socio-economical environment (included political aspect), farmers' family and production factors. The farmers' decision-making process occurs at the entire management level, at the beginning of farming development, at farmers' family level, in the management of production factors, purchasing, stocking, technical production, or at marketing level. Simplified, the factors which influence the farmers' decision-making can be divided into two groups *i.e.* external or environment factors and internal or farmers' strategies. The latter relates closely to the problems farmers are faced with. By outlining the farmer's problems it will be easier to understand how the decision-making process applies to the farmer's style of management.

Several kinds of farmers' problems can be identified resulting from a lack of information, which is an important element in determining the farmers' decision-making process. Other problems that fit better in the realm of traditional farm management can be forms of home environment, family health, family attitude regarding economic progress, education and community life (Castle *et al.*, 1972). The farmers' decision-making process depends on the conditions of the farming environment and its relevancy to the existing problems. MacArthur (1980) described the operational problems and dilemmas faced by the farmer as problems of soil fertility, coping with risk and uncertainty, low labour productivity and problems of seasonality which can be reflected in the system of farming that they follow.

Modelling of farm structure and structural change at farm level by considering factors that were described above, the Structure, Conduct and Performance (SCP) concept that was adapted by Wossink (1993) can be adopted to draw the inter-relationships of factors that explain the decision-making process at farm level (*Figure 2.3*).

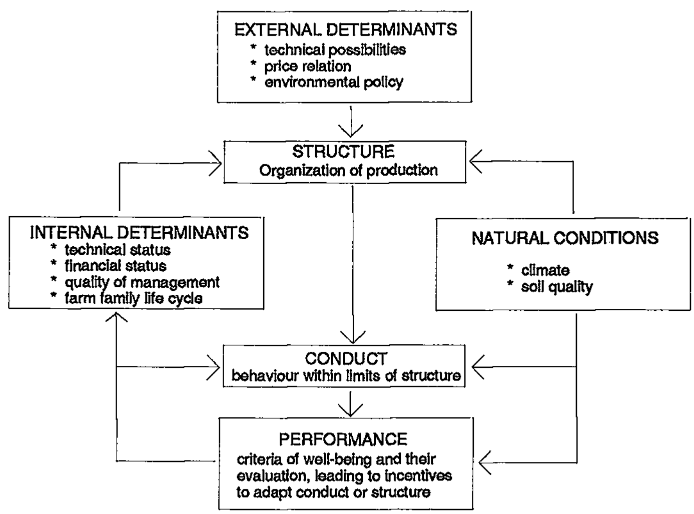

Figure 2.3 Farm structure and structural change at farm level.
(Source: Ada Wossink, Analysis of Future Agricultural Change, Ph.D. thesis, 1993)

As depicted in *Figure 2.3*, the interaction of the natural conditions, the technical and financial status of the farm, and the goals and objectives of farming with the prevailing external determinants gives the potential farm structure. Conduct, that is behaviour within the limits of structure, refers to the behavioural factors described previously. Performance implies an evaluation that can lead to incentives to adapt conduct or structure for the next decision-making process.

2.3.2 Adoption of technological innovation

The concept of the adoption of technological innovation or 'innovation' usually refers to the point in the innovation process where the user moves from not having the innovation to having it (Wolfe *et al.*, 1990; *see* Tornatzky et al., 1990). However, having an innovation can be defined in various ways, most simply it refers to the point of purchase of a technology (Wolfe et al., 1990), or it refers to some form of authoritative commitment (Lambright, 1980). The main difficulty in defining the term adoption is that the adoption process is often made up of a series, or even parallel sets, of decisions that are not visible to all participants. The key issue in the degree to which the conscious attention of the participants is brought to bear on the change.

Numerous definitions of technology can be found. A concise formulation is that technology 'is simply a body of knowledge about techniques' (Freeman, 1974). Another formulation that is described by Tornatzky *et al.* (1990), technologies are tools or tool systems by which one transforms parts of the environment, derived from human knowledge, to be used for human purposes. Innovation can be defined as the introduction of something new, or according to Rogers and Shoemaker (1971) is an idea, practice, or object perceived as new by an individual.

Based on these formulations, it could be stated that technological innovation involves the situationally new development and introduction of knowledge-derived tools, artifacts, and devices by which people extend and interact with their environment (Tornatzky *et al.*, 1990). In this formulation, certain characteristics of technologies can be identified (1) technologies are knowledge-based, or at least have embedded principles, (2) technologies are not purely physical artifacts, they are inseparable from their cultural and social settings; Technologies consist of knowledge about cause and effect relationships embedded into physical tools, combined with knowledge about how to use the tools, all of which is embedded in a social context, (3) technologies often have a social content; This kind of technology is a mixture of physical artifact and human behaviour patterns, some may be primarily the latter.

Concerning to the characteristics of technology that were described in section 2.2, another overview of technological innovation can be approached by an economic point of view. Innovation is virtually synonymous with technical change, which it refers to the first practical use of a new technique. A process innovation is one which changes amount, combination quality, or type of inputs required to produce the same kind output. The standard neoclassical approach to technical change treats it as exogenous to the economic system (Ellis, 1993). The technical change can be neutral or bias. Technical change bias can be identified according to whether the income share of a factor, like labour, decreases, stays the same or rises, for constant factor proportions. If the share of labour falls we have capital-biased or labour saving technical change, while if the income share of labour rises relative to that of capital, then it has labour-biased or capital saving technical change. If the income shares of factors stay the same, it has neutral technical change.

Bias in technical change can be illustrated in *Figure 2.4*, point A is the initial equilibrium representing efficiency of resource use for a given inverse factor-price ratio, r/w, which underlies the slope of the iso-cost line, P_1. At point A capital use is K_1 and labour use is L_1. The biased technical change results in a new equilibrium at point B for the same factor price ratio, involving a greater decline in labour use, from L_1 to L_2, than increase in capital use, from K_1 to K_2. This case is *labour-saving* technical change. An alternative expression of the bias of technical change is to consider the direction of change in relative factor price which would be required in order to maintain the same factor proportions (*L/K*) as before. Suppose constant factor proportions passing through *A* which joins together all points with the same *L/K* ratio. In order to to keep the same factor proportions with the new technology at point *C*, the price of labour (*w*) must fall relative to the price of capital (*r*), yielding a new iso-cost line P_2. This fall in the price of labour relative to capital reduces the share of labour, *wL*, in the total value of output for a given *L/K* ratio.

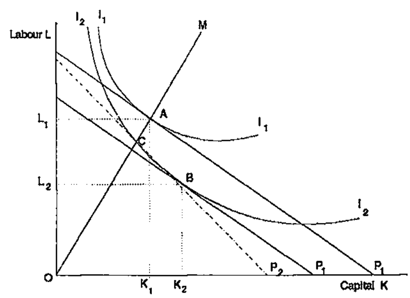

Figure 2.4 Bias in technical change

In the process of diffusion of innovation, time is an important consideration. According to Rogers (1971), the time dimension is involved: (1) in the innovation-decision process by which an individual passes from first knowledge of the innovation through its adoption or rejection; (2) in the innovativeness of the individual, that is, the relative earliness-lateness with which an individual adopts an innovation when compared with other members of his social system; and (3) in the innovation's rate of adoption in a social system, usually measured as the number of members of the system that adopt the innovation in a given time period.

For the innovation's rate of adoption, Rogers and Shoemaker (1971) concluded that rapid adoption probably depends on such aspects as relative advantage or economic profitability for most individuals. Meanwhile, Shultz (1964) argued that socio-cultural variables are important determinants of the rate of adoption of innovation amongst peasants in less developed countries. It is important to pay attention to the farmers' appreciation of innovation which always relates to his interests. For example, it can be said that "for the subsistence farmer, the average projected returns over a number of years are less important than the need to maintain a basic minimum production level in every season" (Gartforth, 1982). In the case of cocoa smallholder farmers, this farmer interest could be relevant only to the first two or three years of cocoa exploitation when their cocoa has not yet produced.

Having made the decision to adopt, one may say that implementation or application begins. Implementation is important because it is a crucial activity in the adoption innovation process (Fleischer and Roitman, 1990; *see* Tornatzky et al., 1990). After all, the science, invention, development, selling and adopting of the technology needs to be implemented. Implicit in the adoption decision is the fact that implementation occurs at individual and group level. Given the complexity of innovation implementation, Fleischer and Roitman (1990) found four perspectives on implementation namely: technocentric, sociocentric, conflict/bargaining and system design. The system design perspective is seemingly the most appropriate for technology implementation at farm level. This perspective emphasized the activities involved in (1) understanding the characteristics of the innovation in the context of both social and technical systems, (2) measuring the effectiveness of the implementation in term of the objective function, rather than in terms of just the technology or just the social system, (3) planning and pacing the implementation process, taking social, organizational and technical issues into account, (4) redesigning the organization, planning for boundary management; that is, movement of information and people across internal organizational boundaries, as well as external boundaries, and (5) modifying human resource development practices to support implementation, taking the interaction between social and technical systems into account.

Several important characteristics of innovations, as sensed by receivers, contributing to their different rate of adoption are:
(1) relative advantage - the degree to which an innovation is perceived better than the idea it supersedes;
(2) compatibility - the degree to which an innovation is perceived as being consistent with the existing values, past experiences and needs of receivers;
(3) complexity - the degree to which an innovation is perceived difficult to understand and to use. We can differentiate between the innovations that are readily understood and others that are not;
(4) trialability - the degree to which an innovation may be experimented with on a limited basis;
(5) observability - the degree to which the results of an innovation are visible to others. Such characteristics are relevant for technology applications of fertilizer, pesticides, herbicide and fermentation in cocoa exploitation.

To sum up, the farmers' behavioural decision-making process is determined by farmers' strategies as controllable factors and the farming environments as uncontrollable factors for reaching the farmers' outcomes. The farmers' strategies embody all the internal family and farming factors, which influence the farmers' decision-making [3]. Meanwhile, the environment factors are the external elements, which are received by the farmers in the form of information and innovation through the extension process or other communication channels. The farmers' outcomes are the resultant decision-making in choosing alternatives, and/or adopting or rejecting the innovation base on their knowledge and their problems. Having made the decision to adopt, an implementation step, that is the most crucial activity in adoption, begins.

[3] *The study will elaborate and examine these factors profoundly.*

2.4 Conclusion

The previous two chapters, the review of preceding cocoa studies and the theoretical framework, could be concluded into several main points as follows:

(1) Several previous studies proved that in comparison with certain other tree crops, cocoa is a profitable crop, which can improve farmers' household incomes and the economic development of the region. In the development of cocoa in certain regions, the role of migrants is important. Farm community, farm and farmer characteristics such as origin, ethnicity, access to sources of information, farm size and education, play important roles in association with cocoa technology adoption and application;
(2) Empirical evidence shows many variances of factors that contribute to the farmer behaviour in adopting and applying technology at a smallholder level. The main constraints for the farmers in adopting and applying certain technology are the ability to mobilize production factors, the availability of capital, access to production supply factors, risk absorption capacity and complexity of technology;
(3) Various factors that influence the decision-making process at farm level are physical environment, socio-economical environment (included political aspects), farmers' family and community, and production factors. Farmers' family and community, and production factors are internal or in other words strategies that relate closely with the problems the farmers are faced with;
(4) Decision-making can take place in various conditions such as, certainty, risk and uncertainty. Risk produces results that vary according to the environment which actually occurs. Uncertainty exists when the probability of the occurrence of the alternative outcomes is unknown;
(5) To facilitate decision-making, it is necessary to develop a model. The model can simplify and define how people make decisions. Organizational and rational decision-making perspectives are two characteristic models that are more suitable at farm management level. An organizational decision-making model emphasizes the centrality of routines and procedures in reducing the effect of uncertainty. A rational decision-making model is based consistently on the principle of economic rationality;
(6) The steps in the decision-making process are developing ideas and making observations, analyzing observations including formulation and reformulation of problems and ideas concerning their solution, decision-making, action and acceptance of responsibility for action;
(7) Three factors, knowledge, information and communication are important for the decision-making process. Knowledge arrives to receivers in the form of information. The availability of information is an essential factor which influences the completeness of decision-making;
(8) A generalized decision consists of the components of strategies and environments producing outcomes. Strategies are the arrangement of variables in the system that are entirely under the control of the decision maker. Environments are composed of uncontrollable factors in the system.

CHAPTER 3 RESEARCH MODEL AND HYPOTHESES

3.1 Introduction

The cocoa crop has dominated the farming system where it has been the main source of livelihood for almost all the farmers in the *Bupon* region, for at least the last fifteen years. In earlier years, farmers in the region were not yet familiar with this crop but now it has a certain superiority and advantage from the point of view of the farmers. Local farmers had have some experience in cultivating other crops, which could prove an asset in the further development of their business. After introducing the cocoa crop, and perceiving its successful use by other farmers, most farmers totally changed their exploitation activities. The opportunity the cocoa crop provides to earn a better income is apparently the most significant reason for farmers to adopt cocoa cultivation.

Although copying the successes of other farmers (Durand, 1991; Pomp, 1992) has motivated the farmers to develop and to exploit the cocoa crop, apparently the cocoa crop itself has certain advantages that strongly influence farmers' decision-making causing them to choose cocoa as the main activity in their farming business. The second part, section 3.2 of this chapter, deals with the description of the research region, in which the research site and the agronomic practices of cocoa plantation are described and reviewed. Several activities concerning to the technical cultivation practiced by farmers in the region are described in detail. The aim of this review is to identify its relation with the level of technological application. Several specific characteristics of the cocoa crop that can be advantageous or disadvantageous for farmers, if cocoa crops are chosen as the main farm activity, as well as providing some insight into the whole farm system of the region are also discribed in this section. The specific characteristics of cocoa together with other factors such as the suitability of agro-physical conditions, a favourable socio-economical environment, and farmer and farm characteristics are presumed to be associated with cocoa development in the region. In a relatively short time, about 15-20 years, the region has become the most potential area for cocoa exploitation. During this time, the farm system has totally changed to that of a dominant preference for cocoa farming. The presentation of the entire farming system aims to clarify the place of the sub-system of cocoa exploitation within the farming system of the region.

Considering all the elements that contributed to the operation of the farming system described previously, a general model of the farming and farmer's household system has been constructed to be the basis of a specific research model related to cocoa farm smallholders. This general model is presented in section 3.3, which is illustrated by a diagram of the farming and farmer's household system framework.

The factors to be formulated in the model of study will be described in detail in section 3.4. In the model constructed, farmer and farm characteristics and productivity which have been selected as independent variables will be explained, giving details of each variable. Several factors within independent variables, that appear to have close relations to each other since they emerge from a similar root of information, are considered for entry in the model. They have been chosen because these factors have specific characteristics which are possibly associated in the process of technology adoption. The model constructed is depicted by the diagram of the research model presenting two approaches to analysis, the positive and normative approaches that are expected to give an alternative solution in making use of cocoa technology available in the region. This last section will also deal with formulating the hypotheses of the study, preceded by the identification of several factors that are presumed to be the most significant variables associated with cocoa technology adoption by cocoa farmers.

3.2 Description of the research region

To acquire a comprehensive insight of research region conditions, in the next section the discussion will be focused on research-site conditions, the historical development of cocoa exploitation in the area, a description of the farming system of the region and a description of the farming system that is dominated by cocoa exploitation.

3.2.1 Research site

The *Bupon* region is located about 400 km to the North-East of Ujung Pandang, the capital of South-Sulawesi in Indonesia. It covers a widely fertile agricultural area that extends from the hills of *Latimojong* to the West down to the coast in the East. The total area of the region is about 360 km^2 that consists of about 38% of the agricultural area cultivated. About 55% of the area is covered by secondary and primary forest vegetation, located in the mountainous region in the West. In the agricultural area almost 50% or about 7,000 hectares are currently cocoa smallholder plantations, which are cultivated by both sole cropping and intercropping.

The site of the research located in *Luwu Regency* (*Appendix 3.1*). The reason for selecting this area is that this site is the earliest and the most widely developed cocoa area in South-Sulawesi and, as such, can represent cocoa exploitation in South-Sulawesi. The selection of South-Sulawesi as the region of study is based on the following reasons:

(1) On the whole, cocoa in this region is grown on smallholder farms, which is relevant for the objectives of this study.
(2) This region is the main cocoa producer in the area providing about 32 percent of the national cocoa production.
(3) This region was one of the earliest cocoa regions to be developed; and
(4) The study can use the data of a previous study that was carried out in the region as a secondary source of information. It is not necessary to carry out a survey to collect secondary information from a large farm population. This will avoid unnecessary time and expense.

At the sub-region level two villages with similar enviromental conditions, *Noling* and *Buntu Batu*, were chosen to represent the villages that had adopted cocoa technology to a greater, and respectively to a lesser, degree. The two villages were the first to develop cocoa in the region. Development of cocoa exploitation in the region was started from these two villages subsequently spreading to the other surrounding villages. Most of the initial generation of developed plants became sources for cocoa plantations in other villages. Moreover in 1992 these villages represented about 32 percent of total cocoa hectares and about 19% of the total production of the Bupon region. Ultimately, the two villages housed multi-ethnic inhabitants who were the pioneers of cocoa development in the region. More details on the agro-physical and socio-economical condition of the region studied are presented in *Appendix 3.1.*

3.2.2 The historical development and the agronomic overview of cocoa in the area

The historical development of cocoa in the region before this crop became the main source of income for the majority of the farming households can be traced back to the beginning of its development era at the end of the 70s (*see Appendix 3.2*). At that time, several elements together contributed to create favourable conditions for cocoa development. Dominant factors can be identified such as: (1) motivation and behaviour of pioneer farmers, both migrants and indigenous inhabitants, who showed an ability for hard work that exceeded the farmers of the other regions. They had already worked to establish their exploitation in jungle fields with a minimum of supporting facilities and poor infrastructure; (2) the behaviour of indigenous inhabitants that showed a welcome willing attitude when it came to receiving and sharing a part of their land with the new arrivals. The land is shared at the lowest price level, mostly it was for free due to a farmer giving up a traditional right to the land; (3) information and suggestions from extension workers and, moreover, the initial introduction of the cocoa crop by installing demonstration seedling plots which further became farmers' first sources of planting materials; and (4) the available market and the price development of cocoa that seemingly stimulated farmers to exploit this crop. Collectors and traders of agricultural products were ready to buy and promising interesting prices of cocoa beans in the villages.

At present, cocoa is cultivated widely using various techniques. It is cultivated by smallholders, either in large or small fields, sometimes even planted in families' backyards. It is also planted in various patterns of exploitation, through sole cropping which is practiced by the majority of farmers, or intercropping cocoa with other tree crops or annual food crops, which is performed by a small number of farmers. The sole cropping exploitation is generally found in new areas and at a higher level or upland and lowland area where cocoa is planted with or without the shade of trees.

To deal with the adoption of certain cocoa technologies, an intimate knowledge of cocoa cultivation is required. Therefore, the agronomic practices of cocoa farmers in the region are described to indicate appropriate levels of technology application. Mostly cocoa plantations in the region are being cultivated in an extensive way. However some farmers have attempted to cultivate and maintain their crop more intensively according to the technical agronomic practice recommended by extension agents. Differences in the application of technology has implications for the labour needed. The cultivation of cocoa in the region will be reviewed from several main aspects such as the suitability of agro-ecological conditions, plant material used and technical cultivation practiced, plantation maintenance and various pre-harvest, harvest and post harvest activities.

(a) The suitability of agro-ecological environment

By comparing the agro-ecological conditions required for a favourable growth of cocoa crop such as described previously (*see* the general introduction), the agro-ecological environment of the region under study (*Appendix 3.1)*, has apparently a suitable condition for cocoa growth. The climatic factors of rainfall, temperature, atmospheric humidity and light that affect directly the morphology, growth, fruiting and general well-being of the cocoa plant is in accordance with a favourable condition needed for the cocoa growth. Roughly, the region has suitable climatic characteristics forcocoa with the annual average rainfall of about 2700 mm, the average maximum and minimum annual temperature of about 32° and 23° C, the average humidity 80-90% and the light all along the year. The rainfall is almost distributed even throughout the year. Rainfall is the most important factor that affects the cocoa yield variation from year to year. Cocoa trees are very sensitive to a soil-water deficiency. In view of the annual rainfall, the water-deficiency of cocoa in the region is not a serious problem. The region has mainly alluvial and podzolic soil. This soil has a high level of fertility with a pH of 6.5-7.2; the top soil is about 0.5 to 1.0 m deep. Brownish and greyish alluvial, and brownish podzolic soil cover the more fertile low-land region. The former is the result of sedimentation process on the upland region. This soil condition is apparently suitable for the appropriate growth of cocoa and certain other tree crops. The different degrees of soil fertility subsequently influence the level of technology application.

(b) Planting material used and technical cultivation practiced

Before describing the agronomic treatment practiced by cocoa farmers in the region, it is necessary to review the original habitat of cocoa crop. All the species of the genus *Theobroma* are found wild in the rain forests of the western hemisphere from Mexico to the southern edge of the Amazon (Toxopeus, 1985; *see* Wood and Lass, 1985). In this habitat rainfall is heavy, the temperature is relatively uniform throughout the year, there is constant high humidity and the shade is dense. Several publications (Braudeau, 1969; Wood, 1985; Mossu, 1992) mentioned that this crop was initially brought into cultivation by the Aztecs and Mayas in Pre Colombian America. They cultivated cocoa in such a way that a cocoa field resembled the natural habitat. The worldwide spreading of cocoa proved that the habit of shading is a continuously reliable method of cocoa cultivation.

Planting materials. The widest type of cocoa cultivated in the region is the Amelonado, which belongs to Forastero group (Toxopeus, 1985). However, other types such as Angoleta and Calabacillo are also cultivated by certain farmers. The source of planting materials came mainly from a local plantation. The cocoa area that is planted with High Yielding Varieties (HYV) covered about 20% of total cocoa area. These planting materials were provided by the Regional Plantation Services in the form of Hybrid F1 seeds. They were first introduced in the region at 1979/1980. Unfortunately the number of seeds that could be provided every year is too limited. When the farmer's interest to cultivate cocoa increased remarkably a few years later, the seed requirements could not be fulfilled by plant material producers. This was to cause the farmers moving to search other alternatives for getting planting materials. The easiest way was to collect or purchase the seeds from their acquaintances or local farmers.

The seeds that were provided came from existant plantations that were planted with unknown (local) planting materials. Cocoa plantations in the region mostly use these planting materials. Although farmers know the advantages of cocoa hybrid planting materials, they cannot make use of the advantages since the limited supply of cocoa hybrid seeds. This problem is not only a local constraint. It has become a national constraint for most smallholding in expanding cocoa plantation. This is caused by the limited production capacity of the cocoa research station and large plantation enterprises that mainly produce cocoa HYV' seeds. If these seeds are available, small farmers who usually have a lack of capital, have a limited possibility to purchase it, since its price at the farmer level is high. The variety of planting materials used by farmers influences not only the plantation practices but also may provoke differences in quality and productivity.

Agronomic practices. Cultivation practiced by farmers varies from extensive to a more intensive one. Factors influencing the level of technical cultivation are possibly the level of technical knowledge, the experience of cocoa farmers, the level of financial and economic ability and the availability of family workforce. The development of the cocoa plantation starts by land clearing and preparing. Trees of primary or secondary forest are felled. It is then followed with the burning of shrubs and small tress. Farmers carry out these operations in the dry season one year before cocoa planting. Farmers with sufficient capital and family workforce or a previous annual crop experience, such as former tobacco farmers who usually come from the southern part of the region, carry out a tidier land preparation. However, the tree stumps and roots, particularly of large trees, are not removed become the shelter of rodents and other predators. Except for felling the large trees, the other operations are carried out by the manual tools which imply a high employment of workforce. At that time shade trees, either permanent or temporary shading, and annual crops are planted. As a permanent shading, most farmers planted *Gliricidia maculata* and *Sesbania sp*. Initially, the number of shade trees planted varies between 100 to 200 trees per hectare. While for temporary shading they plant bananas and sometimes cassava which are felled two to three years later when cocoa starts yielding. After two or three years all temporary shading trees are felled. In most cases farmers cultivate annual crops as interplanting with cocoa one year before until 2-3 years after cocoa planting, depending on the density and growth of cocoa. The annual crops cultivated are maize, paddy, tobacco, soybean, peanut and legumes. These annual crops become the source of revenue for the farmers before yielding cocoa starts.

In the stage of land preparation, farmers make planting holes for cocoa with the size 0.3 x 0.3 x 0.3 m deep for about 1000 trees per hectare and with a spacing about 3.0 x 3.0 m. A few farmers uses a more dense spacing (3.0 x 2.5 m), particularly on more fertile soil. At the beginning of the rain season, cocoa seedlings that are previously prepared in the nursery, are planted. The farmers who do not have a sufficient capital and many family workers, use a simple method. After burning the shrubs and wood that have been felled, farmers directly plant cocoa seedlings. Even certain farmers plant cocoa by sowing seed. The seeds, 1-2 seeds in group, are placed just under the surface of the soil. The latter is the method practiced by the majority of farmers at the beginning era of cocoa development when they still faced a capital problem and a lack of technical cultivation knowledge. For intercropping cocoa with coconut or other tree crops, a simpler operation is carried out. The land is prepared without felling the big trees, and the burning of shrubs is also avoided to eliminate its effect on the existant crops. The number of cocoa planted per hectare is also adjusted to the population of existant crops in the plot. In general, the cocoa population for intercropping plots accounts for less 1000 trees per hectare.

(c) Plantation maintenance

Perfect husbandry of the cocoa trees would provide optimal conditions for growth and yield at minimum cost: The cocoa trees would be regularly pruned for sanitary purposes and their structure controlled, shade trees would be correctly adjusted, weeds, pests and diseases would be effectively controlled and appropriate fertilizer would be applied.

Pruning cocoa trees and adjusting the shading. Particularly for maintaining a sound structure planting, cocoa trees in the region need a regular pruning since the climatic and soil conditions as were described previously allow continuous and fast cocoa growth. The fast vegetative growth could disturb the physiological process of the formation of the fruit if a part of leaves is not pruned. The ratio between the nitrogen supply to the tree and the carbohydrate reserves within the tree will determine the quantity of fruit which reaches maturity (Lass, 1985). The leaf area of the tree and the carbohydrate reserves stored within the hardened wood are the main factors, besides other external factors, that influence this condition. The maximum photosynthetic activity will occur when the maximum surface area of cocoa leaf per unit ground area is exposed to light (Lass, 1985). This is approached by farmers by cocoa pruning and shade tree adjusting. Farmers practice cocoa tree pruning in various manners, with regard to the frequency and the form of pruning, according to their ability and knowledge. The availability of family workforce and capital determine the frequency of pruning operation, while the quality of pruning operations depends on the farmers' technical knowledge.

Farmers following a more perfect treatment, practice three types of pruning. *First*, a formation pruning which is performed for young trees before maturity, usually at about one to two years old, in order to adjust of the height of the first jorquette and to control vertical growth. In this operation, farmers usually left 3-4 main branches for plantation with a more dense spacing and 5-6 branches for plantation with a less dense spacing. *Second*, a production pruning which is carried out for mature cocoa. This operation is carried out by farmers by various manners. Mostly, it is practiced once a year prior to the fertilizer application at the beginning of the wet season. However certain farmers with a more intensive plantation practice this 2 to 4 times a year. Farmers carry out pruning to form canopies too varied according to their experience and knowledge. Sometimes almost all the leaves are pruned, particularly for cocoa planted under coconut trees. This operation shows once more a lack of farmer's knowledge in performing a right pruning. Most farmers do not yet practice prunning accurately. Even cocoa plots exist that are not pruned regularly. The absence of pruning regularly has not only negative implications for these plots, since the humidity under cocoa trees is permanently high which facilitates the infections of diseases that are caused by *Phytophthora sp.*, but it also infects other plantations in the surrounding. *Third*, a maintenance or sanitation pruning which is usually carried out more frequently. A regular removal of unnecessary chupons, dead branches, dry and disease branches and shaded branches in the lower canopy are part of this operation. However, this operation is mostly carried out by diligent farmers who usually regularly visit their farm or those who have a sufficient labour.

Another effort of farmers in maintaining a continuous growth of their cocoa is the adjusting of shade trees. In this operation farmers do not yet use a chemical treatment like that has been practiced in certain other cocoa producing countries. The only one sort used is by hands and/or manual devices. The shade trees are usually pruned before the beginning of the wet season at the same time as the production pruning. The number of branches is reduced, even all shade trees are felled. The pruning is usually carried out once a year.

About 40% of mature cocoa area in the region is cultivated without using shade trees anymore. Another 40% of the area is used for *Gliricidia maculata* and *Sesbania sp.*, and about 20% has coconut and other fruit trees, which are cultivated as intercropping with cocoa, as shade trees. The climatic condition with the high rainfall causes the high proportion of cocoa plantation not having shade trees.

Soil maintenance. Various treatments are practiced by farmers to maintain the soil condition around the cocoa trees. Because of the differentiation of two main types of soil, alluvial and podzolic found at different sites, where the former is mainly found on the low-land and the latter on the upper-land of the region, the degree of soil fertility and the growth of cocoa of each region vary. The upland site that apparently has a less fertile area, has a less dense growth of cocoa canopy. By consequence, the growth of weeds on this area is also more rapid than on the low-land area. Weed control by using herbicides is chosen by many farmers. By using this treatment farmers could reduce maintenance costs spent. If farmers apply herbicides, they mostly use herbicides of glyphosate (marketed as Roundup) and paraquat (marketed as Gramoxone 20%). The dosage of herbicide used by the farmers varies, from the minimum application which was just 0.1 litre up to the maximum dosage of about 12 litres per ha, in 1993. More than 40% of farmers use the annual dosage of less than 2 litres per ha, while almost 20% applied more than 2 litres per ha. The weed control usually takes place at the beginning of dry season.

However, a few farmers without sufficient capital choose hand-weeding. This treatment is also used where the growth of weeds is not too dense. Another effort of farmers in maintaining the soil condition is by digging ditches between the rows of cocoa entering the old leaves with other green materials in the ditches and then bury it. By this, the process of the formation of organic materials takes place more rapidly, which could improve soil texture and fertility. However a disadvantage is that the soil surface under trees will be barer and is unprotected from water flow due to severe rainfall.

Mineral fertilizer. Sporadically, the application of chemical fertilizer for cocoa crop in the region has taken place at least since the beginning of cocoa development. However a regular application just took place since the last ten years. The problem faced, is the inaccurate application. Fertilizer is not buried but just spreads over the surface of the soil. This treatment is less effective since a part of fertilizer washes away when it rains after fertilization or if it does not rain the nitrogen in the fertilizer evaporates into the air. These farmers, think that the application of fertilizer for cocoa should be done in the same way as it is usually applied on a wet paddy, where fertilizer is only spread over soil surface. The mis-application of fertilizing is apparently caused by the lack of technical knowledge and the willingness of farmers to reduce the employment of labour. Besides this problem, the factor of the price of fertilizer also could be a constraint in the application of fertilizer. When the price of fertilizer increased, as it happened in 1992, farmers have a propensity to reduce the volume of fertilizer used. Several other factors that become constraints in application of fertilizer in the region are the limited availability of salaried labour at the time of fertilizing, the availability of fertilizer, the propensity of farmers to purchase fertilizer by a credit system although they are able to purchase by a cash payment, and the lack of economic infrastructure (*i.e.* roads) in farming surroundings.

The types of chemical fertilizer that are usually applied are Urea and ZA for Nitrogen, TSP for Phosphorus and KCL for Potassium mineral contents. Certain other farmers usually use liquid fertilizer. Most farmers still use fertilizer less than the dosage recommended. General recommendations for mature cocoa from the Regional Plantation Services for producing one tonne of dry cocoa beans are 220-330, 180-260 and 179-260 grams for Nitrogen, Phosphorus and Potassium minerals respectively per tree of mature cocoa per year. These recommendations are too general and less suitable for certain regions with a high soil fertility. Plantations with and without shade trees are also still recommended by the same dosage. The evidence shows that by using fertilizer with a lower volume than the dosage recommended, many farmers could attain a production level more than one tonne. In 1993, the minimum fertilizer application was about 50 kg per ha and the maximum was 2 tonnes. About 60% of farmers used a dosage of less than 500 kg, while almost 30% used more than 500 kg per ha.

Plant protection. The favourable habitat of the region that allows growth of cocoa, is also a convenient condition for proliferating of many insects and diseases which to a certain degree can damage and reduce the cocoa production. Apparently farmers are aware of this evidence as can be indicated by their high attention to plant protection activity. However farmers make many mistakes in using pesticide and control methods. The application of appropriate pesticides for certain insects and diseases is still performed inaccurately, therefore it still needs improvement. The kind of pests and diseases that are usually found in the region are mainly caused by Rodents, *Helopeltis sp*. and *Phytophthora sp*. Fortunately, so far the cocoa pod borer (*cocoa moth*) is not yet found seriously in the region. The application of an excessive quantity of pesticide is another serious problem. It may affect the degradation of sustainable environmental development and make insects increasingly resistant. The maximum dosage of pesticide used is about 12.75 litres per ha. About 35% of farmers in 1993 used pesticides with a dosage of more than 2 litres per ha. Besides the propensity of the excessive use of pesticides, other problems faced by farmers in the plant protection operation are: (1) the lack of farmer's technical knowledge of plant protection; (2) the limited availability of labour in the market to carry out pest control regularly being a main problem for farmers with a large cocoa area; (3) a large number of pesticide brands marketed (almost 20 brands are available in the local market[4]) with a varying quality; (4) the price of pesticide

[4] *The kinds of pesticides marketed are too varied such as Organochlorines (i.e. Dieldrin, Aldrin, etc.), Organophosphates (i.e. Basudin, Dusban, Azodrin, etc.), Carbamates (i.e. Sevin) and Pyrethrins (i.e.*

marketed tends to increase from time to time; (5) the unwillingness of farmers to invest their capital to purchase appropriate sprayer tools for their mature cocoa [5]; and (6) the lack of economic infrastructure particularly for the upland region causing a difficulty to carry out pest and disease controls.

(d) Harvest and post harvest activities

The peak season of cocoa harvesting in the region usually takes place from March to August. For the farmers who cultivate local planting materials, the harvesting takes 2-3 months. For those who cultivate HYV planting materials, it takes 6-7 months, and for those who maintain their cocoa perfectly can harvest all along the year. However this harvesting period is shorter if the climatic condition in the preceding year is less normal. The level of production is determined significantly by a climatic condition. The harvesting takes place every 10 or 15 days. Farmers with a large cocoa area exploited usually employ a salaried workforce to supplement the family workforce. During the harvesting season a daily wage of labour increases about 10-20% compared to the off-harvesting period.

Normally cocoa pods are harvested when they have attained full maturity. However some farmers harvest earlier in order to get cash money immediately. The beans are directly separated from the pods and then transported to the home. The beans that will not be fermented are dried directly. The time for drying varies, one to five days depending on the farmers' requirement of cash money and price offered by collectors. The beans to be fermented are put into wooden boxes or baskets. Although fermentation can be performed by using cheap materials, there remain many farmers who are not interested in fermenting their cocoa. Fermentation takes place 3-7 days, depending on the variety. The beans are turned over every 24 hours to obtain an evenly cocoa-fermented spread. The beans then are dried for a few days as mentioned above. Farmers' decision to ferment or not is apparently determined by the price offered by traders. If the price of fermented cocoa is significantly different from the unfermented cocoa price, farmers usually decide to ferment. For the last five years there was a very limited number of farmers that applied fermentation. This causes low qualities of cocoa produced in the region. The requirement of cash money immediately on the one side and a less interesting price preference offered by collector and/or trader on the other side make the most farmers prefer not to ferment their cocoa.

To sum up, the technical operations of cocoa development in the region as described above show from the agronomic point of view several weakness and imperfect technical operations, such as (1) mostly planting materials used are non HYV planting materials; (2) agronomic practices are mainly still conducted extensively; (3) inaccurate practices of pruning; (4) inaccurate application of production inputs, and (5) inaccurate harvest practices and a low application of fermentation causes a low quality of cocoa. These are caused by two main

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Decis). Even DDT that did not recommended anymore is still available in the local market.

[5] *Mostly the age of cocoa in the region has been more ten years old where pesticide treatments by using a hand sprayer for such plantation are not effective anymore.*

factors. *Firstly*, a part of farmers still lacks technical knowledge of cocoa maintenance. *Secondly*, in order to save on labour and costs, farmers apply less perfect maintenance and post-harvest treatments even if this implies a lower quantity and quality of cocoa production.

3.2.3 Elements of the farming system of the region

In describing the research area, those elements that compose the farming system (Fresco, 1988) in the region should be identified firstly. The identification should be more specifically focused on aspects that are associated with the development of the sub-region where the cocoa crop dominates almost all farmers' activities. If the system that characterizes the region is divided into several elements, a group of elements comprises environmental or external elements which are considered as given elements. However, these external elements must be systematized to provide an overall insight into the system in the region.

Based on the agro-bio-physical environment and agro-socio-economic conditions of the region, the system of the region can be classified according to the different elements that draw the sub-systems. Suppose the region is presented in the agro-physical and vegetation environment (*Figure 3.1*), and it is cut across from west to east (*Figure 3.2*), then the differences in bio-physical characteristics of the region can be clearly exhibited.

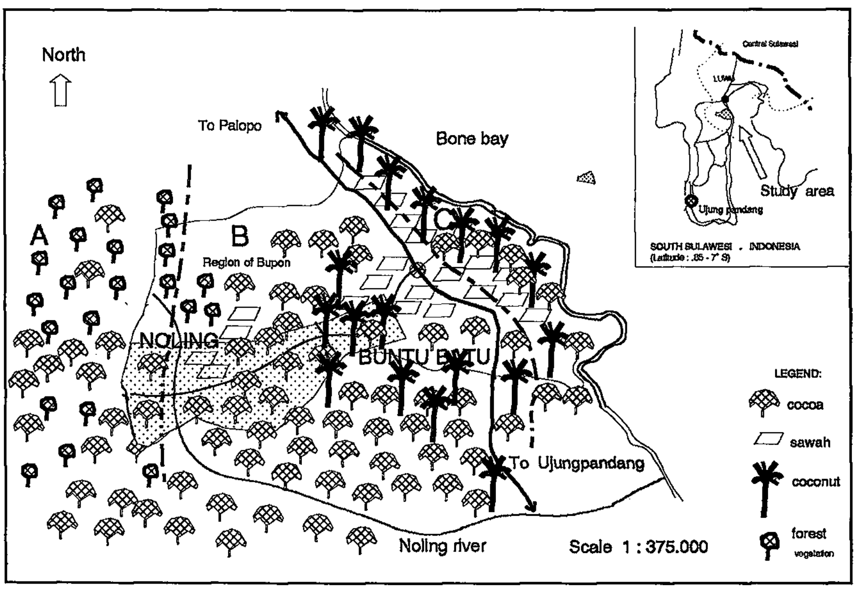


Figure 3.1 Differences of vegetation of each sub system of Bupon Region, South-Sulawesi

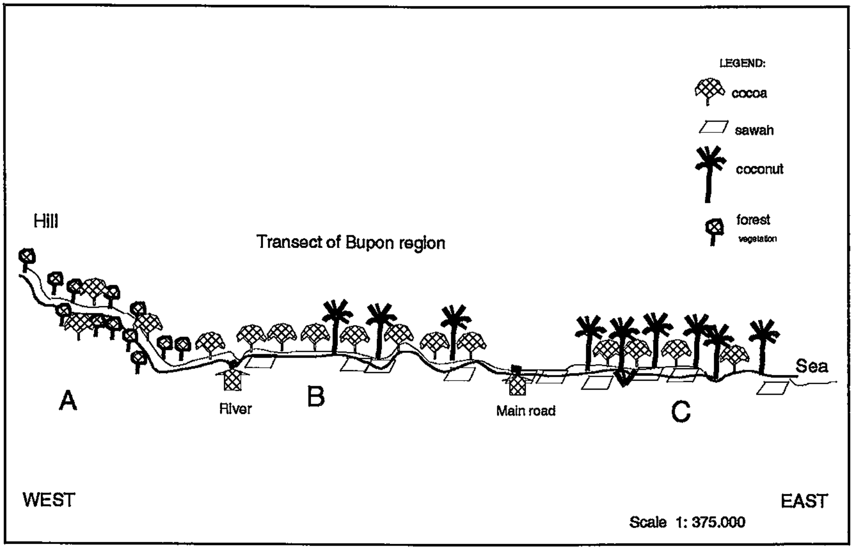


Figure 3.2 Transect from west to east of Bupon region, South-Sulawesi

The differences also generate a tendency to differentiate between other elements such as agro-economical and socio-economical environments. The differences and similarities of such elements determine the decomposition of the farming system of the region into three sub-systems, namely Sub System A (upland), B (upland and lowland) and C (lowland closer to coast). The decomposition into the sub-systems mentioned could be represented as three different pictures of vegetation, which are supplemented by the detailed elements of each sub-system, as exhibited in Table 3.1.

The picture presented shows the main vegetation that characterizes each sub-region, where Sub Region A, upland, is dominated by forest vegetation and infiltrated by cocoa crop expansion, Sub Region B is dominated by cocoa cropping mixed into wet rice land (*sawah*) and tree crops such as coconuts and fruit trees, and Sub Region C is dominated by sawah, coconuts, cocoa, fish-pond and coast plants.

As can be seen in Table 3.1, Sub System A is the sub-region that is located in the Western part of the region. This sub-region is characterized by agro-forestry vegetation which covers most of the mountain and upland region. The region is still lacking in agro-economic and socio-economic development, it has a low population density, poor socio-economic infra-structure and lack of access to development agents, except natural resources. However, this region has been infiltrated by the expansion of cocoa plantations, which are generally cultivated extensively. Since the available land in the lower region cannot fulfil farmer's land requirements anymore, this sub-region has become the easier alternative region when farmers wish to expand their cocoa exploitation. From the point of view of agricultural development, this region could be identified as the less developed region.

Sub System B is more developed and characterized by vegetation that consists of perennial crops intersected by annual crops. Specifically, this sub-region has a crop pattern dominated by cocoa cropping and is cultivated using both sole cropping and intercropping systems. Socio and economic infrastructures are more developed, access to market and capital is more advanced and a dense population dominated by migrant inhabitants is socially and economically more developed.

Description of elements	Sub System A	B	C
1. Sub region	. Mountain to upland	. Upland to lowland	. Lowland
2. Topography	. Hill	. Hill to flat	. Flat
3. Altitude	. > 100 m	. ± 2 m - 100 m	. < ± 2 m
4. Soil			
- types	. Yellow podzolic to brown	. Brownish alluvial and podzolic	. Greyish alluvial
- pH	. 4 to 5.5	. 6.5 to 7.2	. 7.2 to 7.9
5. Climate	. per-humid lowland tropical climate	. per-humid lowland tropical climate	. per-humid lowland tropical climate
- rainfall	. > 2700 mm	. > 2700 mm	. > 2700 mm
6. Vegetation			
- dominated	. by primary and secondary forest	. by Cocoa	. by Sawah and fish-pond
- others	. Cocoa, other tree crops, upland annual crop, unexploited shrub.	. Other tree crops, sawah, other annual crops, unexploited shrub.	. Coconut, cocoa, coast plants, unexploited swamp.
7. Crop pattern	. Sole cropping cocoa . Annual crops under young cocoa	. Sole cropping cocoa, . Intercropping cocoa with coconut or other tree crops	. Intercropping cocoa with coconuts
8. Cocoa prod./ha	. Low	. Mediocre to high	. Mediocre
9. Available land	. Available	. Saturated	. Saturated
10. Water sources	. Rain	. Irrigation, rain	. Irrigation, rain
11. Population	. Low dense	. Dense	. Dense
dominated by	. Indigenous	. Arrival	. Indigenous
12. Economic infra structure	. Minimum	. Mediocre	. Mediocre
13. Access to market	. Bad	. Good	. Good
14. Available inputs	. Far	. Close by	. Close by
15. Extension service	. Far	. Close by	. Close by

3.1 Comparison of several main elements of the agro-physical and socio-economical environment in the farming system of the Bupon region, South-Sulawesi, Indonesia (Source: Primary and Secondary data)

The last is Sub System C which in certain ways shows similarities with Sub System B, such as the socio-economic elements and the physical environment. The differentiation between the two sub-systems lies in the agro-ecological elements, such as vegetation and crop patterns. Sub System C is dominated by *sawah* and fish-pond, followed by coconut, cocoa and coast plants. The population is dominated by indigenous inhabitants.

In general each sub system has different characteristics. An exception can be found only in the climate which is identical for sub regions. Sub-System B, which characterizes the region studied, shows several favourable elements that allow and support the development of cocoa exploitation. The agro-physical and socio-economical environment, such as (1) the suitability of the soil condition, (2) the climate, (3) the availability of economic infrastructures which are relatively more available than in other regions, and (4) the facility of access to market and production inputs are the external elements that together with other factors determine the growth of agricultural development and farm activity, particularly cocoa development in the region.

3.2.4 Farming system dominated by cocoa exploitation

However, the development of cocoa exploitation does not only depend on the suitability and the favourability of external conditions. Apparently, from the farmers' point of view, the cocoa crop has certain advantages over other crops that have been developed previously. Several previous studies (Durand, 1991; Pomp, 1994; Jamal and Pomp, 1993) have pointed out the attractiveness of this crop for farmers. The dynamism of *Bugis* migrants (Ruf, 1993) and the availability of land are the main factors that dominated the acceleration of cocoa development (Durand, 1991). Pomp (1994) also concluded that compared with the food crops non-*sawah* and coconut, cocoa is a profitable crop. It is necessary to elaborate on the characteristics of the cocoa crop, both its advantages, which are presumed to stimulate cocoa development, and its disadvantages, which can become obstacles for cocoa development.

Before describing the advantages of cocoa, one can identify several factors that could impede the development of cocoa exploitation in producing cocoa beans with a high enough quality to be highly competitive in international markets. These factors are:

(1) Cocoa needs relatively fertile soil types with rich nutrient minerals, and which have a good structure and texture for enhancing growth. It differs somewhat from other perennial crops such as coconut and cashew which do not necessitate such a high level of soil fertility. For the cocoa crop the level of soil fertility is an important factor that must be considered to ensure a yield of good quality cocoa;

(2) This crop is susceptible to attack by certain pests and diseases. The cocoa pod borer (*cocoa moth*), for example, although for certain regions its attacks have been very limited (Entwistle, 1985, *see* Wood and Lass, 1985), it is still a pest in Sulawesi. The cocoa moth is the pest that always arouses anxiety amongst most of the farmers and the government plantation services since the damage, caused can reduce cocoa production to its lowest level, causing serious damage, and could reduce cocoa production to the 80-90 percent level. The problem is that up to now no effective control for this pest has yet been found except by interrupting the life cycle of the insects (*Conopomorpha cramerella*) that have been responsible for the attacks.

(3) The activity required to manage this crop is very much varied, for both young and mature plants: maintaining, clearing, pruning, fertilizing, pest and disease control and harvesting, then post-harvest activities such as peeling, fermenting, drying, transporting and packing. All of that demands much more labour compared with other perennial crop activities. The annual labour demand for adult cocoa plants is higher than other tree crops such as coconut, rubber, oil-palm, coffee and cloves. This highlights a subsequent implication that the annual exploitation costs of cocoa crops are higher than the other perennial crops mentioned.

(4) Like other material base products, particularly perennial crop products, cocoa tends to be subject to price fluctuations. Fluctuations in cocoa prices are the main obstacle for farmers in arranging the planning of farm investment and development, or for purchasing production inputs as prices tend to increase from day to day. Smaller farmers have difficulty in anticipating this fluctuation since their cocoa must be sold immediately after harvesting while the prices are still on the decrease. Larger farmers usually wait for the price to go up again.

Besides the disadvantageous factors mentioned above, which can constrain cocoa development, this crop also has several advantages that make it attractive. The latter are the characteristics that are rarely found in other tree crops. Several advantages of the cocoa crop are:

(1) This crop gives relatively quick yields, therefore the investment period before harvesting is also shorter than other tree crops such as coconuts, rubber, oil palm and cloves, which need 6-8, 6, 4 and 8 years respectively to reach the first production. The first production may be harvested after 3-4 years if cocoa is based on local plant materials, only 2-3 years if cocoa is based on hybrid (F1) plant materials.

(2) Cocoa can be cultivated together with other perennial or annual crops in a mixed-cropping or intercropping system. Then, in using these systems other products can be harvested which can be consumed directly or contribute additional revenues. Even after the first 2-3 years of plantation, the annual food crops cultivated as intercrops amongst cocoa plants became the main source of farmers' income. When, for example, farmers' land has been cultivated previously for coconut or fruit trees it is not necessary to cut down the existing plants to plant cocoa. However, the new cocoa plants are only planted between coconut or other crop rows so, farmers' land can be used more efficiently.

(3) Another specific characteristic that differentiates this crop from other perennial crops is that when it starts producing, harvesting can be performed periodically over a long period, twice or three times a month the whole year through for hybrid varieties, and over four to six months for local types. This characteristic is a significant condition for farmers, particularly small farmers, since it can improve a farmer's cash flow, whereas harvesting usually occurs only once a year when they exploit cloves or other tree crops.

(4) Although cocoa exploitation needs relatively higher initial investment costs, this crop can produce a higher revenue compared to other tree crops. This reality is the main reason for farmers picking cocoa exploitation as their first alternative when choosing a perennial crop. All of its production must be sold so farmers always receive cash payment which are used

to pay expenses for farm equipment and family requirements.

(5) Cocoa products can be stocked for a longer period of time before being sold. When the post-harvest activities are performed perfectly, such as harvesting the pods at the right time and obtaining the right quality, fermenting and drying in sufficient time, then cocoa beans can be stored for one to two years. However, in daily practice' stocking cocoa beans is difficult, particularly for small-scale farmers who exploit a small number of hectares since their necessity for cash to meet family expenses like education fees for their children or other daily expenses must be realized immediately.

(6) Another characteristic that helps cocoa to play its own specific role amongst the trading of agricultural products is its strong international market dependency which is different from several traditional agricultural products that have been known in the region. Hence cocoa activities, both exploitation and post-harvest activity, involve many actors, either farmers themselves, other personal and/or institutional traders and supporting institutions, which all have a stake in the cocoa business in the region, and promote its development as well as other businesses concerned with the agricultural sector in the region.

However, cocoa development in the region still appears to be facing various constraints and problems which presumably do not efficiently support development of the cocoa crop and could even impede the development of its exploitation. These problems are regional conditions, exploitation and cocoa plant conditions, which to a certain degree possibly constrain the technology adoption process. These conditions can be identified as follows:

(1) Farmers who are involved in the cocoa business in the region originate from various different backgrounds and origins. Previously, this region was seemingly a stagnant development area that was further established by migrants from other regions and by indigenous farmers, who had different backgrounds and experience. This diversity in the access to natural and capital resources and even to human resources provided some with greater opportunities than others. Different backgrounds accompanied by different motivations and appreciation of technology applications possibly caused a varied performance in cocoa development.

(2) Seemingly, farmers' technical knowledge about cocoa production itself generally remains imperfect, which implies a less efficient use and application of the available cocoa technology. Due to the limited availability of technology and the limited capital resources for purchasing production inputs, the efficient use of technology became important.

(3) Most of the cocoa smallholder plantations that are cultivated in the region are based on traditional planting material that harbour several weaknesses and have a limited production performance. Sometimes plantations with such conditions have not responded sufficiently to the use of production inputs, for example, although farmers sometimes used fertilizer, production persisted at a low level. This result should be different on plantations that use hybrid plant materials where every additional production input tends to increase production.

(4) The cocoa region area is not supported by appropriate facilities and infrastructures. Lack

of transportation facilities, for example, may hamper the difficult process of fertilizer application. Even if they do use fertilizer the benefits may not warrant the cost.

(5) The limited presence of institutional support is another problem faced by farmers. The remarkable development of the cocoa area necessitated improving technical economic treatment by technical and economic support-services like institutional research, extension workers, institutional marketing of production inputs and output. Where there is a lack of supporting institutions, cocoa exploitation in the region tends to develop inefficiently.

The interaction of the specific cocoa characteristics mentioned above, both advantages and disadvantages, and the existing cocoa development problems, result in interaction remaining in a powerfully positive direction which creates favourable conditions to support a farmers' interest in cultivating cocoa crops in the region. Subsequently, it points the way to the possibility of using various available technologies. Apparently, the successful cocoa exploitation has favourably affected farmers' social and economic conditions which, after a relatively short period, could encourage farmers to allocate certain amounts of their revenue to purchasing production inputs. Because the land possessed by farmers fits the minimal condition requirement for cocoa growing, farmers tend to choose this crop as the first alternative to be cultivated. This preference can be seen particularly in the South-Sulawesi region, at least over the last ten to fifteen years, which could be termed a cocoa-boom era.

3.3 General model

Most of the elements that have been discussed above could be identified as farming environmental factors that influenced the operating of the system. Several other factors are farmers' strategies and the availability of technology. To draw the influence of enviromental factors on farmers and farming activities, and its relation with technical production activities, a general model may be depicted as in Figure 3.3. The diagram depicts clearly that environmental factors both agro-physical and socio-economic could influence farmer's household and farming activities, farmer's objectives, technical production operations and even farmer's revenues. In the technical production operation, which is defined as the activities of production process that make use of farmer resources, production inputs and/or available technologies to produce a certain crop, farmers usually attempt to manage their farm production activities by choosing the most profitable combination of resources and available technologies. However, in certain conditions farmers do not use certain production inputs and/or available technologies. Farmers usually have a reason for applying or failing to apply the technology.

However, within the development of agriculture, particularly the development of cocoa in the region, farmers' different development levels can be met. Although they initiated their cocoa business in a similar way and under similar conditions in the course of development, the farmers have achieved different successes which could indicate their different abilities and behaviour in allocating and making use of resources owned and overcoming the constraints they faced. Certain farmers were successful in the improvement of exploitation and improving their families' living standard, there are usually identified as adopter farmers, meanwhile, certain others did not make significant progress.

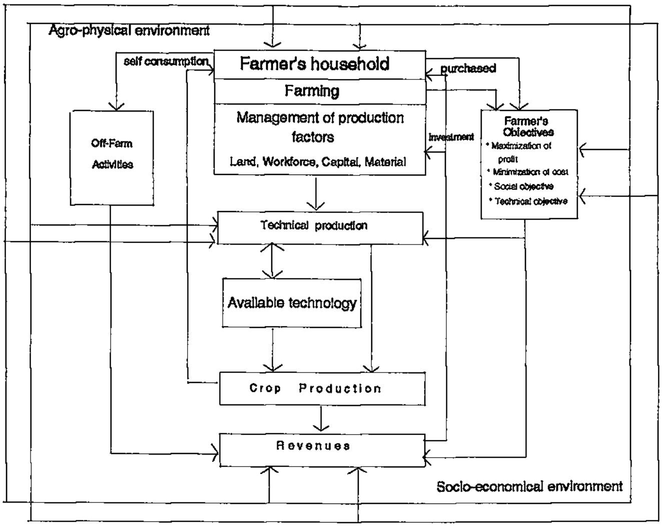


Figure 3.3 The farming and farmer's household system framework

The farmers who exploit cocoa, food crops and/or other tree crops (coconut, fruits), generally consume a part or all of the food crop production. However, in the case of the farmers who only exploit cocoa, all production is sold. Farmer revenues that are the result of farmer-objective implementation, which consist of on-farm and off-farm revenues, are mainly spent on purchasing household requirements and a farm investment.

When the farming environment, which is defined as an uncontrollable factor is presumed as a factor in a stable condition and availabilities of technology are given, then the farmers' strategies that compose farmers and farming characteristics are the factors that are convenient to be subsequently investigated for understanding what the most dominant factors affecting the operating of the system may be. Based on this assumption a specific model will be developed in the next section.

3.4 Research model and hypotheses

If farmers are assumed to operate under stable external factors, then the differences and variations in the farmers development, as mentioned earlier, depend mainly on the decision-making of farmers themselves and their performance. Farmers' behavioural decision-making is determined by the farmers' strategies, related to the characteristics of farmers, characteristics of farmers' households (Reijntjes *et al.*, 1992), farm characteristics, farm productivity (MacArthur, 1980) and even the farmers' community (Feil, 1991; Reijntjes *et al.*, 1992) in which the farmers operate.

As was stated previously, a perfect model shows a close similarity to the actual situation. In fact, it is difficult to reflect the situation of such complex systems as small-scale farmers or farming households completely. In order to incorporate as many influencing factors as possible and to provide a detailed insight into the actual situation several aspects should be taken into consideration (Ruthenberg, 1985; Ströbel, 1990), such as objective function of farmers which can be described by different degrees of objective rationality, supply function and division of activity amongst the members of family, economic performance of farmers' households, farmers and farming characteristics and conditions. This study will pay attention to the specific issue of cocoa smallholder farmers and their problems in adopting and applying certain available technology. The focus will be on the investigation on certain elements mentioned previously. The issues considered are all aspects related to support mechanisms, conditions and problems that constrain the cocoa farmers in achieving their objectives. The elements of the model, objective-function, data, exogenous and endogenous variables will be elaborated on more specifically.

3.4.1 Dependent variables

To exploit the cocoa crop well and to produce good cocoa beans a farmer adopts and applies several kinds of technology both pre-harvest and post-harvest *i.e.* land clearing, land preparation, selecting and treatment of plant materials, technical culture application, production inputs application, processing and other post-harvest activities' treatment. Adoptions of several pre-harvest technologies viz. the application of fertilizer, pesticide and herbicide, and adoption of post-harvest technology which is in the form of application of fermentation-processing are the dependent variables in this study.

Fertilizer application: Fertilizer application is a significant required treatment to increase, or at least to maintain, the production at certain levels. The application of fertilizer is a technology that is recommended for the cocoa crop by research stations or extension services. The amounts and kinds of fertilizer recommended for each application depend on various factors such as location, age of plants and variety. Chemical fertilizers are composed of either Nitrogen, Phosphor, Potassium minerals or a mixture of all three.

Pesticide application: Pesticide application is a part of integrated pest management control for a cocoa crop. It is another significant treatment that is still recommended to farmers on certain level and condition. Pesticides can be used in a preventive or curative way. The kinds and amount of pesticide applied depend on many factors and conditions, *i.e.* the age and condition of the plants, the kinds of pests and diseases, and the level of damage to plants. Nowadays the integrated pest management approach is recommended. This means that pesticide is integrated with other pest control techniques.

Herbicide application: Herbicide application is recommended under certain conditions. The use of herbicide is to facilitate weed control in land clearance for young and adult cocoa. The kinds and amounts recommended depend on certain conditions, such as weed and herb growth and weed species.

Fermentation application: Fermentation application is the processing technology that is recommended to cocoa farmers for the purpose of increasing the quality of cocoa products to certain levels that fulfils international standards. A good quality of the cocoa beans can be reached by improving several factors such as the maturity of the pods harvested, fermentation treatment, the time of drying and storing. However, the most critical stage of the whole process of cocoa quality improvement is the fermentation application. The fermentation treatment is performed by putting cocoa beans that have been separated from their pods into closed wood (or other materials) boxes for three to seven days, depending on their varieties. The beans are turned over every 24 hours to obtain an evenly cocoa-fermented spread.

3.4.2 Independent variables

In this study four main groups of independent variables that are expected to affect technology adoption and application have been selected. Most of these independent variables had been examined in preceding studies and are re-examined in this study. However, some other variables have, seemingly, not yet been examined in other studies such as the number of neighbours known intimately and annual crop area exploited. The conditions under which cocoa farmers work and their behaviour, in particular the application of available technology, have been outlined. Various factors that influence farmers in their decision to adopt or not to adopt a technology have been also described. These conditions and factors should be summarized in order to provide an integrated insight in formulating the hypotheses of the study, such as follows.

(1) The differentiation within the farmers' community which is due to farmers' different origins which are either migrant or indigenous, results in different access levels to natural and capital resources. This results in different opportunities and facilities for making use of the available technology.

(2) The main problems faced by cocoa smallholders are low levels of production, an enormous variation in the levels of production and a low quality of cocoa yield on the one hand, and the need of farmers in using production inputs and other technology within limited conditions, such as a limited number of family workforce, on the other hand. These conditions lead farmers to operate their cocoa exploitation according to their resources owned and their knowledge.

(3) Farm characteristics such as the size of exploitation, the level of farm diversification with other crops and farm gross output determine the use of technology and resources. The tendency is that smaller farmers use a high quantity of a certain technology to reach the highest possible level of production, although in less efficient application. Other problems are fragmented, dispersed and distant plots. The application of production inputs on such plots is hard due to the limited supporting facilities and infrastructures.

(4) Mostly, cocoa smallholders have limited education. A low level of education determines farmer appreciation in grasping technology application. Lack of knowledge about technical applications affects this application. It further implies that applications are used less efficiently.

Referring to the theoretical framework (Section 2.2) and based on the specific problems identified previously, five main groups of independent variables and seven hypotheses are presented and formulated below.

1) Farmers' community elements

Factors that establish the social environment of the farmer (either social, economic or network relations) may well affect the level of technology adoption. In the farmers' community several elements can be expected to affect technology adoption, and production input and fermentation application. The more a farmer is embedded in his social environment, the more interactions between farmers will take place. This provides an opportunity to exchange beneficial or useful experiences as well as to exert influence on group members' behaviour and norms (Van de Ban and Hawkins, 1988). This mechanism can function on neighbourhood communities as well as at the level of ethnical group, and at village levels.

The smallest communal society, the neighbourhood community is usually a medium where the exchange of information occurs easily and frequently. Particularly in a traditional community where members have close relationships, the spreading of information can take place in an easier way. Farmers who have no access to a formal source of information, *i.e.* extension workers, can obtain the information needed from their acquaintances in the neighbourhood community. The importance of the small group, like a neighbourhood community, lies in reciprocal obligations of the type just discussed, but, quite apart from this, it seems to provide a gratifying framework within which to work (Foster, 1965).

Another community element is an ethnical group. Members of an ethnical group usually have a similar cultural background and behavioural attitude. A kin-relationship which fosters reciprocal responsibilities for services and support amongst members of group provides the means to mobilize capital and incur the risks (Berry, 1975) in adopting a certain technology. Because of the close relationship, the exchange information and the transferring of technology amongst the group can take place easier. Factors that establish a village, either social, economic or network relations in which the farmers operate, encounter and affect technology adoption. Compared with migrant farmers, indigenous farmers tend to be less adoptive since they show traditional farmer behaviour (Taher, 1990). These two variables, *the origin of farmers (1)* and *the number of neighbours known intimately (2)*, are included in the model. The following can be hypothesized:

Hypothesis 1 The migrant farmers have shown a more advanced level of development than the indigenous farmers. Therefore it is presumed that migrant farmers have a higher rate of technology adoption than indigenous farmers.

Hypothesis 2 Neighbourhood communities of cocoa farmers can be a media for farmers to exchange and/or transfer information and technology. It is presumed that the number of neighbours that are known intimately has positive relationships with the technology adoption, and the use of production inputs and fermentation.

2) Farmers' characteristics

Farmers' characteristics can affect technology adoption and application by cocoa farmers. Potential farmers' characteristics affecting both pre-harvest and post-harvest technology adoption and application are the education level of farmers, experience, cosmopolitanism, motivation and the age of farmers. Years in education is expected to be the most powerful factor amongst farmers' characteristics that may facilitate the adoption and the use of technology. Education may help motivate farmers towards change, teach farmers to improve decision-making processes and provide farmers with technical and practical information (Norton and Alawang, 1993). Better educated farmers will have a higher level of knowledge regarding all cocoa technology application since normally these methods are taught at school. Moreover, educated farmers seem to gain more knowledge through contact with the extension workers since they are capable of learning fast, they can read and understand farm information better than other farmers (Boahene, 1993).

The preceding experience of farmers can also determine technology adoption and application. Farmers, with more years of experience in cocoa exploitation have the experience to apply a more appropriate level of production inputs and other technologies than those who became involved in the cocoa business later. The level of farmer visits to urban centres or farmers' mobility is presumed to affect farmer behaviour in technology adoption. It is presumed that farmers with higher mobility and farmers who have taken trips to towns frequently will obtain much more information about cocoa technology through their contacts with other more competent persons in the area of cocoa technology. Different farmer motivations can result in different behaviour in adopting and applying technology. The extent to which motivation can affect technology adoption and application depends on how farmers order their motivations related to technology adoption and application.

Age of farmer also affects adoption. The older the farmer the longer he has been involved in cocoa exploitation, and the more he has adopted the available technology. On the other hand, younger farmers who are usually more educated have a greater likelihood of adopting available technology. Since the factors described here are strongly correlated (see also chapter 4) only *the number of years in education (3)* is included in the model. The following can be hypothesized:

Hypothesis 3 More advanced cocoa farmers, whose education is higher, are more adoptive than others. Therefore it is presumed that the level of education has positive relationships with technology adoptions and the use of production inputs and fermentation.

3) Farmers' household characteristics

Farmers' household characteristics may affect cocoa farmers in adopting and applying available technology of both pre-harvest and post-harvest technology. The number of family members and the number of family workforce are presumed to affect technology adoption and use since a farmer with many family and workforce members usually produces much more farm output to fulfil family requirements for food, school fees and other family expenses. The ample availability of labour gives a higher chance of getting higher incomes, out of which investments in technology could be financed. So, according to this argument, labour availability contributes to adoption of technology (Caveness and Kurtz, 1993). According to Schutjer and Van der Veen (1977), there is limited evidence to suggest that the availability of workforce on the farm will encourage the adoption of workforce intensive technology, while a lack of workforce will discourage both adoption and efficient utilization. Contrary to this argument, Hayami and Ruttan (1991) emphasized the workforce-saving impact of certain technologies. The higher the price the lower the availability of labour, the higher the chance of labour substitution by technology. In particular, on small farms, substitution may be encouraged by the necessity to fulfil the basic family requirement. Since the number of household members is strongly correlated with the number of family workforce, therefore, this study includes only *the number of family workforce (4)* in the model as farmers' household characteristic (see also chapter 4). The following can be hypothesized:

Hypothesis 4 It is presumed that the larger the number of family workforce, the more adopted the technology and the higher the use of production inputs and fermentation.

4) Farm characteristics

Farm characteristics may also affect the cocoa technology adoption and application of both pre-harvest and post-harvest technology. This factor can be identified in the form of different characteristics such as farm hectares exploited, cocoa hectares exploited, annual crop area exploited, the number of plots exploited, the distant plots exploited, cocoa production, farm gross output, the total of workforce used and farm expenditure.

Farm size and the number of plots exploited are presumed to affect adoption and application of both pre-harvest and post-harvest technology. Farm size characteristics have different effects in different regions. However, large farms do tend to adopt new technologies first, probably because the revenues on the investment for obtaining information about technologies is higher (Norton and Alwang, 1993). In certain regions large farms sometimes have better access to the source of capital and credit needed to purchase production inputs and have a greater ability to absorb risk. On the other hand, small farms have only one option that the small plot owned must produce farm output to fulfil family consumption throughout the year. Therefore, using available technology is their only option to maximize the exploitation of the small plots. The number of cocoa hectares exploited is expected to affect technology adoption. Farmers with large areas of cocoa, being a cash crop, can afford to purchase production inputs and will therefore adopt available technologies. The annual crop area exploited is also expected to affect technology adoption. Farmers who are successful in their cocoa business usually tend to complete their farm by purchasing annual crop plots. It appears that farmers have a certain motivation to produce their own food. Farmers may feel more secure if they grow their own food, or they may consider that home-grown food tastes better (Ruthenberg, 1985). Since farmers who exploit annual crop areas can ensure their food requirement from their own food crop plots, they are well provided to purchase production inputs from the yields of cocoa.

As farm exploitation is dominated by cocoa-crop activities, the amount of cocoa produced in a year will be the most significant source of farmers' revenue. The level of cocoa production in a year is expected to influence technology adoption and the level of technology application. Moreover, farm gross outputs which are the farmers' revenues that come from cocoa crop, annual crops and other crops are expected to affect technology adoption and application. Farmers with a large gross output of previous year are more able to purchase production inputs and will therefore more adoptive. Because of intercorrelation amongst the variables, the study only includes the variables of *annual crop area exploited (5)* and *farm gross output (6)* in the model. The following can be hypothesized:

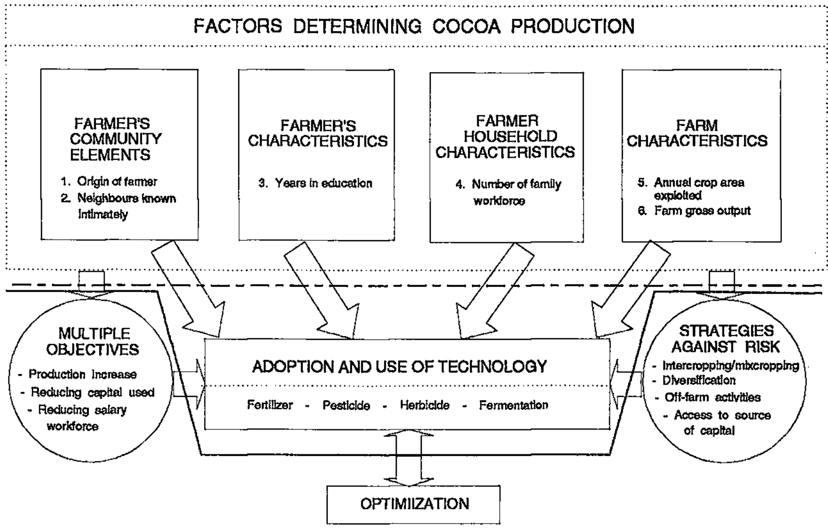
Hypothesis 5 Cocoa farmers with limited resources and a higher link to risk are less adoptive than others. Therefore it is presumed that annual crop area exploited has positive relationships with farmer behaviour in technology adoptions and the use of production inputs and fermentation.

Hypothesis 6 Cocoa farmers who have a larger farm gross output are more adoptive than others. Therefore the farm gross output has positive relationships with technology adoptions and the use of production inputs and fermentation.

When all of the model elements mentioned are systematized in the conceptual framework as described earlier, the operating scheme of the model can be exhibited as in *Figure 3.4.* The model shows that two approaches are used in the study: *Firstly*, the positive approach using microeconomics with production function and statistical elaboration as the basis of analysis. Factors that are presumed to affect technology adoption and application are explored systematically to obtain the most forceful determinant factors that affect farmers' behavioural decision-making on technology adoption and application (chapter 5). *Secondly*, the normative approach which should elaborate on farmers and their exploitation conditions by optimizing the application of farmer resources owned and the available technology. In optimizing the activities, farmer objectives and strategies against risk might be considered as factors that could influence the level-achieving of outcomes (chapter 6).

A

B



Note:
A : Positive approach
B : Normative approach

Figure 3.4 The Model

CHAPTER 4 RESEARCH DESIGN AND ITS IMPLEMENTATION

4.1 Introduction

One step in the process of research design is the choice of research methodology. The methodology used is aimed at achieving the best research results possible. A case study that is combined with a survey has been chosen as the main method for this study for several reasons. The methodology used and the reasons for selecting the case method are described in Section 4.2. In this section the stage and the time of data collection is also described.

The research organization that is divided into respondents and sampling, sources of information and data, and analytical methods used is presented in Section 4.3. The rationale governing respondent selection and sample selection is described in this section. The analytical methods used, consisting of a combination of positive and normative approaches, is presented in the last part of this section.

Section 4.4 describes the measurement of the variables. To achieve the aims of the study, the variables selected should fit the research model developed. To respect this condition, the data collected should be selected to meet the requirements of the model. The type of data collected and its measurement are described in this section. A description of the characteristics of variables that are included in the model will be presented in Section 4.5. This Section is also fitted out by the table of the data distribution, which consists of means and standard deviations of the data. Detailed characteristics of variables are described in *Appendix 4.2.*

An essential part of an empirical study is the choice of an analytical method. The hypotheses should be examined using an appropriate method. In order to obtain a more comprehensive results and to compare the estimation results by different approaches, econometrics and statistical methods will be used. Econometrics by likelihood and OLS production function and technical efficiency estimate are presented in the Section 4.6. In this section the technical operations used are outlined.

4.2 Research design and methodology

Scientific research can be described as a systematic process of discovering, acquiring and using knowledge. This study has been carried out on the basis of inductive methodology. This case study explores the diversity and the heterogeneity of farmers' behaviour under specific socio-economical conditions. There were several reasons for choosing the case study method used in the study:

(1) This method fits the study of management. Yang (1971) also said that the case method is an important tool in studying the management problems of individual farmers in their decision-making and action taking.

(2) Since the objects and the sources of information, particularly farm smallholders, have characteristics that vary in terms of socio-economic ability, technical knowledge, and human and natural resource levels, the case study is suitable for collecting the necessary information and can provide a detailed understanding of farmers' problems.

(3) An intimate study of the realities of farm production and of farmers' attitudes is required to predict how farmers might react to specific policy changes. To collect such data from a large sample of farms might be too expensive. A case study approach may be the only one possible in such circumstances (Dillon and Hardaker, 1980).
(4) The case study approach facilitates the researcher in drawing inferences and in making warranted predictions for the population of interest. Once an understanding of cause and effect relationships has been gained, the next step is how to extrapolate to the population of interest. By supplementing with a simple survey, for collecting data on the distribution of key attributes in the population of concern, the inferences of case study can be extrapolated as the inferences of the population of interest.
(5) The case study method can be easily administrated by one person, which proves a great advantage for a researcher who cannot fall back on extensive research assistance on the spot (Stam, 1982).

The data collection took place in two stages: In the first three month period, from August to October 1993, the time was spent on observing the region of study. At that time appropriate secondary data was collected and recorded. This preliminary research made the researcher more familiar with all the aspects concerned and led to greater understanding of the various components of the system in the region, which were presumed to determine the whole process of agricultural development and innovation adoption. Thus, socio-economic elements and agro-ecological environmental components were identified. To clarify the importance of all the elements that might be associated and/or have a relevant complementary relation with the study, discussions with other researchers and other experts were carried out.

The second period, from November 1993 to July 1994, was spent visiting and interviewing the farmers. Information was collected based on the structured questionnaires and through spontaneous and extended interviews and discussions.

4.3 Research organization

4.3.1 Respondents and sampling

The number of farmers chosen as respondents in the study in two villages, *Noling* and *Buntu Batu* was 100, 50 of whom were representatives of each village. The selection of the farmers was carried out at random, proportionally. Proportionally, that means, at each settlement site in each village farmers were selected at random in proportion to the population represented by the farmers at the relevant site. The reason for selecting 100 farmers as respondents is firstly that this amount is assumed sufficient to represent the entire farming population in the region, being about 10 percent of the total farmers' households of the two villages. Secondly, the necessity to elicit reliable information under limited conditions where time and budget factors must be taken into consideration.

4.3.2 Sources of information and data

The data collected can be classified into two groups according to its sources. The first is the data collected from the available records of various sources and institutions. Although the data used had been valid information for various institutions, it often measured different qualities and quantities of information. The kind of data was data on production, hectare, price and several related details. To maintain data validity, a cross check was carried out using various sources. The second category of data collected is data obtained from interviews with farmers or selected respondents and various other sources of information. The collecting of this data often resulted in incomplete sets of data. The farmers never recorded all their activities, such as production inputs, workforce numbers, and money spent, so respondents often had difficulties in providing the correct information needed. The solution was to extend the discussions to include other family members or colleagues with whom the farmer respondent often worked. Or, a cross check was performed with other information sources, that farmers had provided previously, on activities closely related to the subject concerned.

4.3.3 Analytical methods used

Two methods that will be used in the study's analyses are the positive and normative approach. The positive approach will be carried out by using the Cobb-Douglas production function approach. In this approach factors that possibly influence cocoa technology adoption and application will be estimated. These analyses will be completed with other complementary statistical descriptive analysis to examine the results of analysis. Details of the technical method used will be described in section 4.6.

The normative approach will use a linear programming method as a tool of analysis. This alternative analysis method will be used in order to reveal opportunities of maximizing farmer resources and minimizing problems faced in order to achieve an optimal level of cocoa exploitation in the region. The detailed discussion of the application of the linear programming method in this study should be presented in chapter 6.

4.4 Data collecting and matching data to the research model

4.4.1 Kinds of data and measurement

The data collected in this study were primary and secondary data. The former are the recordings of interviews with respondents based on both questionnaires and separate questions. The latter are the supporting data and information consisting of socio-economical and agro-physical conditions of the region. This data mostly were available and have been recorded previously. Supporting (secondary) data and the information collected are categorized into various sub-headings such as:

(1) Socio-economic factors, which consist of:
- norms and beliefs of the people in the region;
- community structure and politics;
- policies, programmes and projects;
- institutions, health and education, research/extension, input supply, credit, land tenure, cooperatives, marketing boards;
- market and prices of labour, land, capital goods, current inputs, and farm products;
- agro-industry;

- farmer organization;
- set of farming systems.

2) Agro-physical factors, which consist of
   - climate;
   - soil and topography;
   - pests and diseases;
   - vegetation;
   - land use, crops, fodder, fish-ponds, animals, trees;
   - location, access to centres of development.

Primary data were collected in a survey. The questionnaire used in the interviews is included in *Appendix 4.1*. Table 4.1 shows the categories of variables ultimately included in the model. Of every group of variables at least one variable is represented in the empirical model. *Appendix 4.2* contains detailed information about the variables.

Kinds of Variables	Group of Variables	Number of Variables
Technology adoption estimate		
Independent Variables	Farmer community elements	2
	Farmer characteristics	1
	Farmer household characteristics	1
	Farm characteristics	2
Dependent Variables	Technology adoption	4
Technology application estimate		
Independent variables	Farm characteristics	2
	Technology application	4
Dependent variable	Farm gross output	1

Table 4.1 Group of variables and number of variables of each group

Several variables are measured in a serial time. These are variables that measure farm characteristics and variables of technology application. The measurement of variables was performed in two ways, by recording directly from the information extended by respondents and by calculations from several types of data which was obtained from respondents. The way of each factor was measured will be described as follows.

(1) Farmer's community

To measure the farmer's community, the ethnical origin of the farmer and the number of neighbours known intimately are used. These variables are measured as follows. For the variable ethnical origin a dummy variable is used. Migrant versus indigenous farmers are distinguished (0 = indigenous; 1 = migrant). The integration of the farmer is measured by the number of neighbours known intimately. There may be other indicators to measure farmer's community such as the village where they live or the number of meetings attended. These variables, however, are not included in the model for several reasons such as the lack of variance in the variable or a high correlation with one of the other variables.

(2) Farmer's characteristics

The farmer's characteristic that is included in the analysis is years in education. Years in education was measured as the number of years that the farmer has spent in formal education. Then, this variable is designed into two dummy variables, (1) the variable higher level of education that distinguished farmers with higher education (secondary school or higher) and and otherwise; (2) the variable literate farmer that distinguished illiterate and literate farmers. As discussed in chapter 3 there are certain other farmer's characteristics that could have been used as indicators such as farmer's experience and age of farmers. Since these variables have high correlations [6] with variables selected, they are not included in the model.

(3) Farmer household characteristics

To measure farmer household characteristics, the number of family workforce is used. The number of family workforce was measured as the number of active family workforces in exploitation, those who were involved in farming activities and did not receive cash money of compensation from the farming or the farm-household. The number of family members is not included in the model since this variable has a high correlation with the variable number of family workforce. In the case of the study, the latter is more important because it gives more information about the number of family workforce that involved in farm activities.

(4) Farm characteristics

Four variables, annual crop area exploited, farm gross output, farm hectares exploited and the number of workforce used were selected as farm characteristics. The first two variables were selected as the indicators to measure farm characteristics, which are used as predictor variables in the estimation of technology adoption. The others were selected as variable inputs used in the production function estimate of resources used. The annual crop area exploited is selected as a dummy variable. This variable was measured 1 if farmers exploited annual crop and 0 otherwise. The annual crop exploited can be dry or wetland. The variable farm gross output was measured as the total of farm production during the last year (1992) multiplied by the prices received by farmers. However, variable farm gross output in the relevant year (1993) is used as dependent variable in the production function estimate of resources used. The latter, the value was calculated by using a constant cocoa price in 1993. Several other variables such as the number of plots exploited, cocoa hectares exploited, cocoa production and the total expenditure, may be indicators to measure farm characteristics. Again, these variables showed a strong correlation with other variables.

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[6] *In earlier studies age and experience of farmer showed to be important variables in the explanation of the level of adoption. Therefore, for all four applications, a model that includes age and experience instead of education was tested. The results showed that where education has a generally positive effect on technology adoption, age has (as expected) a negative effect; and experience has (as expected) a positive effect.*

(5) Technology adoption and application

The variables of technology are measured in two ways. When the variables are used as dependent variables in the estimation of technology adoption, the variables are measured as dummy variables, 1 if the farmer adopted the technology, 0 otherwise. When the variables are used to estimate the application of resources, the level of fertilizer and pesticide application in the relevant year (1993) are used as indicators to measure pre-harvest technology application. These variables are measured as the amount of fertilizer (x 100 kilograms) and pesticide (litres) used per hectare during the relevant year. In the estimation of technology application, herbicide and fermentation application are measured as dummy variables to predict the different application of herbicide and fermentation.

4.4.2 The suitability of the variables to the research model

The independent variables can be distinguished in two groups. The first group includes origin of farmer, number of neighbours known intimately, years in education and number of family workforce. For these variables the value of 1993 can be used since the distribution of farmers across the values of these variables is not supposed to change over time. This does not hold for the remaining variables. These variables are the annual crop area exploited, farm gross output, farm hectares exploited and the number of workforce used. There are some variables in the model for which it may be important to include the value of preceding year rather than the value of the present year. These variables are the annual crop area exploited and farm gross output. For these variables it can be assumed that the level of adoption in 1993 is affected by the annual crop area exploited and farm gross output in 1992. This means that the technology adoption in 1993 is explained by the state of previous year of farm characteristics. To sum up, Figure 4.1 shows the variables that are included in the model.

A Likelihood Production Function Estimate of Technology Adoption

Independent Variables	*Dependent Variables*
(1) ORIGIN, origin of farmers;	(1) FERTI93, fertilizer adoption in 1993;
(2) NEIGHB, neighbours known intimately;	(2) PESTI93, pesticide adoption in 1993;
(3) EDUC1, high educated farmer;	(3) HERBI93, herbicide adoption in 1993;
(4) EDUC2, literate farmer;	(4) FERME93, fermentation adoption in 1993;
(5) FAMLAB, number of family workforce;	
(6) ANCROP92, annual crop area exploited in 1992;	
(7) FAGROS92, farm gross output in 1992;	

B OLS Production Function Estimate of Resource Use

Independent Variables	*Dependent Variables*
(1) FAMHA93, farm hectares exploited in 1993;	(1) FAGROS93, farm gross output in 1993;
(2) LAB93, workforce used in 1993;	
(3) FERTI93, fertilizer application in 1993;	
(4) PESTI93, pesticide application in 1993;	
(5) HERBI93, herbicide application in 1993;	
(6) FERME93, fermentation application in 1993.	

Figure 4.1 List of variables included in a model developed

4.5 Characteristics of variables

In the first estimate four explanatory variables are dummy variables, namely *the origin of farmer (1), high educational level (3), literate farmer (4) and annual crop exploited (6)*. The others are continuous variables. The detailed characteristics of each variable are described in *Appendix 4.2*. Except the variable number of neighbours known intimately that has a significant T value of less 10%, other variables have significant T values between the group of adoption and non-adoption of less 1%. The descriptive of the continuous variables, all cases (n=100), adoption cases (n=85) and non-adoption cases (n=15) is shown in Table 4.2.

	Means (standard deviation)			
	(n = 100)	(n = 85)	(n = 15)	T value
Neighbours known intimately	25.56 (13.54)	24.51 (13.12)	31.53 (14.80)	1.83 *
Family labour	3.99 (1.62)	3.80 (1.76)	5.07 (1.87)	2.80 ***
Farm gross output in previous year	4.61 (4.14)	4.13 (3.67)	7.31 (5.58)	3.21 ***
Farm gross output in relevant year	5.17 (4.77)	4.65 (4.37)	8.14 (5.89)	3.05 ***
Land cultivated	2.99 (2.87)	2.55 (2.50)	5.50 (4.11)	4.11 ***
Labour used	1.92 (1.45)	1.72 (1.27)	3.05 (1.89)	3.75 ***
Fertilizer	3.55 (2.37)	4.10 (2.12)		
Pesticide	2.82 (2.62)	2.71 (2.32)		

Table 4.2 Descriptive statistics (* = $p < 0.10$; *** = $p < 0.01$)

The dummy variables with their values that equal with one are shown in the following table.

	Number of households for which the dummy variable equals one:
Fertilizer use	85
Pesticide use	85
Herbicide	64
Fermentation	20
Origin of farmers	65
Education 1	38
Education 2	82
Annual crop area cultivated	29

Table 4.3 Number of farmer household for which the dummy variable equals one

4.6 Technical method used

The analyses will be carried out by using the Cobb-Douglas production function. This approach distinguishes two steps. *First*, the technology adoption will be estimated to determine the importance of the various factors which influence the cocoa farmer's adoption of pre-harvest and fermentation technology. The technology adoption depends on whether the contribution of chemical production inputs (fertilizer, pesticides and herbicides) and fermentation processing are zero or positive. *Second*, the technical efficiency is calculated in order to determine its correlation with explanatory variables of farm and farmer household characteristics. The correlation coefficients show the importance of various factors which influence technology application. The procedure of the analyses is based on the OLS estimates of the loglinear production function. Allocative efficiency is not included in the analysis since risk factors (external and environmental factors) as described previously are presumed and taken into account as constant.

4.6.1 Empirical model of technology adoption

The likelihood production function. The logistic regression model (Hosmer and Lemeshow, 1989) is a type of regression model in which the dependent variable is binary or dichotomous (in this case, 1 = adoption and 0 = non-adoption). Logistic regression is used to estimate the parameters associated with the variables that explain the probability that an event occurs. If the conditional probability that an event is denoted as P(Y = 1 | x) where x is the vector of independent variables, the logistic regression model states for P_1 = P(Y = 1 | x)

$$logit\ P_1 = \ln \frac{P_1}{1-P_1} = \beta\text{'x} \qquad (1)$$

and so

$$P(Y = 1 \mid \text{x}) = \frac{e^{\beta'x}}{1+e^{\beta'x}} \qquad (2)$$

The logit of P(Y = 1 | x) is linear in its parameters, and may range from $-\infty$ to $+\infty$

Since the logit model establishes a non-linear function, the value of the parameters does not have an immediate interpretation as in a linear regression; they cannot be easily interpreted as the marginal parameters supplied by linear regression estimation techniques such as OLS. Elasticities can be computed for P(Y = 1 | Xi) by taking the first derivative.

$$\frac{\delta P(Y=1)}{\delta \text{Xi}} = \frac{e^{(\Sigma\beta i Xi)}}{1+e^{(\Sigma\beta i Xi)}} * \frac{1}{1+e^{(\Sigma\beta i Xi)}}\ \beta_i = P_1(1-P_1)\beta_i \qquad (3)$$

The logistic coefficients from the equation (1) can also be interpreted as the change in the log odds associated with a unit change in each variable. The odds is the ratio of the probability of adopting to the probability of non-adopting, *i.e.*, $P_1/(1-P_1)$. The coefficient β_i can also be interpreted by means of the odds ratio associated with a unit change in X_i, given by exp.(β_i). Where the odds ratio is less than 1, it means that an increase in the independent variable will lead to a decrease in the odds of adopting.

4.6.2 Empirical model of technical efficiency

(a) *Resources used.* The empirical model of technical efficiency is initiated by building an estimated model of resources used in production activity. For this purpose Cobb-Douglas production function is adopted. The OLS estimate is used in which the output of equation uses farm gross output in a relevant year. The OLS estimate based on the original model of the production function, is:

$$Y = AX_1^{\alpha} X_2^{(1-\alpha)} \tag{4}$$

where

Y : output
X_1 : labour
X_2 : capital

By transforming to the logarithm model, it therefore becomes a linear equation in parameter or in coefficient, therefore

$$\log y = \log A + \alpha \log X_1 + (1-\alpha) \log X_2$$

If the original model is generalized into a homogenous function whose degree = 1, then

$$Y = AX_1^{\alpha 1} X_2^{\alpha 2} \tag{5}$$

where ($\alpha 1 + \alpha 2$) is not necessary = 1

If the amount of input is extended, it can be grouped into fixed input (X_j) and variable input (Z_j). Therefore the equation is:

$$Y = \prod_{j=1}^{m} X_j^{\alpha j(x)} \prod_{j=1}^{n} Z_j^{\beta j} \tag{6}$$

Cobb-Douglas production function type (5) and (6) can also be improved to production function with input elasticity which changes. Its general model is:

$$Y = A \prod_{j=1}^{m} X_j^{\alpha j(x)} \tag{7}$$

where αj is the function of one or more inputs that is pointed out by x. This input can contain Xm and also the input which is not included in that function. For instance, X is the skill of farmers, therefore the production function skilled farmers will have a larger production elasticity than unskilled-farmers.

(b) *Technical efficiency*. Based on the estimated production function, scores for technical efficiency (T_{eff})are calculated. A Frontier production function will be the basis in determining the technical efficiency score. The frontier production function can be estimated by shifting the (mean) production function upwards until no residual is positive and at least one is zero. To eliminate the distortion by extreme outliers that may possible exist, studentized residuals are calculated. Only residuals with a studentized value that is smaller than two are taken into account. The potential output (Y_{pot}) can be calculated by substituting the inputs that are actually used by a production unit in the frontier production function. The ratio of the actual output and the potential output that is equal with technical efficiency can be formulated as follows:

$$T_{eff} = Y/Y_{pot}$$

where T_{eff} = *technical efficiency*
Y = *actual achieved output*
Y_{pot} = *potential output*

(c) *Efficiency and farmer household characteristics*. The correlation matrices between the efficiency score and several production unit characteristics selected are calculated. These correlations indicate the level of relationship between technical efficiency and the farm and farmer household characteristics or between technology application and the farm and farmer household characteristics.

CHAPTER 5 FACTORS EXPLAINING TECHNOLOGY ADOPTION AND APPLICATION

5.1 Introduction

In this chapter a number of factors is tested and examined to the extent they are associated with technology adoption and application. As has mentioned previously production function approaches are used. Two steps of analyses will be used, the likelihood function and the OLS estimate model. The former analysis will use the dummy dependent variables, while the latter will use the continuous dependent variables.

Section 5.2 presents the finding of the empirical model of technology adoption. This section starts by describing the variables included in the model. Then, the findings of different technology adoption are presented. Section 5.3 presents the results of the analyses of technology application. This section ends with the results of correlation analyses between farm and farmer household characteristics and technical efficiency. In section 5.4, conclusions are drawn.

5.2 Findings of the empirical model of technology adoption

In order to test the hypotheses presented in chapter 3 the following explanatory variables are included in the equation of technology adoption:

Origin of Farmers	: A dummy variable that takes on the value 1 if the farmer is migrant and 0 if indigenous.
Neighbours	: The number of neighbours known intimately.
High educational farmer	: A dummy variable that takes on the value 1 if the farmer has six years or more in education more and 0 if otherwise.
Literate farmer	: A dummy variable that takes on the value 1 if the farmer is literate and 0 if otherwise.
Farm labour	: The number of family workforce.
Annual crop exploited	: A dummy variable that takes on the value 1 if the farmer cultivates a sawah plot and 0 if he does not.
Farm gross output in 1992	: Farm gross output of the previous year.

The estimated coefficients for these variables are used as indicator of the predictor. The estimated results of technology adoption (Table 5.1) show that the different variables affect the respective type of technology adoption. Fertilizer and pesticide adoption are influenced by three variables, while herbicide and fermentation adoption are influenced by one variable. The major factors are:

The origin of farmers. The results show that in the stage of farmers' decision to adopt or not cocoa technology, the origin of farmers significantly and negatively affects fertilizer and herbicide adoption. The negative effect of a dummy variable origin of farmers on fertilizer and herbicide adoption means that the migrant farmers who mostly settled in the first village, *Noling,* adopt fertilizer and herbicide to a lesser extent than the indigenous farmers who dominate the second village, *Buntu Batu.*

Dependent Variables	Fertilizer Adoption	Pesticide Adoption	Herbicide Adoption	Fermentation Adoption
Explanatory Variables		unstandardized coefficients		
Origin of farmers	-2.10 **	- .40	-1.20 **	- .50
(1=migrant; 0=indig.)	(.99)	(. 61)	(.56)	(.62)
Neighbours known intimately	- .07 *	- .02	- .01	.04 **
(no of people)	(.03)	(.02)	(.02)	(.02)
High educational level	.66	- .13	.74	- .02
(1= ≥ 6 years; 0= otherwise)	(.93)	(.64)	(.54)	(.84)
Literate farmer	.92	1.51 **	.03	.31
(1= literate; 0= otherwise)	(.75)	(.67)	(.60)	(.86)
Number of family workforce	- .43 *	- .30 **	.19	.11
(no of people)	(.21)	(.15)	(.14)	(.18)
Annual crop area exploited	- .95	.96	.38	.22
(1= cultivated; 0= otherwise)	(.77)	(.71)	(.53)	(.66)
Farm gross output in previous year	- .06	.15 *	- .02	.03
(x million Rupiahs)	(.08)	(.09)	(.06)	(.08)
Constant	6.63***	1.22	.62	-2.70 *
	(2.02)	(1.21)	(1.06)	(1.44)
-2 Log Likelihood	60.97	90.89	117.23	88.19
R^2	23.57	14.48	13.45	11.88

*** = $p < 0.01$ ** = $p < 0.05$ * = $p < 0.10$
Standard errors are in parentheses

Table 5.1 Estimation results for fertilizer, pesticide, herbicide and fermentation adoption (n = 100)

The migrant farmers, particularly those who came later to the region, mostly have plots that are younger and on a larger distance from the village compared to the plots of the indigenous farmers. These plots usually have lower levels of soil fertility, since they are mostly located on higher land. This limitation, aggravated by a longer distance from the settlement, results in an extensive level of maintenance. The lack of an adequate physical infrastructure apparently contributes to the limited adoption of fertilizer on the distant cocoa plots. Another factor that constrains fertilizer adoption is that on the distant sites many immature cocoa are located. The farmer's attitude is, that these plots do not yet need fertilizer. These plots are usually fertilized by farmers when the cocoa is five to six years old. The extensive level of treatment implies an insufficient cocoa performance because the weeds affect the cocoa crop. The treatment farmers choose to attack the growth of weed is using herbicides. The indigenous farmers who mostly have a larger area than the migrant farmers, in their effort to minimize the use of workforce in weeding control, use herbicides. This is possibly the reason why more the indigenous farmers have adopted herbicide than migrant farmers.

Neighbourhood community. The number of neighbours known intimately affects fertilizer adoption negatively and fermentation adoption positively. The negative effect on fertilizer adoption indicates that farmer families with smaller number of acquaintances, which are usually those who came later in the region and have smaller farms have adopted fertilizer more than the families with a larger network of neighbour. More new-comer farmers, apparently, adopted fertilizer than the farmers who have established earlier in the region. This is different with fermentation adoption: fermentation has been adopted more by farmers with a larger network of neighbours than by farmers with smaller networks. This can be explained the fact that the farmers who usually have wider relationships with other farmers also have a better access to the source of information on market development, including the cocoa price development over time. Farmers with information about the market have a better chance to obtain a higher price for their fermented cocoa. The price is the main determinant factor for the farmer to decide to ferment their cocoa.

Years in education. A positive effect of education on adoption was predicted. The results show that this expectation is not confirmed. The dummy variable high educational level has no significant effect on technology adoption. However, when farmers are grouped into literate and illiterate farmers, a significant effect occurs. A dummy variable literate farmer has a significant and positive influence on pesticide adoption. This indicates that there is a positive relationship between pesticide adoption and the literacy of farmers.

Family workforce. The results show a significant negative influence of workforce on adoption. This contradicts the prediction of a positive relationship of family workforce and technology adoption. The larger the family workforce, the more adopted the technology. Farmer families with a smaller family workforce, which are usually those with smaller farms, adopt fertilizer and pesticide than families with a larger workforce. A reason for this may be the substitution of labour by technology and the objective to increase cocoa yields in order to fulfil their family requirements.

Annual crop area exploited. A dummy variable annual crop area exploited shows an insignificant effect on all technology adoptions. The expansion of farms with wet paddy does not influence technology adoption.

Farm gross output. Farm gross output in the previous year positively affects pesticide adoption. This indicates that more farmers with higher gross output adopt pesticides than those with lower gross output. This can be understood because farmers with higher revenues are more able to purchase pesticides than the farmers with lower gross output. However, gross output has an insignificant effect on fertilizer adoption.

5.3 Findings of the empirical model of technology application.

Next, the application of fertilizer, pesticide, herbicide and fermentation is analyzed, based on the production function. There are two stages in the analysis. *First,* the resources and efficiency are estimated. The dependent variable is farm gross output in 1993. Land, labour, chemical production inputs and fermentation are selected as independent variables. The number of cases included in the equation is equal to the number of farmers that adopted chemical inputs. In estimating the application of herbicide, a dummy variable herbicide application is used in the equation since the actual application of herbicide is too limited and the effect of herbicide on production, will not directly occur in the same year. For fermentation application, a dummy variable fermentation application is also used. In this stage the OLS estimate of production function model is used. The explanatory variables that are included in the equation are:

Land	: Money value of cocoa farm area cultivated.
Labour	: Money value of labour used.
Fertilizer	: Money value of fertilizer used.
Pesticide	: Money value of pesticide used.
Herbicide	: A dummy variable that takes on the value 1 if the farmer uses herbicide and 0 otherwise.
Fermentation	: A dummy variable that takes on the value 1 if the farmer applies fermentation and 0 otherwise.

Second, the technical efficiency score is determined and correlation coefficients with farm and farmer household characteristics analyzed. The number of cases that is included in the second stage (technical efficiency) analysis is 85 cases, which are equal to the number of farmers that have adopted fertilizer and pesticide. Table 5.2 shows the estimation results of technology application.

Variable	Coefficient	Standard error	T Value
Inputs			
Land	.54	.08	7.04***
Labour	.23	.10	2.28***
Fertilizer	.08	.07	1.16
Pesticide	.21	.08	2.47 **
Other variables			
Herbicide	-.10	.08	-1.23
Fermentation	-.07	.09	- .74
(Constant)	1.52	.21	7.07***
Adjusted R^2 = .81 F = 51.10***	*** = $p < 0.01$	** = $p < 0.05$	

Table 5.2 Coefficients of the production function of resources used (n = 85).

The estimation results of resources used show that all input coefficients have the expected positive sign. Inputs that significantly affect cocoa production are land, labour and pesticide. Fertilizer application does not show a significant influence. Two reasons may possibly explain this result. *First,* heteroscedasticity of explanatory variables. *Second,* because the inaccurate application of fertilizer, as has been discussed in chapter 3 (section 3.2.2). Fertilizer was not incorporated but just spread over the surface of the soil. This treatment is less effective since a part of fertilizer washes away when it rains after fertilization. This reason may be highly significant if one considers that the application of fertilizer in the region generally takes place in the beginning of rain season. The dummy variable of herbicide does not influence production since herbicide is mostly used for immature cocoa. Therefore herbicide application does not influence, significantly, the gross output. The dummy variable fermentation also does not influence farm gross output.

From the table above the possible returns of scale can be calculated. Its result is apparently more than 1. This result is not too high. Factors that may possibly provoke this low returns of scale of cocoa production in the region are the lack of farmer knowledge of applications of production inputs, as was discussed previously. The technical efficiency obtained has a mean of almost 70%, with a range of a minimum of 35% and a maximum of 90%. This shows that there remains sufficient room for increasing cocoa production in the region.

Table 5.3 shows the correlation coefficients between the technical efficiency and farmer household characteristics. Two variables, the origin of farmers and the literacy level of the farmer have no significant correlations with technical efficiency.

Variable	Correlation	Significance
Origin of farmers	-.06	.27
Neighbours known intimately	.27	*.004*
High educational level	.16	*.06*
Literate farmer	-.12	.14
Number of family workforce	.44	*.00*
Annual crop area exploited	.15	*.07*
Farm gross output	.82	*.00*

Table 5.3 Correlations between technical efficiency and farmer household and farm characteristics.

The dummy variable *origin of farmers* has no significant correlation with technical efficiency, that means that the origin of farmers does not influence the application of technology. While the farmers' origin influences the farmer decision in adopting certain technology, in the stage of determining the level of technology application the origin of farmers is not important anymore.

Neighbours known intimately. Just, as in the case of fermentation adoption, the number of neighbours known also influences technical efficiency positively. Apparently, farmers with a larger number of colleagues, who possibly have more access to technical information, have more knowledge of technology application than those with a smaller number of neighbours known intimately. Access to the source of technological information is important as a media for acquiring recent knowledge of cocoa development.

Years in education. The dummy variable high educational level has a significant and positive correlation with technical efficiency. In the other words, the higher the education of farmers, the higher the application of technology. Although the dummy variable literate farmers has an insignificant influence on technical efficiency, however this evidence still indicates that a sufficient level of farmer education is important to achieve technical efficiency.

Family workforce. The number of family workforce has a positive significant correlation with technical efficiency. This proves the important contribution of the available workforce to the level of application of technology. A high level of technology application needs more labour than a low level. Since all inputs can be used in different volumes according to the farm size, a different use of production inputs implies a different volume of labour. The available family workforce is a determining factor in deciding on the application of production inputs.

The annual crop area exploited. This factor influences technical efficiency positively, which could prove that farmers who also exploit the annual crop (*sawah*) have more ability in operating their farm than the farmers without paddy crop plots. The explanation of this condition is that the farmers who have fulfilled the basic family food requirement can use the revenue from cocoa yields to finance cocoa production. In such condition farmers have a more favourable condition in spending their budget for purchasing production inputs.

Farm gross output. Farm gross output in the previous year has a positive and significant correlation with the technical efficiency score. The higher the gross output of the previous year the higher the ability in purchasing production inputs and applying fermentation. Once the larger farmers adopt production inputs, they are more able to apply the production inputs on appropriate levels.
The findings of analysis, both technology adoption and application, will be discussed in chapter 7.

5.4 Conclusion

1 Four types of adoption were studied in this chapter: fertilizer, pesticide, herbicide and fermentation adoption. The main factors that explain technology adoption can be summarized as follows:
(1) Fertilizer adoption is negatively affected by the variable origin of farmers, the number of neighbours known intimately and the number of family workforce.
(2) Pesticide adoption is positively affected by the variables of literate farmers and farm gross output, and negatively by the variable number of family workforce.
(3) Herbicide adoption is negatively affected by the variable origin of farmers.
(4) Fermentation adoption is positively affected by the variable number of neighbours known intimately.

2 Factors that influence the application of technology that were studied by estimating their correlations with technical efficiency were also analyzed in this chapter. Technical efficiency of cocoa production is positively affected by the variables: the number of neighbours known intimately, high educational level, the number of family workforce, annual crop area exploited and farm gross output. This indicates that almost all variables selected as explanatory variables have positive relationships with technology application in cocoa production.

3 The model fits best for the adoption of pesticide and worst for the adoption of herbicide. This means that the variation amongst farmers in adoption of technology is best explained for pesticide. For herbicide adoption, almost all variables that are included in the model did not explain the variation amongst farmers. Apparently, other factors that are not included in the model are more important. The model fits for technology application.

CHAPTER 6 TOWARDS AN OPTIMAL APPLICATION OF TECHNOLOGY

6.1 Introduction

After presenting the analysis, in which empirical approaches and production function methods were used, it is still necessary to apply another, alternative, analysis that contributes to an overview of the problems faced by cocoa farmers in the region. This analysis employs a normative approach through optimizing activities and resources by using a linear programming analysis. The analysis is based on an actual situation at farm level.

Linear programming can be considered as providing an operational method for dealing with economic relationships which involve discontinuities (Koutsoyiannis, 1979). In other words, it is a specific approach within the general framework of economic theory. The characteristics that differentiate this method from traditional economic analysis are that this method yields a specific numerical solution to the particular optimization problems and all relationships between the variables involved are assumed to be linear.

Linear programming analysis, or variations of it (Heady and Candler, 1966; Boehlje and Eidman, 1984), has been widely used in the study of the optimization of resource utilizations. Since several variants of linear programming exist, the choice of a particular approach should fit the problem to be solved and the objectives to be achieved. In this study, the models that have been chosen have been adapted with the objective of optimizing farm situations. In Section 6.2 the theoretical framework of the technical method that will be the basis of further analysis is described. In the same section a specific explanation will be given of the technical method, the general mathematical model (presented in *Appendix 6.1)* and the linear programming technique in general.

Subsequently, the characteristics of the linear programming model used in the study are described in Section 6.3. In this part, details of activities that became elements of the model are also presented. Attempts have been made to make the model represent the real situation in the research area so that the discussion could run parallel with the previous analysis in order to obtain a more realistic alternative for the activity analysis of cocoa smallholder development.

In the last section, Section 6.4, in which the results of the linear programming calculations are presented, the discussion of the optimal application of technology leads to examining how the optimizing of the various variables concerned might improve cocoa exploitation practices amongst smallholders. It is not only the application of technology itself that should be stressed, but also the need for supporting institutions to stimulate and strengthen the optimal application of technology. Also presented in this section is a diagrammatic illustration of different optimal solution for different farm situation activities in order to compare the result and advantage of each situation and constraints related to it, and to find out the best optimal farm solution amongst various farm situations.

6.2 Technical method used

When the problem of an economic unit, *i.e.* farm household, is that of choosing the best product mix to maximize its profits, then the total profit function is called the objective function. This objective function generally represents the goals of that economic agent. In pursuing the maximization of the objective function, the farm household faces technical and non-negative constraints. The technical constraints are set by the state of the technology and the availability of the factors of production. The quantity of the factors that will be absorbed in the production of certain products cannot exceed the available quantities of factors. Therefore, the technological constraints take the form of inequalities. Other constraints are the non-negative constraints that express the necessity that the levels of production of products cannot be negative, since negative quantities do not make sense in economics. The level of production of any one product can either be zero or positive.

It can be deduced from the above, that all the constraints take the form of inequalities. The constraints of the primal problem exhibit inequalities. However, these inequalities can be transformed into equations by defining an additional variable, namely the slack or surplus variable, for each inequality. Its principle role is that of taking up the slack between the right-hand side and the left-hand side of the inequality sign (Paris, 1991). The linear programming technique can help to solve the equation problem. When the variables whose optimal values must be determined from the linear programming method amount to more than two, the simplex method may be used for reaching the optimal solution. An iteration is that the optimal solution is defined by examining the set of possible alternative solutions and gradually eliminating the suboptimal ones until the optimal is reached (van de Panne, 1971; Koutsoyiannis, 1979; Hillier and Liberman, 1990). The formulation of a general model in a mathematical equation is described in *Appendix 6.1.*

The use of computer programs can facilitate the elaboration of the problems formulated; it is still desirable to know and understand the method used (van de Panne, 1971). This analysis used the *PC-PROG* package program.

6.3 Linear Programming model developed

The linear programming model that will be developed is a rather simple model due to the limitation of available information. The risk factor and time dimension are not included in the model. The farm condition is assumed to be stable. The linear programming analysis should be focused on the farm level activities which are operated in different kinds of technologies. If the type, scale and model of exploitation at farm level could be assumed to represent the regional level, then the analysis on regional level can be generated by the results at farm level. The main objective of cocoa farm households, to achieve an optimal farm gross margin, should be the main focus of activities. The optimal farm gross margin can be realized through the optimalization of a gross margin for several crops and off-farm activities. Three main crops exploited by farmers in the region are cocoa, coconut and paddy. These activities could also be sub-objectives of cocoa farm households. To make the analysis simpler the model developed will be focused to the main farm objective on the different types of farm.

Considering the goal variable that should be optimized and constraints that should be imposed, an activity matrix that contains all these activities should be described as follows. The activities of farmers in the region that generate revenues can be specified as cocoa exploitation, non-cocoa exploitation and off-farm activities. It means the farm systems can be distinguished on the basis of the main source of income. Therefore, the various situations in which farm activities take place can be differentiated:

Situation A: farmers exploit cocoa as a single crop. Cocoa planted as a sole cropping with or without shade plants. In this model, cocoa yields are the only source of farm income. Therefore, the main objective of such farmers is to maximize cocoa production in both quantity and quality by intensifying the application of pre-harvest and post-harvest technologies with the expectation of generating a maximum gross margin. There are further objectives of farms which can be identified such as minimizing cocoa input costs which can be realized in several ways, by reducing workforce and production input costs and improving the efficiency of inputs application. However, the focus of the solution rests on the farm's maximum gross margin.

Situation B: in this farm situation, besides exploiting cocoa, farmers also plant other crops either as intercropping or as a sole cropping on other plots, such as other perennial crops, mainly coconut crops, and wet paddy or *sawah*. Farmers' income is generated by cocoa and other crop yields. The farmers' main objective remains that of maximizing the farm gross margin, through maximizing cocoa and other crop production both in quantity and quality. The latter goal could be achieved by (1) intensifying the maintenance of other tree crops. To serve this objective, the maintenance and treatment of other tree crops such as fertilizing and pest and disease control, might be integrated with the maintenance and treatment of cocoa plants; (2) maximizing the frequency of annual crop cultivation and optimizing the use of production inputs. In the case of paddy cultivation on *sawah* plots, maximization of cultivation can be achieved by adjusting the cultivation time to fit the water distribution scheme for irrigation.

Situation C: this farm situation consists of the most diversified set of activities carried out by cocoa farmers in the region. Sources of income are generated by all existing activities, either from agricultural, cocoa or other crops, or non-agricultural activities. The farmers' objective is to maximize a farm gross margin by maximizing cocoa and other crop production, both in quantity and quality, and maximizing revenues for off-farm activities.

Situation D: this farm situation, besides employing family workforce members within the farm, farmers also pay for salaried labour from outside the farm as a complementary of family workforce in order to allow for intensifying the application of a certain technology.

Different technologies are defined for each crop on the basis of the criteria: (1) application of chemical production inputs; (2) employment of labour; and (3) the existence or actual application of technology. This leads to formulation techniques at three levels of intensity for cocoa and coconut crops and two levels of practice for rice crops. These levels are:
(1) extensive, without any application of external chemical production inputs;
(2) intensive, with high levels of such inputs; particularly for paddy crops, besides the high application of inputs, the frequency of cultivation is twice a year;

(3) semi-intensive, with intermediate level of inputs; for the paddy crop only the last two levels of intensity are used, since the extensive technique of paddy cultivation was not practiced in the region anymore.

To facilitate the identification of each activity and to make the application of production inputs for each activity more detailed, the input-output table of cocoa and other crop production techniques is presented (*Appendix 6.2*). From this table, it can be deduced that the extensive, semi-intensive and intensive technique should be the basis of the optimization of activities for cocoa and coconut crops and semi-intensive and intensive technique as the basis of the optimization of paddy crop activity. The levels of yield used are the average yields for each crop activity. The extensive technique for the paddy crop both in terms of the application of production inputs and the frequency of cultivation is considered not to enter into the table since this technique did not exist in the region anymore.

The actual circumstance shows that the farming system of the region, which is dominated by the cocoa crop, composes several types of exploitation. This exploitation consists of a sole cropping plot of cocoa which covered about 80% of total exploitation, an intercropping cocoa with coconut (7%), a sole cropping plot of coconut (2%) and a paddy crop plot (10%). The coconut population of plots that is cultivated by intercropping with cocoa is generally lower than the sole cropping of coconut. Therefore, the employment for the workforces on such plots is also lower than plots that are cultivated as a sole cropping.

The kind of technology used is divided into two categories: (1) pre-harvest technology, such as the application of chemical fertilizer, pesticide and herbicide which is intended to increase production, and (2) post-harvest technology, that is fermentation for cocoa beans, which is meant to improve the quality of cocoa production. The final objective of the application of both types of technology is to maximize the farm gross margin. In the model developed, the different technologies are separated into different activities. Then, the implication is that the yield will also sell separately: unfermented cocoa yield being sold directly, and fermented cocoa being sold indirectly. After fermentation the weight of cocoa produced could be about 5 to 15% lower than of non-fermented cocoa (Bennet and Hasan, 1993) The weight loss between fermented and unfermented cocoa is influenced by several factors, *i.e.* planting material used, application of fertilizer and harvest treatment. In this analysis the weight loss of fermented cocoa is assumed 10% on average.

The off-farm employment of the family workforce is another source of income for farmer households. This is mainly possible for farmer households where the number of active family workforce members exceeds the labour requirement for their farm activities, both during the peak season and the other periods. These farmers cultivate a smaller farm. A number of the family workforce worked as a member of a salaried workforce at other farms particularly at the beginning and the end of rainy season, and during the cocoa harvest period, which usually takes place in January and September, and from March to August respectively. However, in other cases, a certain number of farmers pays for salaried labour from outer farms.

Farmers in operating their cocoa exploitation in the region are subject to various constraints, such as the size of farm exploited, the suitability of land used for different crops, the number of the family workforce available and the seasonal peak requirement of labour for each activity. It is assumed a farm is in a stable condition, therefore risk and time perspectives are avoided. The set of constraints that are considered to enter in the model could be described as follows:

(1) The size of farm exploited shows its variability between about 1 and 10 hectares per farmer family. However, the average farm size in the region is 2.9 hectares per household whilst the average size cocoa exploited is 2.6 hectares. The variation of the farm size from 1 to 2, 3 and 4 hectares can be selected as the land size constraint.

(2) Land description shows that two main types of land are cultivated for the crops described previously. Firstly, the land with an alluvial soil type is located in the low and flat part of the region, where cocoa, coconut and paddy on the wet land are cultivated. In this region too irrigation is available which allows the cultivation of paddy twice a year. Secondly, on the land located in the upper part of the region only cocoa is cultivated. These conditions show that the basic restriction for land is, that it can be used for one purpose at a time only, thus introducing the competition for land. Moreover, the different characteristics of the land can be a constraint for maximizing the activity of a certain crop. As has been mentioned previously, only about 10% of farm size was exploited for rice crops. Therefore, in the model of farm situation B and C, it is assumed that, proportionally, only 10% of each farm size can be cultivated with a paddy crop, which will be another land constraint on farm activity.

(3) Although the average number of farm household members is 5.8 persons, the number of workforce active per farming household is only 3.9 persons. If the number of working days in a year is assumed to be 250 man-days, on average the number of members of the workforce available per farmer household is 975 man-days a year. This can be considered as a labour constraint in maximizing farm activity for different farm sizes.

(4) Workforce problem did not only relate to the availability of the family workforce, but also related to the allocation of workforce requirement that tended to fluctuate within different periods throughout the year. The fluctuation of labour requirement is determined by the intensity of field activities. In the beginning and the end of the rainy season, that usually takes place in January and September, when mostly crop treatments such as fertilizing, weeding, pruning and pest control are carried out, the labour demand increases. A similar situation also occurs during the cocoa harvest period that generally takes place from March to August. During the other months, the demand for labour tends to be lower than in the peak periods. The requirement of labour for each activity per period that is presented in *Appendix 6.3* shows the distribution of labour requirement. This is used to determine the constraint of labour requirement for each season of activity.

By using the actual costs of various inputs such as chemical fertilizer (Urea, TSP and KCl), pesticide, labour wage, tractor hire, small material and fermentation box, and outputs such as non-fermented cocoa, fermented cocoa, coconut (copra) and paddy which are in detail presented in *Appendix 6.4*, the models of linear programming problems are developed. The models are presented in Table 6.1, the model of situation A with the sole cocoa cropping activity problem, Table 6.2, the model of situation B with cocoa and other crops' activity problems, Table 6.3, the model of situation C with cocoa, other crops and off-farm activity problems, and Table 6.4, the model of farm situation D using wage labour as a complementary of family workforce available.

	P01	P02	P03	P04	P05	P06	RHS
R01	1	1	1				≤ 1 2 3 4
R03	125	199	256	36			≤ 975
R04	37.5	43	43				≤ 90
R05	37.5	43	43				≤ 90
R06	50	109	166	36			≤ 500
R07	-.5	-1	-1.5	1	1		≤ 0
R08				-.9		1	≤ 0
Variable cost (.000 Rupiah)	10	375	530	50			
Selling price (.000 Rupiah per 1000 kg)					1500	1800	
Gross margin	-10	-375	-530	-50	1500	1800	

Table 6.1 The model of situation A, the sole cocoa cropping farming system

The explanation of columns and rows of table 6.1 is:

P01 = an extensive cocoa growing activity. The unit of activity is a hectare.
P02 = a semi-intensive cocoa growing activity. The unit of activity is a hectare.
P03 = an intensive cocoa growing activity. The unit of activity is a hectare.
P04 = a fermentation activity. The unit of activity is 1000 kg.
P05 = a direct selling of cocoa activity. The unit of activity is 1000 kg unfermented product.
P06 = a non-direct selling of cocoa activity. The unit of activity is 1000 kg fermented product.
R01 = land restraint. The RHS column entry is hectares.
R03 = labour total restraint. The RHS column entry is man-days.
R04 = January (the first fertilizing, weeding and pruning) labour restraint. The RHS column entry is man-days.
R05 = September (the second fertilizing, weeding and pruning) labour restraint. The RHS column entry is man-days.
R06 = March - August (harvesting and drying, and fermentation) labour restraint. The RHS column is man-days.
R07 = unfermented cocoa production. The transfer unit is 1000 kg.
R08 = fermented production. The transfer unit is 1000 kg.

	P01	P02	P03	P04	P05	P06	P07	P08	P09	P10	P11	P12	P13	P14	P15	P16	RHS
R01	1	1	1	1	1	1	1	1	1	1	1						≤ 1 2 3 4
R02										1	1						≤ .1 .2 .3 .4
R03	125	199	256	50	80	125	150	264	364	100	250	36					≤ 975
R04	37.5	43	43	5	9.5	12	40.5	50.5	55	30	30						≤ 90
R05	37.5	43	43	5	8.5	13	44.5	59.5	69	0	30						≤ 90
R06	50	109	166	24	36	60	57	130	200	50	125	36					≤ 500
R07	-.5	-1	-1.5				-.5	-1	-1.5			1	1				≤ 0
R08												-.9		1			≤ 0
R09				-0.6	-1	-1.5	-.3	-.6	-1						1		≤ 0
R10										-.3	-.8					1	≤ 0
Variable cost (.000 Rupiah)																	
	10	375	530	10	197.5	375	10	622.5	955	200	510	50					
Selling price (.000 Rupiah per 1000 kg)																	
													1500	1800	800	250	
Gross margin																	
	-10	-375	-530	-10	-197.5	-375	-10	-622.5	-955	-200	-510	-50	1500	1800	800	250	

Table 6.2 The model of situation B, cocoa and other crops' farming system

The explanation of columns and rows of table 6.2 is:

P01 = an extensive cocoa growing activity. The unit of activity is a hectare.
P02 = a semi-intensive cocoa growing activity. The unit of activity is a hectare.
P03 = an intensive cocoa growing activity. The unit of activity is a hectare.
P04 = an extensive coconut growing activity. The unit of activity is a hectare.
P05 = a semi-intensive coconut growing activity. The unit of activity is a hectare.
P06 = an intensive coconut growing activity. The unit of activity is a hectare.
P07 = an extensive cocoa-coconut intercropping growing activity. The unit of activity is a hectare.
P08 = a semi-intensive cocoa-coconut intercropping growing activity. The unit of activity is a hectare.
P09 = an intensive cocoa-coconut intercropping growing activity. The unit of activity is a hectare.
P10 = a semi-intensive rice growing activity. The unit of activity is a hectare.
P11 = an intensive rice growing activity. The unit of activity is a hectare.
P12 = a fermentation activity. The unit of activity is 1000 kg.
P13 = a direct selling of cocoa activity. The unit of activity is 1000 kg unfermented product.
P14 = a non-direct selling of cocoa activity. The unit of activity is 1000 kg fermented product.
P15 = a direct selling of coconut activity. The unit of activity is 1000 kg
P16 = a direct selling of rice activity. The unit of activity is 1000 kg.

R01 = land restraint. The RHS column entry is hectares.
R02 = wet rice land restraint. The RHS column entry is hectares.
R03 = labour total restraint. The RHS column entry is man-days.
R04 = January (the 1st fertilizing, weeding and pruning) labour restraint. The RHS column entry is man-days.
R05 = September (the 2nd fertilizing, weeding and pruning) labour restraint. The RHS column entry is man-days.
R06 = March - August (harvesting, drying and fermentation) labour restraint. The RHS column is man-days.
R07 = unfermented cocoa production. The transfer unit is 1000 kg.
R08 = fermented cocoa production. The transfer unit is 1000 kg.
R09 = coconut production. The transfer unit is 1000 kg.
R10 = rice production. The transfer unit is 1000 kg.

	P01	P02	P03	P04	P05	P06	P07	P08	P09	P10	P11	P12	P13	P14	P15	P16	P17	P18	P19	P20	P21	RHS
R01	1	1	1	1	1	1	1	1	1	1	1											≤ 1 2 3 4
R02										1	1											≤ .1 .2 .3 .4
R03	125	199	256	50	80	125	150	264	364	100	250	36					1	1	1	1	1	≤ 975
R04	37.5	43	43	5	9.5	12	40.5	50.5	55	30	30							1			.08	≤ 90
R05	37.5	43	43	5	8.5	13	44.5	59.5	69	0	30								1		.08	≤ 90
R06	50	109	166	24	36	60	57	130	200	50	125	36								1	.5	≤ 500
R07	-.5	-1	-1.5				-.5	-1	-1.5			1	1									≤ 0
R08												-.9		1								≤ 0
R09				-0.6	-1	-1.5	-.3	-.6	-1						1							≤ 0
R10										-3	-8					1						≤ 0
Variable cost (.000 Rupiah)	10	375	530	10	197.5	375	10	622.5	955	200	510	50										
Selling price (.000 Rupiah per 1000 kg)													1500	1800	800	250						
Wage/man-day (.000 Rupiah)																	2.5	5	5	5	3	
Gross margin	-10	-375	-530	-10	-197.5	-375	-10	-622.5	-955	-200	-510	-50	1500	1800	800	250	2.5	5	5	5	3	

Table 6.3 The model of situation C, cocoa, other crops and off-farm activity problems

The explanation of columns and rows of table 6.3 is:

P01 = an extensive cocoa growing activity. The unit of activity is a hectare.
P02 = a semi-intensive cocoa growing activity. The unit of activity is a hectare.
P03 = an intensive cocoa growing activity. The unit of activity is a hectare.
P04 = an extensive coconut growing activity. The unit of activity is a hectare.
P05 = a semi-intensive coconut growing activity. The unit of activity is a hectare.
P06 = an intensive coconut growing activity. The unit of activity is hectare.
P07 = an extensive cocoa-coconut intercropping growing activity. The unit of activity is a hectare.
P08 = a semi-intensive cocoa-coconut intercropping growing activity. The unit of activity is a hectare.
P09 = an intensive cocoa-coconut intercropping growing activity. The unit of activity is a hectare.
P10 = a semi-intensive rice growing activity. The unit of activity is a hectare.
P11 = an intensive rice growing activity. The unit of activity is a hectare.
P12 = a fermentation activity. The unit of activity is 1000 kg.
P13 = a direct selling of cocoa activity. The unit of activity is 1000 kg unfermented product.
P14 = a non-direct selling of cocoa activity. The unit of activity is 1000 kg fermented product.
P15 = a direct selling of coconut activity. The unit of activity is 1000 kg
P16 = a direct selling of rice activity. The unit of activity is 1000 kg.
P17 = off-farm activity on the period not including peak season. The unit of activity is a man-day.
P18 = off-farm activity in January (peak season). The unit of activity is a man-day.
P19 = off-farm activity in September (peak season). The unit of activity is a man-day.
P20 = off-farm activity in March-August (peak season). The unit of activity is a man-day.
P21 = off-farm activity in all through the year. The unit of activity is a man-day.

R01 = land restraint. The RHS column entry is hectares.
R02 = wet rice land restraint. The RHS column entry is hectares.
R03 = labour total restraint. The RHS column entry is man-days.
R04 = January (the first fertilizing, weeding and pruning) labour restraint. The RHS column entry is man-days.
R05 = September (the second fertilizing, weeding and pruning) labour restraint. The RHS column entry is man-days.
R06 = March - August (harvesting and drying, and fermentation) labour restraint. The RHS column entry is man-days.
R07 = unfermented cocoa production. The transfer unit is 1000 kg.
R08 = fermented cocoa production. The transfer unit is 1000 kg.
R09 = coconut production. The transfer unit is 1000 kg.
R10 = rice production. The transfer unit is 1000 kg.

	P01	P02	P03	P04	P05	P06	P07	P08	P09	P10	P11	P12	P13	P14	P15	P16	P17	P18	P19	P20	P21	RHS
R01	1	1	1	1	1	1	1	1	1	1	1											≤ 1 2 3 4
R02										1	1											≤ .1 .2 .3 .4
R03	125	199	256	50	80	125	150	264	364	100	250	36					-1	-1	-1	-1	-1	≤ 975
R04	37.5	43	43	5	9.5	12	40.5	50.5	55	30	30							-1			-.08	≤ 90
R05	37.5	43	43	5	8.5	13	44.5	59.5	69	0	30								-1		-.08	≤ 90
R06	50	109	166	24	36	60	57	130	200	50	125	36								-1	-.5	≤ 500
R07	-.5	-1	-1.5				-.5	-1	-1.5			1	1									≤ 0
R08												-.9		1								≤ 0
R09				-0.6	-1	-1.5	-.3	-.6	-1						1							≤ 0
R10										-3	-8					1						≤ 0
Variable cost (.000 Rupiah)	10	375	530	10	197.5	375	10	622.5	955	200	510	50										
Selling price (.000 Rupiah per 1000 kg)													1500	1800	800	250						
Wage/man-day (.000 Rupiah)																	2.5	5	5	5	3	
Gross margin	-10	-375	-530	-10	-197.5	-375	-10	-622.5	-955	-200	-510	-50	1500	1800	800	250	-2.5	-5	-5	-5	-3	

Table 6.4 The model of farm situation by employing a salaried workforce from outside the farm.

The explanation of columns and rows of table 6.4 is:

P01 = an extensive cocoa growing activity. The unit of activity is a hectare.
P02 = a semi-intensive cocoa growing activity. The unit of activity is a hectare.
P03 = an intensive cocoa growing activity. The unit of activity is a hectare.
P04 = an extensive coconut growing activity. The unit of activity is a hectare.
P05 = a semi-intensive coconut growing activity. The unit of activity is a hectare.
P06 = an intensive coconut growing activity. The unit of activity is hectare.
P07 = an extensive cocoa-coconut intercropping growing activity. The unit of activity is a hectare.
P08 = a semi-intensive cocoa-coconut intercropping growing activity. The unit of activity is a hectare.
P09 = an intensive cocoa-coconut intercropping growing activity. The unit of activity is a hectare.
P10 = a semi-intensive rice growing activity. The unit of activity is a hectare.
P11 = an intensive rice growing activity. The unit of activity is a hectare.
P12 = a fermentation activity. The unit of activity is 1000 kg.
P13 = a direct selling of cocoa activity. The unit of activity is 1000 kg unfermented product.
P14 = a non-direct selling of cocoa activity. The unit of activity is 1000 kg fermented product.
P15 = a direct selling of coconut activity. The unit of activity is 1000 kg
P16 = a direct selling of rice activity. The unit of activity is 1000 kg.
P17 = a hired labour activity on the period not including peak season. The unit of activity is a man-day.
P18 = a hired labour activity in January (peak season). The unit of activity is a man-day.
P19 = a hired labour activity in September (peak season). The unit of activity is a man-day.
P20 = a hired labour activity in March-August (peak season). The unit of activity is a man-day.
P21 = a hired labour activity in all through the year. The unit of activity is a man-day.

R01 = land restraint. The RHS column entry is hectares.
R02 = wet rice land restraint. The RHS column entry is hectares.
R03 = labour total restraint. The RHS column entry is man-days.
R04 = January (the first fertilizing, weeding and pruning) labour restraint. The RHS column entry is man-days.
R05 = September (the second fertilizing, weeding and pruning) labour restraint. The RHS column entry is man-days.
R06 = March - August (harvesting and drying, and fermentation) labour restraint. The RHS column entry is man-days.
R07 = unfermented coco production. The transfer unit is 1000 kg.
R08 = fermented cocoa production. The transfer unit is 1000 kg.
R09 = coconut production. The transfer unit is 1000 kg.
R10 = rice production. The transfer unit is 1000 kg.

6.4 An optimal application of technology

If the results of analysis are recapitulated in a simple table as can be seen in table 6.5 below, for the farming situation A with the sole cocoa cropping activities, the optimal solution can be reached on the farm size level of about 2.1 hectares. At this stage the object function of gross margin is Rupiah (Rp.) 3,819,000. The same value will be obtained when the limit of farm size constraint is increased to 4 hectares, however at this stage 1.9 hectares (Table 6.6) of unused land emerges. The maximum production selling in the form of fermented cocoa is also obtained at this level with the volume of 2.82 tonnes.

Farm size (ha)	1	2	3	4
1 Optimal farm plan				
- Intensive cocoa (ha)	1	2	2.10	2.10
- Non-direct selling cocoa (1000 kg)	1.35	2.70	2.82	2.82
- Gross margin (1000 Rupiahs)	1825	3650	3819	3819
2 Reduced cost				
- Extensive cocoa (1000 Rupiahs/ha)	1050	1050	816	816
- Semi-intensive cocoa (1000 Rupiahs/ha)	630	630	630	630
- Direct selling cocoa (1000 Rupiahs/kg)	70	70	70	70

Table 6.5 Summary results of optimal solution for problem of sole cropping of cocoa exploitation.

The optimal used of family workforce is also achieved at this stage, which is 649 man-days. The reduced costs of extensive treatment are Rp. 1.050,000 per hectare at the levels of 1 and 2 hectares, diminish to Rp. 816,000 at the levels 3 and 4 hectares. For the semi-intensive cocoa treatment, the reduced costs are lower, at Rp. 595,000. While the reduced cost of fermented cocoa for all levels of exploitation is Rp. 70,000. This optimal farm size is lower than the average farm hectare actually exploited per farmer household which is about 2.9 hectares. In this optimal stage, all farm workforces available have not yet been used, since 326 man-days of farmer workforce remain (Table 6.6).

Farm size (ha)	1		2		3		4	
Constraint	Slack	Shadow price	Slack	Shadow price	Slack	Shadow price	Slack	Shadow price
- land (ha)	0	1825	0	1825	*.90*	0	*1.90*	0
- total labour (man-day)	*665*	0	*355*	0	*326*	0	*326*	0
- January's period (man-day)	*47*	0	*4*	0	0	0	0	0
- September's period (man-day)	*47*	0	*4*	0	0	42	0	42
- March-August period (man-day)	*280*	0	*60*	0	*39*	0	*39*	0

Table 6.6 Constraints of farm activity in a sole cocoa cropping situation

At the peak harvest season for cocoa, that takes place from March to August, 39 man-days remain. Other constraints on the model seem to be zero or binding. The shadow price, which is defined as the value level of the object function approximately changes if the right-hand-side of that constraint increases one unit, apparently for the land constraint at the level 1 and 2 hectares shows Rp. 1,825,000; this means, every increase of one hectare of farm size in these levels will increase Rp. 1,825,000 of farm gross margin. The shadow prices for September's period for the farm sizes' level of 3 and 4 hectares that are Rp. 42,000 per man-day, are also a prevailing value for the constraint of January' period, since these two limitations exhaust in the same time. It can be concluded that the optimal solution for sole cocoa cropping farm is achieved by introducing intensification treatment through application production inputs and fermentation, and by employing the family workforce available optimally.

For the second situation (Table 6.7 and 6.8), situation B or the situation of diversified exploitation which consists of a cocoa-coconut intercropping plot with a paddy plot, it is found that the farm size with 4 hectares has the best value object function of gross margin, of Rp. 4,581,000. With this farm size, 235 man-days of the total family workforce remain unused. Besides that, 52 man-days of the workforce in the peak harvest season remain unused. At this level the reduced costs of all activities have become constant, as follows:

Farm size (ha)	1	2	3	4
1 Optimal farm plan				
- Intensive cocoa (ha)	0	1.85	1.68	1.30
- Intensive coconut (ha)	0	0	1.22	2.60
- Intensive cocoa-coconut intercropping (ha)	1	.15	0	0
- Semi-intensive paddy (ha)	0	0	.04	.09
- Intensive paddy (ha)	0	0	.05	.01
- Non-direct selling cocoa (1000 kg)	1.35	2.70	2.27	1.75
- Direct selling coconut (1000 kg)	1	.15	1.82	3.90
- Direct selling paddy (1000 kg)	0	0	.59	.36
- Gross margin (1000 Rupiahs)	2200	3707	4187	4581
2 Reduced cost				
- Extensive cocoa (1000 Rupiahs/ha)	1425	970	867	867
- Semi-intensive cocoa (1000 Rupiahs/ha)	1005	630	630	630
- Intensive cocoa (1000 Rupiahs/ha)	375	0	0	0
- Extensive coconut (1000 Rupiahs/ha)	1730	806	90	90
- Semi-intensive coconut (1000 Rupiahs/ha)	1597	724	76	76
- Intensive coconut (1000 Rupiahs/ha)	1375	567	0	0
- Extensive cocoa-coconut intercropping (1000 Rupiahs/ha)	1185	831	852	852
- Semi-intensive cocoa-coconut intercropping (1000 Rupiahs/ha)	772	635	929	929
- Intensive cocoa-coconut intercropping (1000 Rupiahs/ha)	0	0	462	462
- Semi-intensive paddy (1000 Rupiahs/ha)	1650	654	0	0
- Intensive paddy (1000 Rupiahs/ha)	710	147	0	0
- Non-fermented cocoa (1000 Rupiahs/kg)	70	70	70	70

Table 6.7 Summary results of optimal solution for exploitation problem of cocoa-coconut intercropping and paddy diversification.

This result is not yet the optimal value since the maximum value will be achieved on the farm size level of 18 hectares, with 18 hectares of extensive coconut and direct selling of 10.8 tonnes of coconut. At this stage the value object function will attain Rp. 8,460,000, although 75 man-days of the total family workforce and 68 man-days of March-August's workforce remain unused. Further, if the farm size is increased further at the same level, maintaining other constraints, the value object function of gross margin remains equal. This means that the optimal solution to farm problems in the situation of cocoa-coconut intercropping plot with paddy plot farming can be obtained on the farm size level of about 18 hectares.

Farm size (ha)	1		2		3		4	
Constraint	Slack	Shadow price	Slack	Shadow price	Slack	Shadow price	Slack	Shadow price
- land (ha)	0	2200	0	1204	0	394	0	394
- paddy land (ha)	*.10*	0	*.10*	0	0	97	0	0
- total labour (man-day)	*557*	0	*338*	0	*282*	0	*235*	0
- January's period (man-day)	*35*	0	2	0	1	0	0	9
- September's period (man-day)	*21*	0	0	14	0	31	0	31
- March-August period (man-day)	*246*	0	*55*	0	*47*	0	*52*	0

Table 6.8 Constraints of activity in the situation of cocoa intercropping with other crops

The activities that possibly contribute to an optimal solution for the farm situation cocoa intercropping with other crops at a farm level of 1 hectare are that of intensive cocoa intercropping and fermentation. At a farm level of 2 hectares the contributions become different with emerging of the intensive cocoa of 1.85 ha, diminishing with intensive cocoa intercropping to 0.15 ha, the increase of the selling of fermented cocoa up to 2.70 tonnes and diminishing of coconut selling to only 150 kg. At farm levels of 3 and 4 hectares the activities are more diversified with the emergence of semi-intensive paddy (.04 and .09 ha) and intensive paddy exploitation (.05 and .01 ha). Moreover in the last two levels, the contribution of intensive cocoa diminishes to 1.68 and 1.30 hectares, and otherwise there is an increase in intensive coconut cultivation, 1.22 and 2.60 hectares, and of course an increase in coconut production selling. This can be explained by the fact that the constraint of workforce used for intensive cocoa is higher than intensive coconut. As a consequence, the decrease of intensive cocoa causes the diminishing of labour used, particularly at the peak season of the cocoa harvest. As table 6.8 shows, the labour unused for the March-August period diminishes up to the farm size 3 hectares, which further increases to 52 man-days on the farm size of 4 hectares, since the decrease of the intensive cocoa is more noticeable than the increase of the intensive coconut area.

If a farm size of 3 hectares in situation B is compared with farm situation A, the optimal farm gross margin that can be obtained is about Rp. 4,187,000, being about Rp. 368,000 more than at the same size in situation A with sole cocoa cropping. However, at this stage there is still about 282 man-days unused. This result shows the possibility of increasing the gross margin of small farmers to at least 10% when farmers exploit cocoa intercropping with coconut and paddy plots.

In situation C where cocoa intercropping with coconut is accompanied by paddy plots and off-farm activities, the best gross margin obtained is Rp. 5,529,000 for the farm size of 4 hectares. The optimal farm plan in this situation is achieved by the combination of an intensive cocoa, an intensive coconut production and by employing part of the family workforce off-farm. The activities that contribute to the objective function at this farm size level are intensive cocoa (1.21 ha), intensive coconut (2.69 ha), intensive paddy (.10 ha) direct selling of cocoa (1.81 tonnes), direct selling of coconut production (4.0 tonnes), direct selling of rice (.80 tonnes) and employing family workforces at the off-peak season (176 man-days) and the peak harvest season (125 man-days) during the period of March-August (Table 6.9). While for the farm size of 1 and 2 hectares, the contribution to the optimal farm plan of family workforce members who works at off-farm activities comes from the off-peak period, January, September and peak harvest periods, which are for a farm size of 1 hectare of 291, 47, 47 and 334 man-days and for a farm size of 2 hectares of 287, 4, 4 and 168 man-days respectively. As could be seen from the table 6.9, the reduced costs become constant when the farm size level becomes higher. The same indication could be found in the case of the shadow prices of constraint. Up to the farm size levels of 3 and 4 hectares all land for paddy are used.

Farm size (ha)	1	2	3	4
1 Optimal farm plan				
- Intensive cocoa (ha)	1	2	1.64	1.21
- Intensive coconut (ha)	0	0	1.25	2.69
- Intensive paddy (ha)	.10	0	.10	.10
- Direct selling cocoa (1000 kg)	1.5	3	2.46	1.81
- Direct selling coconut (1000 kg)	0	0	.80	4.0
- Direct selling rice (1000 kg)	0	0	.80	.80
- Off-peak season activity (man-day)	291	287	231	176
- January's off-farm activity (man-day)	47	4	1	2
- September's off-farm activity (man-day)	47	4	0	0
- March-August off-farm activity (man-day)	334	168	139	125
- Gross margin (1000 Rupiahs)	4587	5037	5294	5529
2 Reduced cost				
- Extensive cocoa (1000 Rupiahs/ha)	335	335	307	307
- Semi-intensive cocoa (1000 Rupiahs/ha)	310	310	310	310
- Extensive coconut (1000 Rupiahs/ha)	190	145	0	0
- Semi-intensive coconut (1000 Rupiahs/ha)	182	107	10	10
- Intensive coconut (1000 Rupiahs/ha)	150	37	0	0
- Extensive cocoa-coconut intercropping (1000 Rupiahs/ha)	200	177	207	207
- Semi-intensive cocoa-coconut intercropping (1000 Rupiahs/ha)	352	307	435	435
- Intensive cocoa-coconut intercropping (1000 Rupiahs/ha)	75	0	205	205
- Semi-intensive paddy (1000 Rupiahs/ha)	332	332	152	152
- Selling of fermented cocoa (1000 Rupiahs/kg)	122	122	110	110
- September's off-farm activity (1000 Rupiahs/man-day)	0	0	5	5
- Along year off-farm activity (1000 Rupiahs/man-day)	1.15	1.15	1.55	1.55

Table 6.9 Summary of results of optimal solution for exploitation problem of cocoa-coconut intercropping with paddy plot and off-farm activity diversification.

Farm size (ha)	1		2		3		4	
Constraint	Slack	Shadow price	Slack	Shadow price	Slack	Shadow price	Slack	Shadow price
- land (ha)	0	450	0	450	0	235	0	235
- paddy land (ha)	*.10*	0	*.10*	0	0	17,5	0	17.5
- total labour (man-day)	0	2.5	0	2.5	0	2.5	0	2.5
- January's period (man-day)	0	2.5	0	2.5	0	2.5	0	2.5
- September's period (man-day)	0	2.5	0	2.5	0	7.5	0	7.5
- March-August period (man-day)	0	2.5	0	2.5	0	2.5	0	2.5

Table 6.10 Constraints of activity in the situation of cocoa intercropping with other crops and off-farm activities

With a farm size of 2 hectares in situation C, the maximum farm gross margin obtained is Rp. 5,037,000, being about Rp. 1,387,000 and Rp. 1,330,000 higher than situation A with sole cocoa cropping and farm situation B, cocoa diversified with coconut and paddy. The result shows the opportunity of farmers to increase their gross margin by at least 38 and 35% when they also make use of their family labour in off-farm activity. The additional revenue can be obtained by making optimally use of the remaining family workforce in larger, surrounding farms.

The optimal farm plan solution obtained becomes different when farmers hire a workforce from another farm. As can be seen in Table 6.11, the optimal farm plan is obtained through an intensive cocoa intercropping with other crops, an intensive paddy crop, fermentation of cocoa or the indirect sale of cocoa, and the direct sale of coconut. However, fermentation cocoa contributes to the optimal farm plan only at 1 and 2 hectare levels. At 3 and 4 hectare levels the direct selling or unfermented cocoa emerges in the optimal farm plan. The gross margins obtained for all farm size levels are Rp. 2,200,000; 4.044,000; 4,889,000 and 5,484,000. This result shows that the farm size levels of 4 hectares give a higher gross margin which is almost the same with gross margin of farm size of 4 hectares of farming situation D. This means that despite farmers spending an amount of money for paying hired labours at this farm size level, it is more profitable for the farmers to apply pre-harvest related to intensive cocoa-coconut intercropping which are combined by employing hired labour, than to exploit their farm using other forms of technology, such as fermentation application. This indicates that at certain level the application of fermentation is determined by the availability of labour. The problem faced by farmers in this situation is that the workforce requirement during peak periods cannot be fulfilled by the workforce available. As can be seen in Table 6.12, the unused workforces are still high for each level of farm size. However these workforces are the ones which are allocated in off-peak periods.

Farm size (ha)	1	2	3	4
1 Optimal farm plan				
- Intensive cocoa intercropping (ha)	1	2	2.9	3.9
- Intensive paddy (ha)	0	0	.10	.10
- Non-direct selling cocoa (1000 kg)	1.35	2.50	0	0
- Direct selling cocoa (1000 kg)	0	.22	4.35	5.85
- Direct selling coconut (1000 kg)	1	2	2.9	3.9
- Direct selling rice (1000 kg)	0	0	.80	.80
- Hired labour in January (man-day)	0	20	57	80
- Hired labour in September (man-day)	0	48	98	135
- Hired labour in all through the year (man-day)	0	0	185	585
- Gross margin (1000 Rupiahs)	2200	4044	4889	5484
2 Reduced cost				
- Extensive cocoa (1000 Rupiahs/ha)	1425	818	450	450
- Semi-intensive cocoa (1000 Rupiahs/ha)	1005	603	379	379
- Intensive cocoa (1000 Rupiahs/ha)	375	118	35	35
- Extensive coconut (1000 Rupiahs/ha)	1730	712	280	280
- Semi-intensive coconut (1000 Rupiahs/ha)	1597	643	240	240
- Intensive coconut (1000 Rupiahs/ha)	1375	902	159	159
- Extensive cocoa-coconut intercropping (1000 Rupiahs/ha)	1185	641	290	290
- Semi-intensive cocoa-coconut intercropping (1000 Rupiahs/ha)	772	531	359	359
- Semi-intensive paddy (1000 Rupiahs/ha)	1650	783	460	460
- Intensive paddy (1000 Rupiahs/ha)	710	139	92	0
- Selling non-fermented cocoa (1000 Rupiahs/kg)	70	0	0	0
- Selling fermented cocoa (1000 Rupiahs/kg)	0	0	88	88
- Direct selling paddy (1000 Rupiahs/ha)	0	35	0	0
- Hired labour in non-peak season (1000 Rupiahs/man-day)	2.5	2.5	2.5	2.5
- Hired labour in January (1000 Rupiahs/man-day)	5	0	0	0
- Hired labour in September (1000 Rupiahs/man-day)	5	0	0	0
- Hired labour in March-August (1000 Rupiahs/man-day)	5	3	.6	.6
- Hired labour in all through the year (1000 Rupiahs/man-day)	3	1.2	0	0

Table 6.11 Summary of results of optimal solutions for exploitation problems, employing salaried workforces

Farm size (ha)	1		2		3		4	
Constraint	Slack	Shadow price	Slack	Shadow price	Slack	Shadow price	Slack	Shadow price
- land (ha)	0	2200	0	1086	0	595	0	595
- paddy land (ha)	*.10*	0	*.10*	0	0	45	0	45
- total labour (man-day)	*557*	0	*215*	0	*235*	0	*331*	0
- January period (man-day)	*35*	0	0	5	0	5	0	0
- September period (man-day)	*21*	0	0	5	0	5	0	5
- March-August period (man-day)	*246*	0	0	1.9	0	4.4	0	4.4

Table 6.12 Constraints on activity in farm situation D, employing salaried workforces

To illustrate, when the results of the optimization of cocoa farm activities are compared with the actual practices of cocoa farmers in the region, and by considering the farm size of 2 hectares as the basis of comparison as can be seen in table 6.13, there are still great opportunities for farmers to gain higher gross margins by making optimal use of the available technology and of their own resources.

Farm situation	Actual (Rp.000) (*)	Optimal (Rp.000)	Percent of Increase
Situation A	2.880	3.650	26
Situation B	3.160	3.707	17
Situation C	3.377	5.037	49
Situation D	3.106	4.044	30

Table 6.13 The comparison of farm gross margin between actual and optimal conditions of cocoa farmers of the Bupon region, South-Sulawesi. (*) *premier data*

In optimal farm situations, farmers who exploit cocoa as a sole cropping have the scope to increase their gross margin up to 26% and those who exploit cocoa and other crops have an opportunity to increase it by 17%. Farmers in farm situation C, diversification of cocoa with other crops and off-farm activities, could increase their gross margin by about 49% compared with the actual average level of farm gross margin. This opportunity will decrease to 30% if farmers hire labour from outer farms. Factors that contributed to the optimal farm plan will be described in the later discussion.

When the results of the optimal gross margin solution are summarized and depicted diagrammatically as in *Figure 6.1*, it can be concluded that a great opportunity remains to increase a gross margin of cocoa farmers who are cultivating a diversified cocoa farming.

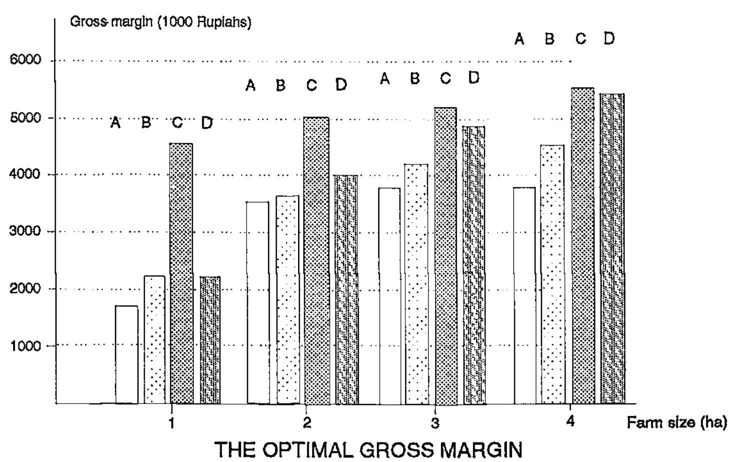

Figure 6.1 The optimal gross margin of cocoa farmers in various farm systems

Amongst these farm systems, apparently the most diversified farm system, cocoa intercropping with coconut crop, wet paddy plots and off-farm activities (situation C) shows intercropping with coconut crop, wet paddy plots and off-farm activities (situation C) shows the highest gross margin for all farm size levels. The more diversified activity the higher gross margin can be obtained by farmers. This can be achieved by farmers through:

(1) Intensifying the employment of the family workforce owned, according to the requirement period and the type of activity. As can be seen in *Figure 6.2*, the more diversified the activity, the more intensive the employment of the family workforce. When the two graphics (*Figure 6.1 and 6.2*) are juxtaposed, it can be seen that the more intensive the employment of the family workforce, the higher gross margin obtained by each situation and level of activity. Undoubtedly, in the case of cocoa smallholders in the region, the farmers' family workforce contributes significantly to the optimal farm plan of cocoa farmers.

The optimal solution results point out that in as far as the farmers only employ their family workforce, neither level of farm size or farm situation of the farm systems has used all the family workforce power available. This unused workforce within the farm can contribute revenue by working on off-farm activity. This indicates that cocoa farmers in the region possibly continue to expand and/or to intensify their cocoa exploitation.

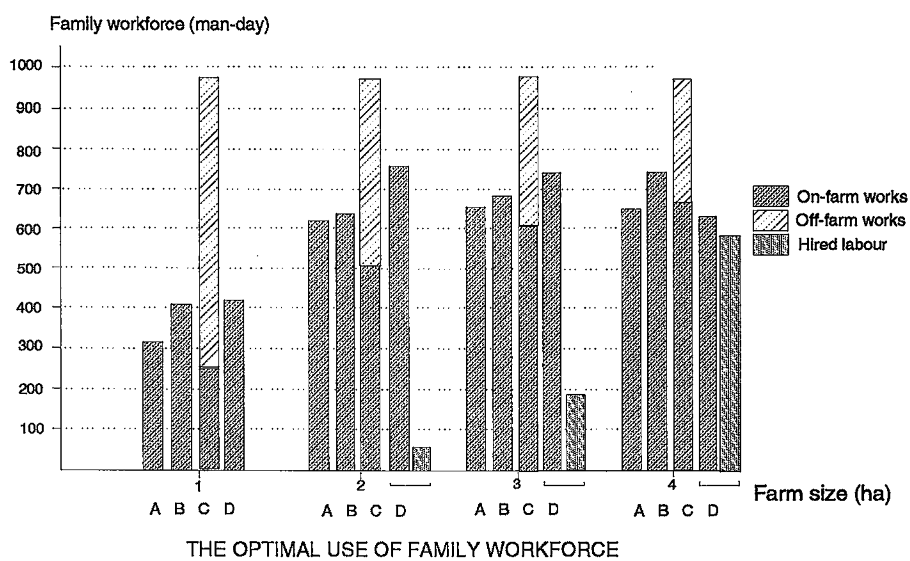

Figure 6.2 The employment of family workforce at each level and situation of farm system

(2) Intensifying and diversifying the application of land owned. This means that the use of technology might be adapted to a farm condition and the suitability of land available. With the farm situation A, sole cocoa cropping, an intensive cocoa treatment is the best solution. With the farm situation B, cocoa intercropping with coconut and *sawah* plots, the degree of

optimal solution at each level of farm size is different. At a farm size of 1 hectare, 1 hectare of the intensive cocoa-coconut intercropping gives the optimal result solution of gross margin. This intensive intercropping diminishes to .15 ha at a farm size of 2 hectares. However, at this stage it appears 1.85 hectares of intensive cocoa. At a size of 3 and 4 hectares, intensive coconut and a semi-intensive and an intensive paddy crop are included in the optimal farm plan. The contribution of intensive coconut increases from 1.22 hectares at a farm size of 3 hectares to 2.60 hectares at the farm size of 4 hectares. The contributions of semi-intensive and intensive paddy which are .04 and .05 hectares at 3 hectares, changes to .09 and .01 hectares at 4 hectares. With the situation of the most diversified activities, situation C, an intensive cocoa and an intensive coconut production contribute to the optimal solution of gross margin. At a level of 1 and 2 hectares, only the intensive cocoa with a land size of 1 and 2 hectares contributes to the optimal farm plan. The size of this activity diminished (1.21 hectares) at a farm size of 4 hectares which is replaced by an increase in intensive coconut cultivation of 2.69 hectares. If farmers hire labour (situation D), an intensive cocoa-coconut intercropping for each level will result in the best optimal solution of gross margin.

By comparing the description above, which is depicted in *Figure 6.3*, with the graphic in *Figure 6.1*, it becomes clear that the more intensively the land is used and the more diversified the farm system, the higher the object function of gross margin obtained. The contribution of land used for each size level and situation of activity can be presented in the following figure.

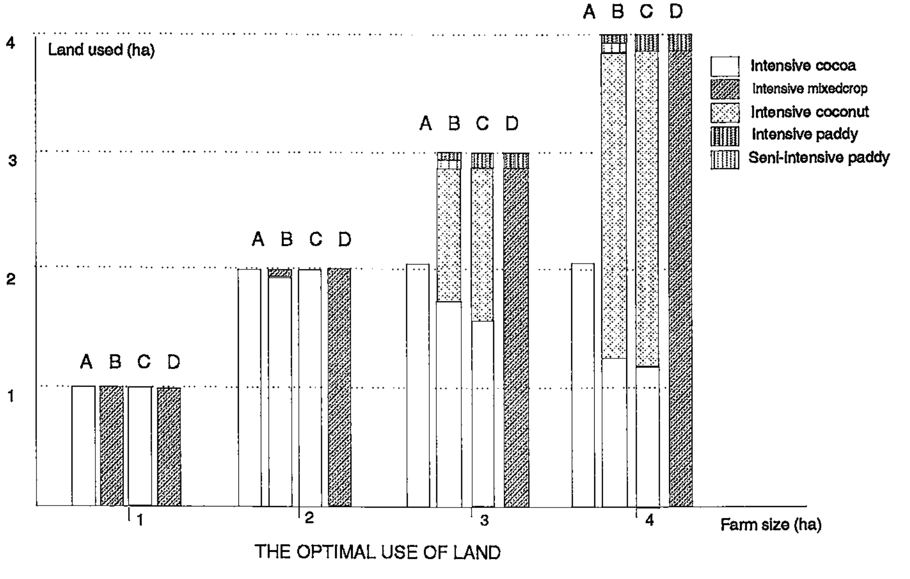

Figure 6.3 The optimal amount of land used for each level of farm system

(3) Particularly for the most diversified farm system, farm situation C, off-farm activity contributes remarkably to the optimal farm plan. 303 man-days of off-farm wage which

consists of 176 man-days in off-peak season work, 125 man-days in September's peak period and 2 man-days in January's peak period contribute to the best optimal solution of the farm situation C, at a farm size of 4 hectares. Apparently, working off-farm will give a higher revenue than the revenue disparity between fermentation and non-fermentation of cocoa. The graphic for production and selling activities which is also drawn in *Figure 6.4* shows that the larger the farm size, the smaller the number of family workforce-members working on the surrounding off-farm. This occurs since the greater the farm size, the more diversified the activities of farms. The latter needs a higher workforce than the smaller farms. It could be concluded that the economic gain in employing the family workforce off-farm would only be profitable for smaller cocoa farmers in the region who exploit a farm of less than 4 hectares.

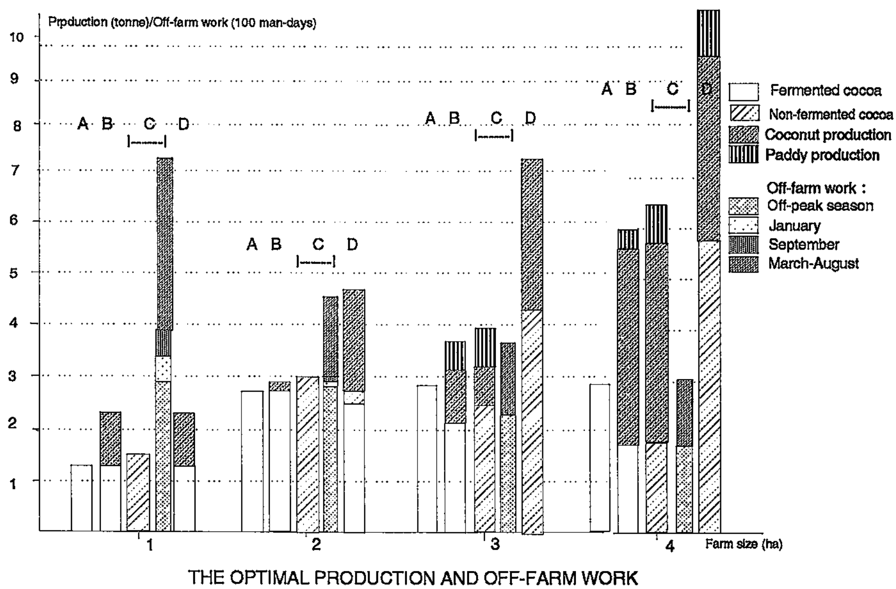

Figure 6.4 The optimal production and off-farm works for each level of farm systems

(4) Application of post-harvest technology to improve cocoa yield contributes to the optimal farm plan only at certain level and/or condition of farming. Fermented cocoa or the indirect selling is more profitable for farmers when farm activities are less diversified. The contribution of this activity combined with other production activities is also drawn in *Figure 6.4.* In the farm situation A, the indirect selling of all cocoa production are the main factors that determine the optimal solution of production. The activity becomes more diversified in farm situation B, which includes the direct selling of coconut and paddy in the optimal farm plan. At a farm level of 1 and 2 hectares, fermented cocoa or the indirect selling of cocoa, and the direct selling of coconut contribute 1.35 and 2.70 tonnes of fermented cocoa, and 1 and .15 ton of coconut. At a farm size of 3 and 4 hectares the three activities, selling of

fermented cocoa, direct selling of coconut and paddy yields contribute to the level of production by 2.27, 1.82, .80 and 1.75, 3.90, .80 tonnes respectively. With the farm situation C direct selling or unfermented cocoa and the direct selling of coconut accompanied by off-farm income contribute to the optimal farm plan. With the farm situation D where farmers hire labour also non-direct selling of fermented cocoa, direct selling of unfermented cocoa contribute to the optimal farm plan. However, while the fermented cocoa appears in the optimal plan on the levels of 1 and 2 hectares with 1,35 and 2.78 tonnes the selling of fermented cocoa, unfermented cocoa appears on the levels of 2, 3 and 4 hectares with .22, 4.35 and 5.85 tonnes the selling of unfermented cocoa.

Intensive treatment or application of production inputs does not run parallel with application of post-harvest technology. Contribution of intensification to the optimal farm plan is not pursued by fermentation application. The direct selling of cocoa production is more profitable than applying fermentation. However, the level of land diversification runs parallel with intensification treatment in contributing to the optimal farm plan. In the farm situation C, 3 tonnes of unfermented cocoa is obtained at a farm size of 2 hectares. This diminishes to 2.46 and 1.81 tonnes at a farm size of 3 and 4 hectares, since with these farm sizes, the intensive cultivation of coconut enters into the optimal farm plan. The latter contributes .80 tonnes in direct sales of coconut to the optimal gross margin if the farm size of 3 hectares, and 4.0 tonnes if the farm size is 4 hectares.

The price offered for fermented cocoa at the level of Rp. 1800/kg allows fermentation only in the case of labour is not limiting in the relevant period. This is the case in situation A and B and in situation D at the levels of 1 and 2 hectares. In the case of farming situation C and the levels of 3 and 4 hectares of farming D, a higher additional price of fermented cocoa is needed to allow fermentation to contribute to the optimal farm plan: attractive activities, such as salaried workforce at off-farm activity, result in a higher increase of gross margin than fermentation activity at a price of Rp. 1800/kg. In table 6.14 the critical price levels of fermented cocoa are presented for all farm situation.

	Farming situation			
Hectare	A	B	C	D
1	1720	1720	1922	1720
2	1720	1720	1922	1800
3	1720	1720	1910	1888
4	1720	1720	1910	1888

Table 6.14 Levels of critical price of fermented cocoa

To sum up, there is available room to optimize gross margin of cocoa farms in the region, which could be achieved by (a) intensifying the employment of the family workforce owned; (b) intensifying and diversifying the application of land owned; (c) making use of hired labour from farm surroundings; and (d) intensifying and optimizing the application of technology available.

Farmer's family was drying unfermented cocoa

CHAPTER 7 CONCLUSION AND DISCUSSION

7.1 Introduction

This study has contributed to the previous studies of technology adoption by cocoa farmers. This study distinguished four cocoa technologies, fertilizer, pesticide, herbicide and fermentation adoptions and applications. The empirical analysis and the linear programming analysis have resulted in a set of factors that contribute to explaining variance in technology adoption and application amongst cocoa farmers and factors that are maximized to reach an optimal outcome. Before discussing these results in detail, the overview of technology adoption and application in recent years is presented first. The conclusions of the analyses will be complemented by a résumé of relationships between the technology adoption and application and determinant factors that are associated with technology adoption processes. This will put the discussion in a general perspective.

The results of the study will also be compared to the results of other studies. Therefore, outcomes of previous studies will be important in drawing final conclusions. Based upon earlier empirical evidence and theoretical references, the discussion should provide the essential conditions, problems and factors that are associated with cocoa farmer decision-making processes in the region. The discussion of the results of the study that is preceded by the examination of hypotheses, will be presented in section 7.2. The conclusion of the findings will be presented in section 7.3 in terms of explaining several questions submitted previously.

At the end of this chapter, in section 7.4, implications and suggestions for future research will be presented. Both technical and socio-economic aspects that still need clarification by further studies will be discussed. Recommendations will be suggested for further studies in the context of cocoa development.

7.2 Discussion of results

The model and hypotheses that were developed in chapter 3 will be the basis of this discussion. Before starting the discussion on factors that are associated with cocoa technology adoption in the study, first the adoption levels of technology over time will be dealt with. All technologies used in the study as dependent factors are divisible and can be dispensed in small quantities. These technologies are said to be neutral in terms of scale (Ruthenberg, 1985) since they can be adopted as easily on small farms as on large ones. The divisible characteristic allows farmers to apply more than one kind of technology, particularly those farmers with limited economic resources with which to purchase production inputs. In this respect the constraint of lack of capital may be eliminated.

7.2.1 Technology adoption in recent years

Almost all farmers who adopted fertilizer also applied pesticides; there is a significant correlation between the two technologies ($r = .49$). The application of fertilizer influences the use of pesticide. When farmers in a limited financial condition, they tend to choose pesticide as a first priority. Despite their limitations, however, farmers always attempt to apply production inputs, particularly fertilizer and pesticide, to realize their objective of increasing cocoa production. Amongst the technology of production inputs, pesticide application is the one that is used most frequently. This seems to be because farmers have limited technical knowledge of the advantages and disadvantages of each form of technology. They often misinterpret the benefits and functions of a certain input. Pesticide application, for instance, is regarded as not only being a pest and disease control method but also a way of improving plant fertility. Besides that, the limited economic ability of farmers causes farmers to choose the most suitable alternative in accordance with their wealth when applying production inputs. Farmers tend to use pesticide combined with a small amount of fertilizer, even so the doses of pesticide and fertilizer used were less than the doses recommended. However, when their financial position allows them to purchase all production inputs needed, they usually apply those technologies to the full.

Broadly speaking, farmers recognize the objectives behind using a certain technology. They apply a technology at different levels according to their economic ability to purchase production inputs. We identify three levels of adoption of technologies: (1) not adoptive: farmers who do not apply a technology, (2) partially adoptive: farmers who adopt a technology under the level recommended, and (3) fully adoptive: farmers who adopt a technology at or over the recommended levels. Fermentation application is a special case as it is identified as not adopted or adopted. The feature which shows the proportion of cocoa farmers adopting technology in the region in 1993, as can be seen in the Table 7.1, shows the different levels at which of technologies are adopted.

Level of adoption	Technology application			
	Fertilizer	Pesticide	Herbicide	Fermentation*
Not adoptive	15	15	37	80
Partially adoptive	59	49	44	-
Fully adoptive	26	36	19	10
Total	100	100	100	100

Table 7.1 The proportion of cocoa farmers in the Bupon Region (South-Sulawesi) adopting technologies in 1993. (* *in the case of fermentation, data for 1992 and only not adoptive and adoptive)*

The proportion of cocoa farmers that apply production inputs is quite high, except for herbicide application (only used by 60% of farmers because in the remaining cases weeds did not grow anymore since cocoa canophies have contacted each other, giving them no reason to prolong use of the herbicide). The others, fertilizer and pesticide, were applied by a higher proportion of farmers. About 85% of farmers applied fertilizer and pesticide in 1993. The inverse is true for fermentation application, as about 80% of farmers in 1992 did not ferment cocoa.

The process of adopting technologies has taken place for a long time, as long as cocoa has been developed in the region. However, the levels of application have differed from time to time. The technology itself was recognized by farmers before cocoa development began in the region. At least, farmers had practiced the technology on other crops that they had exploited previously before getting involve in cocoa exploitation. The application of fertilizer, for instance, has generally been recognized and applied since 'the green revolution era' introduced in South-Sulawesi in the mid sixties. Therefore, it did not astonish extension services that, in the technical fertilizing of a paddy crop, fertilizer is only spread over soil surfaces and that farmers did this also on cocoa plantations, even though this practice is less effective. During the last five years (1989-1993), production input applications have tended to increase from year to year, as can be seen in *Figure 7.1*.

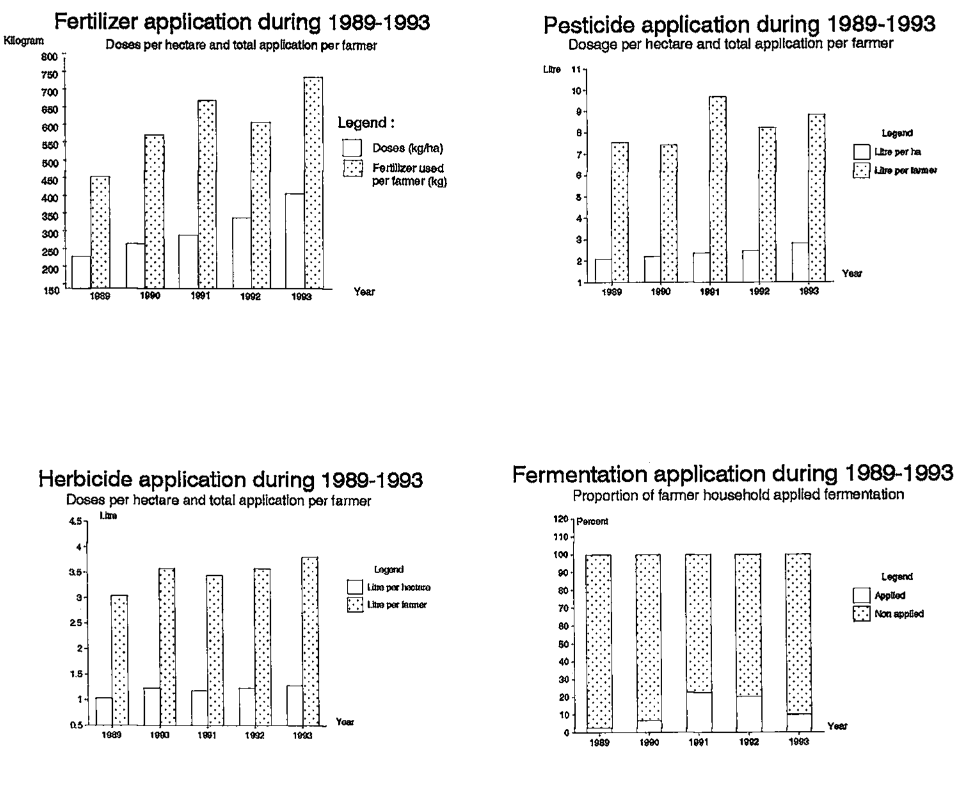

Figure 7.1 Levels of production input and fermentation applications during 1989-1993 by cocoa farmers in the Bupon Region, South-Sulawesi

In 1992, fertilizer consumption decreased because in that year the prices of fertilizer increased by about 35%. However, the following year fertilizer consumption increased again.

Similar tendencies can also be seen with pesticide and herbicide, although their increases were not as sharp as in the case of fertilizer. Fermentation was adopted by a low proportion of farmers. During the last five years it was only in the years 1991 and 1992, that 20% farmers fermented their cocoa, in other years fewer farmers, only 10% practiced fermentation. In 1993, 90% of the farmers did not ferment their cocoa, although 50% of them had had some fermentation experience in the past. This evidence is similar to the findings of Monu (1982) about the number of Nigerian' farmers that adopted fermentation technology recommended. The main obstacles that caused farmers to stop fermenting regularly were the small differences in prices between fermented and non-fermented cocoa and workforce and time efficiency. The prices of fermented cocoa were not attractive enough for them to put in the extra work needed for fermentation. The benefits from fermenting cannot compensate for the investment spent during the fermentation process. While the prices of unfermented cocoa were 1,400-1,500 Rupiahs/kg, the prices offered for fermented cocoa were only 1,500-1,600 Rupiahs/kg. This price differential was too small to compensate for the cost of minor materials and labour used when fermentation is performed. Farmers, particularly small farmers, have a considerable reason for not implementing fermentation since the price disparity is only 100-200 Rupiahs/kg, that means when they ferment their cocoa which is usually only in a small quantity (50-100 kg wet cocoa beans) for each harvest, farmers could obtain the additional revenue of about 5,000-10,000 Rupiahs. These amounts are not enough to compensate for expenditure on fermentation over 4-5 days. According to farmers, a difference of 300-500 Rupiahs/kg is sufficient to compensate for the costs of fermentation. This means that when the price of unfermented cocoa is 1,500 Rupiahs/kg, the price level of fermented cocoa must be about 1,800 Rupiahs/kg. The necessity of cash money immediately afterwards to spend on buying production inputs is another reason for not fermenting or not wanting to delay the selling of their cocoa. This means that for small farmers it is more efficient in terms of workforce used and time spent if their cocoa is unfermented than to delay selling cocoa 4-5 days more for fermenting and drying.

In general, farmers seemingly understood the advantages that can be obtained by using production inputs. Since the technology promises quite substantial increases in yield or big reductions in costs (Mosher 1970, Upton, 1983), farmers adopted the technology based on calculations of their gain. Apart from earning a better income, most farmers mentioned the objectives of increasing production and improving crop conditions by as their main reason for applying production inputs. About 88% of farmers gave increased production as the reason for the application of fertilizer. While 29% of farmers mentioned increased production as the main reason for using pesticide, 64% said improving the crop condition was their reason for applying pesticide. Improving the crop condition was mentioned by 26% of the farmers in the case of herbicide (Table 7.2). This main farmers' reason runs parallel with the finding by Clark and Akinbode (1968) in their study of farm practices in the Western State of Nigeria.

Most of the farmers had pre-conceived ideas about utilizing pesticides, and even herbicides, that went beyond the bounds of their true function. They presumed that pesticide application was not only for pest and disease controls but that these chemical products could provide other benefits. They thought, for example, that pesticide might improve cocoa fertility directly. According to them, after spraying cocoa with certain pesticides or herbicides, their plants became greener straight away. Farmers rarely used fungicide. Certain farmers never used it, even though their cocoa was seriously injured by plant diseases.

Reason	Fertilizer application	Pesticide application	Herbicide application	Fermentation application
1 No opinion	1	3	3	1
Reason for using				
2 Production increasing	88	29	-	2
3 Crop condition improving	6	64	26	-
4 Workforce, time efficiency and facilitating land clearing	-	-	26	-
Reason for not using				
5 Soil is still fertile	4	-	-	-
6 Lack of capital	1	4	1	-
7 No weeds any more	-	-	44	-
8 Insignificant price differentials	-	-	-	52*
9 Workforce and time efficiency	-	-	-	45

Table 7.2 Farmers' reasons for adopting and/or not adopting cocoa technology, in percentages, 1993 (n = 100). (* : *In 1993, 7% amongst these farmers was still fermenting although they mentioned insignificant price differentials were the problem faced in not fermenting)*

Apparently, the reason for farmers mentioning the improvement of crop conditions is that most of them are convinced that herbicide application, besides being able to control and reduce the growth of weeds, can also improve the yields of the cocoa trees. In the short term this is not entirely true. For the longer term, however, it may be reasonable, because by using herbicide, the nutrient competitiveness between cocoa and other intruder plants such as weeds and herbs can be reduced with possible positive effects on herbicide application. The second reason to use herbicide is to reduce workforce costs. This is also a reasonable argument. Since, in comparison with the use of a manual workforce, practicing weeds control with a herbicide treatment can minimize the use of a workforce and reduce maintenance costs by at least 20%. To illustrate, in certain conditions, assuming the farmers must use a salaried workforce, for a young cocoa tree aged 1-2 years old, when herbicides are used, inputs are needed per hectare of 2-4 litres of herbicide and 4-8 workforce man-days, which are equivalent to 60-100,000 Rupiahs. In comparison, when only weed control treatment is used the workforce required is about 30 man-days which is equivalent to about 90-120,000 Rupiahs. That mean weed control costs can be reduced by about 20 to 50% by herbicide treatments.

Besides the objectives of increasing production and improving crops, in the case of herbicide application in particular, farmers stated that using the workforce efficiently and facilitating land clearance are the reasons for applying herbicide. About 26% of farmers mentioned those reasons. All reasons that were given by farmers ultimately contributed to the likelihood of achieving a better income and reducing expenditure as much as possible. However, in the technology-adoption process farmers in the region also faced several problems, which came from the farmers themselves and were also due to external factors. The limited involvement in extension services meant that farmers' knowledge about technical application of production inputs for tree crops in general and the cocoa crop in particular, was too limited. This conforms with farmers' responses when they were asked what the main problems were in adopting the technology. In fertilizer, pesticide and herbicide applications 57, 54 and 31% of farmers said that limited technical knowledge (Table 7.3) was their main problem in applying those production inputs perfectly. This fact concurs with the findings of Nyoku (1991) and Kashem *et al.* (1993).

Problems	Fertilizer application	Pesticide application	Herbicide application	Fermentation application
1 No problem	21	24	48	13
2 Lack of knowledge	57	54	31	20
3 Price input/output	17	-	13	67 *)
4 Lack of workforce & capital	5	6	-	-
5 Availability on the market	-	9	8	-
6 Treatment supporting	-	7	-	-

Table 7.3 Major problems faced in cocoa technology adoption by cocoa farmers in the Bupon Region, South-Sulawesi, in percentages; * Note: *prices of cocoa fermented and non-fermented are not different*

The evidence shows that most farmers in the region who apply fertilizer use it in the wrong manner. Fertilizer was not incorporated but just spread over the surface of the soil. As a result, losses occur due to, e.g., leaching, volatization and denitrification. Most farmers still have a lack of knowledge about how to apply fertilizer. Seemingly, they presume that fertilizer application for a cocoa crop should be done in the same way as it was usually performed on a paddy, where fertilizer was only spread between plants over soil surfaces. This misapplication is supported by the tendency for farmers who always try to minimize the size of their workforce and reduce the time required to apply fertilizer consequently sacrificing the effectivity of fertilizer application.

Poor technical knowledge on pesticide application methods can also be indicated by a lack of understanding on how to apply pesticide. Farmers usually use pesticide excessively. The types of pesticide used are varied, and farmers change the type of pesticide too frequently. Farmers appraise the effectiveness of certain pesticides based on monitoring by their colleagues. Farmers can easily buy various kinds of pesticides at the local market or in agricultural shops, which offer about 20 trademarks of pesticides including pesticides that are not recommended anymore, such as DDT. Some farmers even have used several kinds of poor quality pesticides, as non-significant effects after application. These pesticides are rather difficult to distinguish from the proper ones. The high prices that have to paid for proper pesticides and the wide area of dissemination in the region (where it is difficult to monitor the quality), are factors that stimulate the sale of inferior pesticide.

These practices indicate that appropriate information about the right way to apply pesticide has not yet been widely received by farmers. Farmers' technical knowledge of various aspects of pesticide, *i.e.* customs and manners, appropriate pesticide for appropriate needs, the level and the time of application, have not generally reached most farmers. Farmers receive information by seeing and listening to what other farmers have done. They can not verify the correctness of the information obtained. Besides the lack of technical knowledge on pesticide application, farmers face other problems that become obstacles to achieving efficient applications of pesticide. On the whole farmers are still using manual devices when spraying their cocoa. Mostly, the age of cocoa plantations in the region at the present is about ten years old or more, with plants of a height no longer suitable for spraying with manual devices or hand sprayers. Farmers seem to be unwilling to invest their capital on purchasing mechanical sprayers. The application of pesticides in higher doses and at a frequency exceeding the requirements is another serious practice that can work to the detriment of farmers themselves and regional development. The excessive application of pesticide can seriously affect the equilibrium of the agro-biological environment in the region. Apparently the integrated pest management (IPM) control method (Entwistle, 1972; Teng and Heong, 1988) which will benefit farmers greatly without damaging the environment, has not yet been adopted by local farmers.

For farmers who did not apply herbicide, about 44% mentioned that their cocoa was no longer troubled by weeds so they had no need to apply herbicide anymore. About 52% of farmers gave the reason that the price of fermented cocoa does not often differ greatly from the price of non-fermented cocoa. Also 45% of the farmers argued that by not using fermentation they economize on the workforce and time spent while the revenues they receive would be more or less similar. These two reasons indicate that most farmers did not adopt post-harvest cocoa technology since this technology does not generate a significant increase of their farm margin.

Besides problems described above, the physical condition of the region may be another constraint for farmers in adopting technology. Two specific physical characteristics of smallholder estates in the region are that they have a minimum economic infrastructure and that their locations are scattered and usually far from the settlements. It is different for the wet rice areas that are located in a concentrated area close to villages or settlement centres, making it easier for the farmers to manage their activities. Or, large-scale estates that are exploited by government or private estate enterprises, which from the start of their development have complete physical and economic infrastructures. These infrastructures are very important to facilitate the transport of production inputs and crop yields, and on intensifying the maintenance of the exploitation. Smallholder estates in the region at the beginning of their development have no economic infrastructures since there is no government intervention. Farmers established their estates traditionally and spontaneously ignoring a plan for the estates. At the time they had not yet taken into account the possible development of their cocoa business. With their limited resources there was no way that they could establish an economic infrastructure to facilitate their future activities.

It is different for smallholder estates where an initiative came from the government at the start of the development, such as the development of plasma estates of Nucleus Smallholder Estates (NES) which are carried out by the government or private estate enterprises. For these smallholder estates, the plantation was developed according to large estate patterning, including the planning of an economic infrastructure which provides high standards of crop husbandry and processing (Goldthorpe, 1985; *see* Tiffen and Mortimore, 1990).

The process of smallholder estates' development traditionally included land clearance and plotting of secondary and primary forests or fallow and shrub land but it was done irregularly and was left to the farmer's household abilities and the availability of capital and workforce at the time. In the earliest stage of cocoa development in the region, the locations of estates were still nearby villages. Farmers still exploited a small number of plots according to the availability of the family workforce. However, in the further development, after the plots near the village started to produce, they expanded their farm on more distant sites and into premier forest area. When the later wave of migrants came to the region they could only exploit land by infiltrating into forest areas that were more distant from the villages and settlements. Or, if they had sufficient capital, they purchased farms from farmers located near the villages. Then, usually the earlier farmers cultivated new plots at a greater distance from villages by spending small amounts of initial investment capital, accepting the higher cost entailed for intensive maintenance.

Recently, cocoa farms have not been able to expand in the forest areas any longer although the number of farmer households has increased due to new households created by farmer's adult children after marriage or the households of new arrivals. They have decreased the farm area exploited by earlier farmers. To maintain the level of income from the plots that have diminished in size, farmers must cultivate their land more intensively, which of course needs to be supported by an economic infrastructure. The evidence shows that a dynamic interaction amongst land infrastructure, technology and institutional innovation exists. It may be viewed as a process of augmenting (a saving) land in order to overcome growing population pressure on limited land resources (Hayami and Ruttan, 1985).

Given poor economic infrastructures, farmers have difficulties in maintaining their cocoa exploitation intensively. They must transport voluminous production inputs (such as fertilizer) from villages at additional high costs, which can cost about 30% of the fertilizer price. The availability of economic infrastructures can facilitate the diffusion and application of technology. Investment in land infrastructure and the diffusion of agricultural technology reinforce each other (Hayami and Ruttan, 1985).

Presently, the physical condition of the estate area in the region shows that although the smallholder estates are concentrated in a wide area, each farmer exploits fragmented plots on scattered locations. In these conditions farmers have difficulty in making effective use of fertilizer, herbicide and insecticides. Farmers in the region exploit one to ten plots, located up to about 10 km from villages, at an average distance of 2 km. In fact, this distance is not too far away, but, because most plantations are located on the other side of a river that has no bridge to connect the plantation area and the villages, production inputs are difficult to transport. In practice, farmers transport the fertilizer to the farm site and use horses or a paid workforce. Problems of communication get more significant when the rainy season comes or the river overflows. The river can be crossed on foot in the dry season, but when the river floods the communication to farm sites on the opposite side of the river is broken off. This usually happens very frequently during the rainy season. The rainy season in the region takes place twice a year from March to June and from September to December. In these conditions it is not only impossible to transport production inputs but maintenance of plants suffers too.

After describing in detail the application of various technologies in recent years, a preliminary conclusion can be drawn, namely that: (1) although in a restricted form, cocoa technology adoption has taken place during recent cocoa development in the region; (2) several main constraints that are faced by farmers in adopting the technologies are a lack of knowledge, limited reliable sources of information and lack of capital; (3) under limited conditions, the adoption of technology still tends to increase from time to time in compliance with farmers' efforts to find a way to increase their incomes; (4) farmers select the technology that they will adopt according to outcome benefits for their enterprise; technology that does not significantly affect the increase of a farmer's income is not adopted.

7.2.2 Factors associated with the adoption and the use of technology

To initiate and facilitate the discussion of factors that affect technology adoption and use of cocoa farmers, the following table presents the results of the preceding analyses. From six independent variables that were included in the model, respective five variables were associated with decision-making processes of both the adoption and the use of cocoa technology. The variable *'annual crop area exploited'* and *'the origin of farmers'* did not affect adoption and application technology respectively.

	Technology Adoption				Technology application
Independent Variables	Fertilizer	Pesticide	Herbicide	Fermentation	
1 Origin of farmers	-	ns	-	ns	ns
2 Number of neighbours	-	ns	ns	+	+
3 Education	ns	+	ns	ns	+
4 Family workforce	-	-	ns	ns	+
5 Annual crop area	ns	ns	ns	ns	+
6 Farm gross output	ns	+	ns	ns	+

Table 7.4 Factors associated with technology adoption and application of cocoa farmers in Bupon region, South-Sulawesi (*Note: - : negative effect; + : positive effect; ns : non-significant*)

(1) The origin of farmer

Rates of adoption for migrant and indigenous farmers (Table 7.5) show insignificant differences for pesticide and fermentation adoption but significant differences for fertilizer and herbicide adoption. However, the origin of farmers has a significant negative effect on fertilizer and herbicide adoption. This means, the less migrant farmers who mostly live in the first village, *Noling*, have adopted fertilizer and herbicides than indigenous farmers who mostly live in the second village, *Buntu Batu*. This points out that *hypothesis 1* predicting a higher rate of technology adoption by migrant farmers is rejected. Two factors, the location and the size of farm exploited, may possibly influence the significant differences on fertilizer and herbicides application between the indigenous and migrant farmers. The plots for the migrant farmers are mostly located on a distance from the village and are connected by a poor infrastructure, provoking the problem of transport of fertilizer to the farm site. The larger farm size of indigenous farmers caused a higher application of herbicide. Their objective is to reduce the volume of labour needed for weeding and cleansing.

	Rate of adoption (%)			
Farmer origin	Fertilizer	Pesticide	Herbicide	Fermentation
Migrant	80.0	75.4	52.3	15.4
Indigenous	97.1	82.8	82.8	28.6
Significant X^2	.02*	.39	.002**	.11

Table 7.5 Adoption rates of migrant and indigenous cocoa farmers. (* and ** *significant level of less than 5 and 1%*)

It cannot be ignored that cocoa development in the region was initially mainly stimulated by the dynamics of migrant farmers (Ruf, 1993), with higher economic motivation (Sartono, 1991) to achieve a more successful life, which was their main reason for leaving their previous home. Several factors have contributed to cocoa development in South-Sulawesi in the last 20-25 years. The area is suited for cocoa crops. This makes cocoa, according to the farmers, more profitable than other crops (Pomp, 1992). A similar finding was found by Durand (1991) in South-East Sulawesi. He argued that this crop has a considerable number of comparative advantages both in terms of required labour and market price. Wanting to copy the success of other cocoa farmers in the surrounding area and in other regions (Pomp, 1992; Durand, 1991) has also contributed to the development.

Previously, the region consisted of primary and secondary forest, and stagnant agriculture (*Appendix 3.2*). Later it became an advanced agricultural region in a relatively short period. The availability of more fertile land than they had previously experienced encouraged the migrants to take risks in exploiting a long gestation period crop which grows for several years before the first harvests (Durand, 1991; Berry, 1975). They were convinced that by exploiting the cocoa crop, their income, and of course their family's fortune, would improve. However, it was not only the availability of land that motivated cocoa development in the region. The dynamics of migrant farmers led them to support their institutional communities in the form of information, economic facilities and the like. The development of the cocoa region by pioneering migrant farmers shows a similar pattern in other regions of cocoa development, as such Nigeria (Berry, 1975) and Ghana (Hill, 1970). In South-East Sulawesi, close to South-Sulawesi (Durand, 1991) a vast cocoa development region is run by *Bugis* migrants from South-Sulawesi. They are ready to invest their capital, labour and income on a single crop, even though there are significant dangers such as the risk of a prolonged drop in world market prices or the development of a serious parasite like the pod borer (Durand, 1991).

As far as further development is concerned, differences in development between regions or between villages show that differences between migrant and non-migrant farmers are not the main worry anymore. This is apparently because most migrants, particularly those who have settled, have integrated into local society. They have adapted to the behaviour of the indigenous inhabitants and this also implies that most of the positive behaviour displayed by the new arrivals has been adopted by indigenous farmers. So a renewed community characterized by dominant characteristics of the two groups has developed. Particularly on the use of production inputs and fermentation technology, such can be seen in Table 5.3, the effect of the origin of farmers on technical efficiency is insignificant. Apparently the difference in soil fertility of villages and regions (Sartono, 1991; Pomp, 1992), farm and farmer characteristics can be identified as determining factors in differentiating the speed of cocoa development rather than the origin of farmer.

(2) The number of neighbours known intimately

The number of neighbours known intimately does not affect the adoption of pesticide and herbicide. This factor affects fertilizer adoption negatively and fermentation adoption positively. This factor also has a positive correlation with technical efficiency of cocoa production. *Hypothesis 2* predicting positive relationships between the number of neighbours known intimately and the adoption and the use of cocoa technology is confirmed in the case of fermentation adoption and the use of technology. This factor was expected to draw the level of farmers' involvement in the dissemination of information, particularly through the informal sources of information. It may be expected that farmers with a larger number of neighbours known intimately can receive more information concerning their cocoa business, which can influence their behaviour in technology adoption and application. Apparently, the level of farmers' participation in an informal contact group did not influence the farmer behaviour in adopting production input significantly. However, informal and neighbourhood meetings could only be the effective media to disseminate the information of fermentation adoption. Although this factor does not affect production input adoption, however it could influence the technical application of production inputs. When cocoa yields have been harvested and farmers are faced with the choice of whether or not to ferment the cocoa yields, the information of cocoa price seemingly becomes important. Farmers with a lower number of acquaintances have smaller farm size and lower participation in neighbourhood communities and adopted fermentation less than the farmers with much more neighbours known intimately. The former usually has a limited access to market information and has a low gross output. Such farmers tend to sell their cocoa production directly, while farmers with a high gross output ferment their cocoa more often than others do. Cocoa farmers who exploit smaller farms with lower gross outputs generally do not practice fermentation. Several factors that prevent them from doing so are: (1) the relatively low prices offered for fermented cocoa; (2) the immediate necessity for cash income, since their savings have been spent to pay for production inputs, particularly for fertilizer costs; when they ferment, it means they must postpone the selling of their cocoa for at least 4-5 days; without fermentation the cocoa can be sold one day after harvesting; (3) the price differentials are not sufficient to compensate for the capital, workforce and time spent on fermentation, since, small farmers generally produce a small quantity of cocoa for each harvest, usually less than 100 kg; the premium price for that volume is lower than the outlay for the fermentation; (4)

after fermentation the weight of cocoa produced could be about 5 to 15% lower than non-fermented cocoa. According to Bennet and Hasan (1993) this may be the most significant reason for not fermenting. Besides factors mentioned above, the results of optimization analysis (chapter 6) show that the availability of labour in the relevant period determines the level of fermentation application. While concerning to low prices and price differentials, the optimization analysis indicates that there are several levels of critical price for fermented cocoa. In case of labour is not limiting in the relevant period for farm situation with less diversified activities, the critical price is Rp. 1720/kg fermented cocoa or Rp. 220/kg (about 15%) over the price of unfermented cocoa. For farm situation with more diversified activities, the critical price for fermented cocoa ranging from Rp. 1888 to Rp. 1922; or Rp. 388 to Rp. 422/kg (27 to 28%) over the price of unfermented cocoa. To motivate fermentation application, the price of fermented cocoa must be at least equal or higher than these price differentials.

Obviously, the different prices for fermented and unfermented cocoa offered by both the international cocoa market and local exporters, are attractive enough. However, the problem is that the price of fermented cocoa offered by trader or collector at farm level was only marginally more than for unfermented cocoa. According to collectors, they cannot differentiate fermented cocoa from unfermented cocoa when the volume that is traded is not a feasible economic quantity. For that reason when collectors buy a certain amount of fermented cocoa, it is mostly partly mixed with unfermented cocoa. Otherwise, from the farmers' point of view it is impossible to ferment their cocoa in mass quantities when the prices offered are not attractive enough. The number of cocoa traders and collectors in both horizontal and vertical marketing chains is another aspect that contributes to a complicated mechanism of cocoa marketing in the region. However, this subject is beyond the scope of the discussion.

Newcomer farmers who generally produced smaller cocoa yields obtained smaller gross output. To obtain a revenue as higher as possible, two strategies are implemented: fermentation on the one hand and fulfilling the primary requirement of family incomes on the other hand. Usually farmers prefer the latter strategy. This means they do not ferment their cocoa. This may indicate that an economic factor remains a determinant factor in a farmer's decision to adopt fermentation technology or not. This resembles the findings of Monu (1982) on the acceptance of cocoa fermentation by peasant cocoa farmers: farmers who adopted fermentation technology, also had more access to sources of market information. Monu found that younger farmers who had more frequent contacts with extension agents adopted fermentation technology more often. Similarly, neighbourhood communities of cocoa farmers can also be a media for farmers to exchange and/or transfer the information of cocoa technology application. The finding show a positive correlation between the number of neighbours known intimately and technical efficiency of cocoa production. As was stated by Van de Ban and Hawkins (1988) the more a farmer is embedded in his social environment, the more interactions between farmers will take place which could provide an opportunity to exchange beneficial or useful experiences.

(3) Education

The dummy variable literacy has a positive effect on pesticide adoption, while the dummy variable high level of education affects technical efficiency significantly and positively. This indicates positive relationships between the level of education and pesticide adoption, and technology application. This finding shows that *hypothesis 3* predicting positive relationships between education and technology adoption and application is accepted for pesticide adoption and technology application. Other studies show no significant relation between farmers' educational levels and cocoa technology adoption. Boahene (1995) concluded that the level of education had a non-significant impact in the adoption of hybrid cocoa by Ghanaian cocoa farmers. However, several other studies have shown that farmers' education is a factor associated with farmers' technology adoption (Kumar and Wasink, 1989; Metzger, 1991; Doorman, 1991; Sen and Doijod, 1983). In general, they reported that illiterate farmers are less adoptive than educated farmers. Nyoku (1991) and Kashem et al. (1993) concluded that the farmer's knowledge influences the farmer's behaviour in crop technology and fertilizer application. A similar finding is also reported by Jamal and Pomp (1993) that the level of education determined a farmer smallholder's adoption of cocoa crop in South-Sulawesi. The results of this study run parallel with the latter study as far as pesticide adoption and production inputs and fermentation application are concerned.

As has been mentioned previously, the problem faced by farmers in properly implementing cocoa technology is their lack of technical knowledge. This was related to the level of farmers' education. The cocoa farmers in the region have an average of only 4.6 years of schooling, which is equivalent to primary school level. The lowest educational level is illiterate, which is true for 19% of farmers. About 59% has had a primary school education. About 44% of this group has been to primary school for only 3 years and almost all are illiterate. Farmers at this educational level are limited in their ability to grasp written information. About 12% of farmers has had a secondary school education. The rest, about 10%, has had a high school education or has a college degree. The latter two farmer's groups have the positive relationship with pesticide adoption. When the illiterate and the poorly educated farmers are compared with those who have followed higher education, a significant difference can be seen mainly in pesticide application. However, in fertilizer application the differences are fairly insignificant (Table 7.7).

Educational level	Production input applications		
	Fertilizer x 100 kg/ha	Pesticide lt/ha	Herbicide lt/ha
1 Illiterate and lowest (none and 3 years of schooling)	2.60	3.93	2.45
2 Educated (6 years schooling and more)	3.75	2.57	2.28
Significant *F* (** = $p < 0.05$)	-1.89	2.05**	.49

Table 7.7 Production input applications according to different educational level.

In fact, about 63% of farmers is almost illiterate and has a limited educational background.

This lack of education makes it difficult for them to comprehend technical knowledge perfectly. The visits of extension contact agents are too rare, and what is more, new additional agricultural information and knowledge through farmer training and informal courses takes place too infrequently. Therefore, their way to receive information is only through their relatives, cronies, traders and/or media exposures, who do not have the educational level to comprehend the information perfectly. In turn, the technology adopted will not have the optimal effect. However, farmers with higher levels of education, such as secondary school and college graduate levels, in general, can apply the technology in the proper way, either in quantities, qualities or times of applications.

Farmers with higher educational level have a smaller family workforce. Farmers with higher education, are the younger farmers with a smaller number of family members and of course a smaller workforce. The evidence is contradictive with findings reported by Chandra and Singh (1992) that the lower adoptive farmers absorb relatively more members of the workforce than those with higher adoption levels. It can be concluded that the positive effects of years in education on production inputs' application will be more effective when support institutions can be reached easily by farmers. Appropriate information available, extension and research services' surroundings of farmers could improve farmer knowledge.

(4) Family workforce

The findings show that number of family workforce has negative relationships with fertilizer and pesticide adoption and a positive relationship with technical efficiency. *Hypothesis 4,* predicting positive relationships between the number of family workforce and technology adoption and application is accepted for technology application. Farmers with a smaller family workforce more adopted fertilizer and pesticide than farmers with a larger family workforce. In fact, farmers with a small number of their family in the workforce are also the ones with small families. These farmers are usually young farmers with a smaller size of farm. The finding shows that the farm size has a positive correlation with the number of members of the family workforce. The smaller the family workforce the smaller the size of the farm. The reason why smaller farmers are more adopted fertilizer and pesticide than larger farmers who are generally older, is that they must exploit their enterprise more intensively to meet their subsistence needs. Their farm yields at least allow to fulfil the primary family requirements such as staple food. This should be also discussed in more detail in the discussion of farm gross output factor. However, once production inputs are adopted, the level of production input use has a significant relationship with the number of family workforce. The number of family workforce owned will be a determinant factor in deciding the level of production input applied.

This finding is concordant with the citation by Schutjer and Van der Veen (1977) that there is limited evidence to suggest that the availability of workforce on the farm will encourage the adoption of workforce intensive technology, while a lack of workforce will discourage both adoption and efficient utilization. Apparently, in the case of cocoa smallholder in the region, the economic gain of objective function is the main consideration in adopting cocoa technology, although they might pay salaried labourers. By employing a certain number of salaried workforce labourers farmers adopted a certain level of cocoa production technology which is supported by production inputs' application. This is possible since the high output return of cocoa allows the wages of a salaried workforce to be paid. This option has been practiced widely by cocoa farmers in the region. Obviously, this practice conformed with the result of optimization analysis, which shows that by using an intensive cocoa intercropping treatment, combined with employing salaried labourers, they could provide the cocoa farm plan. The positive relationship between fermentation application and the number of family workforce also conformed with the optimization analysis, which indicates that the availability of labour in relevant period is important in applying fermentation.

(5) Annual crop area exploited

Technology adoption is not affected by the variable annual crop area exploited. This variable has only a positive correlation with technical efficiency. This means that *hypothesis 5* in which positive relationships between the annual crop area exploited and technology adoption and use were expected, is accepted in the case of technology application. This evidence is the implication of farmers' practice for wet paddy exploitation which of the application of technology, at least in a moderate level (semi-intensive), is an obligation in maintaining paddy production. Their objective is to ensure the basic food requirement level. An important aspect of the farmers' behaviour in pursuit of their goals is their choice between long-term and short-term goals (Harwood, 1979). In the case of cocoa farmer in the region the two objectives are attempted to achieve in a dynamic balance condition. The reasons for farmers to exploit farms comprising wet paddy plots combined with cocoa plots can be distinguished in several ways and motivations. First, farmers who had succeeded with their cocoa exploitation expand their farm further by buying a *sawah* (wet paddy land) plot in order to diversify their activities. In this respect, the risk avoidance of cocoa production and price fluctuation, and to ensure family food requirements are the main reason for their decision. Second, farmers who exploit a limited cocoa area and have an abundant family labour rent *a sawah* plot by periodical contract, usually several years, or 'yield sharing' from the larger farmers. Third, farmers who initiate their farm business with *sawah* plots and expand later their exploitation by establishing cocoa plots. Farmers' effort is further directed to how to complete their farm with cocoa plots. The capital owned in the form of the rest of family workforce that is not employed in *sawah* is made use in cocoa exploitation, which is usually by working in the form of salaried labour or 'cocoa land sharing' with the farm owners after cocoa plots produced. Farmers are able to do that since usually their daily food requirement had been ensured. Since the price substitution of cocoa is higher, the economic motivation is the main reason for this decision. By their own cocoa farm they could ensure their cash revenue to satisfy the secondary family requirements such as education of children, health of family, building construction and other family expenditures. As in the case of the number of family workforce, once technology is adopted, in determining the level of production inputs' use, the factor of the area of annual crop exploited will influence technology application. Farmers who also exploited annual crops apparently, applied more production inputs than those without annual crops. As was discussed previously, the former has a better opportunity in spending their budget for purchasing production inputs, since their basic family food requirement has been fulfilled from their own farm.

Exploiting cocoa which is combined with *sawah* plots is apparently an important objective to achieve the satisfaction of farmers' daily life. Although, economically, the revenue obtained from paddy crops is lower than cocoa crops, the preference of cocoa farmers in expanding their farm with a paddy plot is still increasing. The preceding optimization analysis of diversification on cocoa farms showed that in the limited availability of land and family labour, wet paddy activities contributed the lowest economic value for the farm gross output. This proves that from the economic point of view, expanding farm area with *sawah* plots would seem to be less supported by conventional economic reasoning, as was described by Ruthenberg (1985). Under the constraint of a limited family workforce, most of farmers have chosen to hire salaried labour for treating their cocoa activities, or use yield-sharing systems with other farmers for exploiting their *sawah* plots. This farmers' preference runs parallel with the results of the previous analysis on optimal cocoa farm gross margins (chapter 6) that shows that the diversified cocoa farm provides the best optimal solution for farm margins. The second reason related to the involvement of farmers' personal preferences (Ruthenberg, 1985), is a reasonable background that justified a tendency in expanding a cocoa farm with *sawah* plots. Farmers may feel more secure if they grow their own food and/or they may consider that home grown produce tastes better.

As outlined above, application of pre-harvest technology is also influenced by non-economic considerations. The economic benefits of the paddy crop are less than the cocoa crop. When economic considerations are the only motivation for farmers in exploiting *sawah* plots, they will certainly not give this high priority in terms of farm expansion to paddy crop.

(6) Farm gross output

The farm gross output positively affects the adoption of pesticide and technical efficiency of technology application. Therefore, *hypotheses 6* predicting positive relationships between farm gross output and technology adoption and use is confirmed in the case of adoption of pesticide and the application of technology. The higher the gross farm margin, the more pesticide is adopted and the more technology is applied.

The farm gross output is closely related to the scale or the size of farm exploited. Usually the larger the farm, the higher the farm gross output. In many previous studies on developing countries a consistent pattern of size of holding was not seen *per se* as a barrier to technology adoption by farmers. Several studies (Kumar and Wasink, 1989, Chandra and Singh, 1992; Shree and Sidaraman, 1993) reported that farmers who have larger areas adopt fertilizer more than farmers with smaller holdings. Several others (Van der Veen, 1975; Rawal and Noraula, 1988; Onte, 1988) found an inverse relationship between farm size and the amount of fertilizer, labour used and productivity per unit of land. Smaller farmers who usually yield a small gross output (particularly those with farms of one or less than one hectare), have no alternative other than to exploit their enterprise more intensively to meet their subsistence needs (Van der Veen, 1975). They must produce cocoa, or other crops, to a certain level of productions to fulfil the family requirements. For the subsistence farmers, the need to maintain a basic minimum level of production in every season is more important than the average projected returns over a number of years (Gartforth, 1982). Apparently, this holds for small farmers that exploit mainly annual crops. However, it also holds for small farmers who exploit perennial crops as their main activity; this strategy is relevant in the short term.

For these farmers the strategy leads to a long term objective, and a long term investment. In the two or three years when their cocoa has not yet produced, farmers still attempt to maintain a basic minimum income to finance family requirements and maintenance costs for their cocoa. To fulfil these needs farmers usually cultivate other annual crops intercropped with their cocoa. After their cash crop starts to produce, when farmers have sufficient capital to purchase production inputs, farmers improve on their maximum production objective. As a consequence, farmers often invest their capital in an excessive manner in applying production inputs in order to obtain the highest possible levels of cocoa production.

When the application of production inputs amongst different levels of farm size is reviewed comprehensively, it can be seen that the average level of fertilizer application is still under the dosage recommended, which is about 500-1000 kg of NPK fertilizer per hectare per year. On average, cocoa farmers in the region use 355 kg of NPK fertilizer per hectare per year (Table 7.8).

Farm hectares	Technology application			
	Fertilizer (x 100 kg/ha)	Pesticide (lt/ha)	Herbicide (lt/ha)	Fermentation (kg/ha)
1 Small (≤ 2 ha)	395	2.2	1.5	270
2 Large (> 2 ha)	307	3.5	3.0	1200
Average	355	2.8	2.1	710
Significant *F*	.06	.01	.01	.01

Table 7.8 Technology applications of different groups of farmers

However, when the dosage is measured according to the size of farm exploited, it appears that farmers who exploit two, or less than two, hectares apply about 395 kg/ha/year fertilizer, which is higher than for large farmers who exploit farms of more than 2 ha. The latter use about 307 kg/ha/year NPK fertilizer, even that is higher than the average fertilizer application in the region. This finding is not parallel with the results of previous study (Kumar and Wasink, 1989; Chandra and Singh, 1992; Shree and Sidaraman, 1993), that reported that more farmers with the large areas adopt fertilizer than farmers with smaller holdings.

Except for fertilizer application which only has a different significant F level at 6%, there are significant differences between smaller farmers in the use of pesticides. Small farmers use less pesticides, that is 2.2 l/ha, compared with the average application by farmers in the region of 2.8 liter/ha. In herbicide application, the smaller farmers use on average 1.5 liter/ha, which is less than the larger farmers who use on average 3.0 liter/ha.

Once technology has been adopted by farmers, the finding shows that farm gross output has a highly positive correlation with technical efficiency. This means that smaller cocoa farmers apply less production inputs and fermentation than the larger ones. However, as a result of the intensive treatment, a part of the smaller farmers' group may also obtain a higher gross output. Such farmers, smaller farmers with a higher gross output, also use more production inputs (particularly fertilizer) than farmers with a lower gross output.

Differentiation of economic gains (Clark and Akinbode, 1968) and farmer motivations may also be important. This may be the case if one considers that when the cocoa has produced a crop the farmers' income becomes more stable, because every year they will then obtain an income to meet family requirements. Under these conditions, some farmers are satisfied with what they have achieved, and their further motivation and objectives are only to maintain the family's income, shifting to less economic objectives, such as improving the education of their children, maintaining a religious family life-style and concentrating on the social aspects of family and neighbourhood. However, other farmers are not satisfied under these conditions. They continue to improve their cocoa farm activities by searching for other opportunities to obtain higher yields to fulfil economic goals. They attempt to expand their cocoa farm to other sites more distant from their settlement, to purchase annual crop plots and/or to maintain their farm intensively by making use of the available technology, including more applied fermentation.

7.3 Conclusions of the findings

Apart from the findings described and discussed previously, several conclusions can be drawn:
(1) The farming system that is dominated by the cocoa crop has profoundly changed and evolved as the result of the encountering of suitable agro-environment, and the dynamic behaviour of indigenous and migrant farmers in adopting the technology and resources available. Farmers have adopted cocoa technology, both pre-harvest and post-harvest technology, but it is a different level of application and kind of technology. The findings of the study show that amongst the technology of production inputs, the model we tested fits best for pesticide and worst for herbicide application model. Almost all farmers who adopted fertilizer also applied pesticides. The use of herbicide diminished over time because immature cocoa areas that are more frequently treated by herbicides tended to diminish significantly. Fermentation is less adopted by cocoa farmers since the price of fermented cocoa offered at farm level was only marginally more than for unfermented cocoa and the limited availability of labour in the relevant period.

(2) The farmers' strategy in adopting and applying cocoa technology is related to a complementary achievement between long term and short term farmer objectives. Although farmers initiate their cocoa businesses as different types of exploitation, in a subsequent development they tend to evolve forward towards a similar farm objective, that of exploiting multicrops which are both cocoa and annual crops. Farmers who had succeeded with cocoa exploitation expanded their farm further with wet paddy plots, although the latter gives lower revenues than cocoa, in order to ensure family food requirements. Inversely, farmers who in the beginning practice a system of annual crops, later attempt to expand their farm with cocoa plots to satisfy secondary family requirements such as education, health, housing restoration and other household and family expenditure.

(3) Factors that affect farmers in decision-making on technology adoption were the origin of farmers, the number of neighbours known intimately, education, the number of family workforce and farm gross output. Factors that affect the level of technology application were the number of neighbours known intimately, education, the number of family workforce, annual crop area exploited and farm gross output. Cocoa production is insignificantly affected by fertilizer application and significantly affected by pesticide application. There is still available room for increasing cocoa production in the region. Technical efficiency of cocoa production in the region is about 70% on an average.

(4) Under various constraints of family workforce, availability and suitability of land, and crop production treatment, the most profitable adoption that should be obtained for a smaller farm, less than 3 hectares, is an intensive cocoa, coconut and paddy, and semi-intensive paddy with fermentation application. For the larger farm, an intensive cocoa, coconut and paddy, non-fermented cocoa and working on the off-farm activities will give the best farm gross margin. This means that gross margins of actual farmer practices remain possibly to be increased by maximizing the use of land available, introducing a more appropriate application of technology and employing family labour optimally in both on-farm and off-farm activities.

7.4 Subsequent research implications and suggestions

The evolving of farming systems and the developments of cocoa exploitation and farmer households, which have taken place during the last 25 to 30 years and probably will continue in the future, have produced a new style of farmers and farming system and even led to regional development phenomena. The development has caused many aspects of farming and regional conditions to change. One aspect that has been described was the development of farmers' appreciation of technology adoption and use. Factors that are associated with farmers' decision-making processes in adopting and using the technology have been identified in the study. However, the results imply that many other aspects that contribute to cocoa development in the region still have questionable consequences for technical, social, economic or regional development. Briefly, several main aspects can be mentioned that could be suggested as objects for subsequent research that may add depth to the insights into cocoa and regional development, and moreover, may contribute to further theoretical development.

(1) The study has identified farming system models of the region, which consist of sole cropping cocoa, cocoa intercropping with other perennial and annual crops and cocoa diversified with a wet rice crop. These models have evolved from time to time over the last twenty years and should be further developed to match farmers' and regional demands. In recent years, the development of livestock and the diversification of freshwater fish between two cultivation seasons of a paddy culture have been practiced by certain farmers on a small-scale. These experiments show the efforts of farmers to develop their farm by continuously grasping new opportunities. Farming systems dominated by a cocoa crop and/or combined with other crops and activities seem to enrich an interesting farming system model that could accelerate farmers' development. Therefore, a profound study of appropriate farming system models under these regional conditions would be a useful suggestion, including micro farming and macro regional aspects.

(2) A further implication of the study is that the technology, particularly production inputs, are often applied ineffectively and inefficiently. This is another factor that causes the low productivity of cocoa in the region. Production input applications were not based on real requirements nor on reaching optimal economic and technical opportunities. Production input applications for sole cropping and intercropping tend to be treated in the same way. Also the kind of production inputs applied did not satisfy the real demands of the farming community. Apparently a profound study of production inputs and other technology formulae suited to each crop would be useful to provide up-to-date and appropriate information for cocoa farming development in order to improve cocoa productivity in the region.

(3) With the exception of fermenting, technologies tend to be adopted increasingly. These technological adoptions and applications have positive implications both at farmers and regional level. To what extent benefits have been achieved and improvements accomplished, a further study for benefit analysis of technology adoption and application is still essential. It is necessary to describe the profitability of applying technology. Then, the profitability level of each technology application and their interrelations in technical, social and economic terms, may be calculated and modelled. To meet these requirements, the study of social, economic and even environment benefit analyses of cocoa technology application on micro and macro perspectives is recommended. The study could be integrated with the previous suggestion for the study of production input formulae.

(4) On the whole, technology adoption and application have tended to develop positively. However, certain technologies are not adopted by cocoa farmers, and over the years they have not shown any signs of a positive change. Farmers seem to have their own reasons for not adopting these technologies. A margin share that is acquired by cocoa farmers of about 70-80% of export prices (Bennet and Hasan, 1993) seems to be quite high, however, when it is compared with other parties involved in the whole cocoa business, the part that is received by cocoa producers is the smallest. The share of consumer spending for the parties involved (Heijbroek and Konijn, 1995) are for the cocoa producer (3.3%), marketing (10%), trade and transport (13.3%), chocolate industries (22%), wholesale and retail (26%), other raw materials (6.3%), and taxes and import levies (18.9%). The margin share is not yet sufficient if the risks that farmers face are taken into consideration. Compared with other participants involved in the cocoa business, farmer producers face the highest risks. Besides that, the prices that farmers receive tend to be unstable. Also farmers face uncertain situations in operating their cocoa business. These market conditions, which are reinforced by other external factors, are still a predominant determinant that influences the optimal operation of an economic cocoa mechanism in the region. Moreover, net added-values that are produced in the region are too small, sometimes nothing at all. This occurs because cocoa development in the region has taken place in a disintegrated way. Cocoa activity development has not yet integrated with agribusiness activities as a whole. This influences a farmer's bargaining position with other cocoa business participants. The integration of cocoa development should, theoretically, give farmer producers a better chance to develop their cocoa business under more favourable conditions. The net added-values for farmers can be maximized by installing at least an intermediate processing plant to the by producing region. The presence of such a plant in the region, if the ownership of the processing plant is shared by the farming community and/or organization, could stimulate farmers to produce a cocoa

quality according to the demands of the processing plant, which could ultimately optimize farmers' gross output. Therefore, the study of integrated cocoa development that takes into consideration all agribusiness aspects is advisable. The study could also describe the farmer producer's position, both strong points and weakness in terms of reinforcing their bargaining position.

(5) In the last two decades the regional development of cocoa has profoundly changed and evolved. Empirical evidence shows that cocoa development in the region has had an impact on regional development. The implications of cocoa development on social, economic and regional development in the past are essential to support and reinforce regional development model in the future. However, the lesson from a historical development of Indonesian cocoa since the late of the 19th century, that is its production went down at a stagnant level until the end of seventies, also has to be taken into consideration. Up to that time the government had only a little intention to expand and develop the cocoa crop for a smallholder sector. The previous experience of the disaster of cocoa plantation in certain regions that was caused by the attacking of cocoa pod borer led the government in launching prudently cocoa development policies. Later, the development of cocoa was initiated by the gradual small pilot projects in smallholder surroundings which were completed by the provision of technological treatment and supervising, particularly in anticipating the possible threat of certain cocoa pests and diseases. This attempt encountered with the dynamic and the response of farmers to cocoa price development brought Indonesia into the initial era of cocoa boom in the beginning of the eighties. This evidence was pulling the government to provide supporting facilities in the form of provision of cocoa plant materials, regulating and to facilitate the transfer of cocoa technology from large state and private estates to a smallholder sector. To avoid the repeating of the unsatisfying historical cocoa in the past, the evidence of previous cocoa development, both the impressive development and the acute threat of cocoa pod borer, could be considered in the subsequent cocoa development model. The future model of cocoa development suggested might consider integrated aspects in terms of long term perspectives. Several main aspects that need to be taken into account are:

(a) The implication of the increasing scarcity of land available. This might be considered in assessing the model and the level of production technology introduced. Apparently, the cocoa development model which composes an abundant land factor is over. The experience of declining of cocoa production from Brazil and West Africa (Ruf, 1993) that was caused mainly by the scarcity of land available are a good lesson for cocoa development in the region.

(b) The possible increase of labour costs which also can determine the model and system of cocoa development. Seemingly, the diminishing of labour source since the more and more number of young and educated farmers move out to non-agricultural sectors, besides the growing of other sectors' development, both other agriculture and non-agriculture sectors, will compete with cocoa development in employing labour. The consequence, the increase of labour costs is inevitable. The case of Malaysia' economic growth that was pulling labour costs upwards (Ruf, 1993) might be a lesson for cocoa development in Indonesia.

(c) The increase of food requirement for a growing population, which is also very close to the scarcity of land available, is another factor might be considered in the model. Although from an economic value point of view exploiting food crops tended less advantage than cultivating cocoa crop, however a tendency to secure firstly a family food requirement is another farmer decision could influence cocoa development. A competition in the use of land, particularly in the areas where are also suitable for *sawah* area will force the decrease of cocoa area.

(d) A chronic threat of certain main cocoa pests and diseases particularly cocoa pod borer might be integrated into both each cocoa development policy and regulation, research and extension implementation.

(e) Besides various possible constraints that were described above, on the other side, a good prospective contribution of cocoa for a sustainable development placing this crop as an important alternative. Ecological evidence for growing cocoa and other perennial crops could contribute to maintaining the sustainability of farming system and even regional environment. The characteristic of cocoa crop which returning back a bio-mass into soil can maintain soil fertility or at least could reduce a vast degradation of soil quality.

The study suggested would cover integrative aspects of regional development, which consist of agronomic, social, economic and even ecological and environment aspects, dealing with the existing situation such as the benefit and implication of technology adoption and application, and future farming systems with cocoa exploitations as a core of activity.

SUMMARY

The objectives of the study were to expand present knowledge on the technology adoption and application rates for production inputs and fermentation processing related to farmers' decision-making, and to formulate an optimal technology application policy, particularly for smallholder cocoa farmers. To achieve these objectives it is necessary to understand factors that are associated with farmers' decision-making in adopting and applying these technologies and problems related to them. Given the two objectives, the study develops and tests (1) a model that assesses factors which explain cocoa farmers' technology adoption and application, and (2) a model that presents the optimization of cocoa farmers' activities both at the cocoa farmer and regional level.

This research was carried out in South-Sulawesi, Indonesia. This choice was motivated by the fact that (1) on the whole, cocoa in this region is grown by smallholder farms; South-Sulawesi is the region which makes most significant contribution to national cocoa production; (2) this region is the main cocoa producer in the area providing about 32 percent of the national cocoa production; and (3) this region was one of the earliest cocoa regions to be developed. At the sub-region level two villages, *Noling* and *Buntu Batu,* with similar environmental conditions, in the regency of *Luwu*, were chosen to represent the villages that had adopted cocoa technology to a greater and respectively to a lesser degree. The two villages were the first to develop cocoa in the region and housed multiethnic inhabitants who were the pioneers of cocoa development in the region.

This study has been carried out on the basis of inductive methodology. This case study explores the diversity and the heterogeneity of farmers' behaviour under specific socio-economical conditions. The number of farmers chosen as respondents in the study in the two villages was 100, 50 for each village. The model was developed on the basis of two approaches, namely a positive approach in which empirical analysis uses production function methods, and a normative approach in which linear programming models are used as a tool of analysis.

The models concentrate on the specific issue of cocoa smallholder farmers and their problems in adopting and applying certain available technology which focuses the investigation on certain elements in the model. The issues considered are all aspects related to farm and farmer characteristics, conditions and problems that constrain the cocoa farmers in achieving their objectives. The first element of the model developed is the objectives' function which is specified in terms of technology adoption and application by cocoa farmers. The second element of the model is data that relate to factors that may explain the variation in the use of technologies. The third element of the model is the set of independent variables that are treated as given variables within the cocoa farmer's operations. It is assumed that farmers' behavioural decision-making is determined by the farmers' strategies as controllable factors. The farmers' strategies embody the farmer and farming factors. The technology adoption model of study includes six specific factors, which are grouped into four main groups: farmer community, farmer's characteristics, farmer's household and farm characteristics as independent variables. The technology application model includes all production inputs used, land, labour and chemical production inputs as independent variables. The latest element of

the model is the dependent variable. Four technology adoption variables, which are fertilizer, pesticide, herbicide and fermentation adoption are included as dependent variables in the model of technology adoption of the study, and farm gross output is included as dependent variable in the model of technology application.

The results of the analyses showed that the main factors explaining technology adoption and application are the origin of farmers, the number of neighbours known intimately, the number of family workforce members, years in education, annual crop area exploited and farm gross output. These factors affect different technology adoption and application at different levels:

Origin of farmer. This affects fertilizer and herbicide application negatively and has insignificant correlation with technology application. The migrant farmers who mostly housed in the first village are significantly lesser adopted fertilizer and herbicide. This occurs since most of cocoa area exploited by farmers from the first village is located at a more distant site from the village, on the upland areas, which are although usually less fertile than the plots located close to the village; however, the lack of infrastructure in this region contributes to the limited adoption on fertilizer. The indigenous farmers who mostly have a larger area than the migrant farmers have adopted herbicide more than the migrant farmers, in their effort to minimize the use of labour for weed control.

The number of neighbours known intimately. This affects fertilizer adoption negatively and fermentation adoption positively. Fertilizer is more adopted by the farmer families with smaller number of acquaintances, which are usually those who came later in the region and have smaller farms. This is different with fermentation adoption. Fermentation has been more adopted by farmers with more neighbours than by farmers with smaller social networks. The farmers who usually have wider relationship with other farmers have better access to the source of information about market development, including the cocoa price development over time. Farmers with information about the market have a better chance to obtain a higher price for their fermented cocoa. The price factor is the main determinant in the farmer decision to ferment their cocoa. The number of neighbour family knowing intimately has also a significant correlation with technical efficiency of cocoa production. Farmers with better access to the source of technical information have more knowledge of technology application.

Years in education. This influences pesticide adoption and technical efficiency positively. Literate farmers are more likely to adopt pesticide than illiterate farmers. Farmers with higher education levels are generally the younger farmers who started their cocoa farming business recently, who usually exploit distant plots, that usually have lower levels of soil fertility and have a smaller farming area. To increase production they have to adopt pesticide.

Number of family workforce members. This influences fertilizer and pesticide adoption negatively and has a significant correlation with technology application. Farmers with a lower number of family workers have adopted more fertilizer and pesticide than those with a larger number of family workers. The former are the farmers who exploit a smaller number of cocoa hectares and/or younger farmers who usually attempt to exploit their plot intensively by using fertilizer and pesticide in order to increase cocoa production on their limited farm area. The result also imply a negative relationship between the number of family and technology adoptions in the case of fertilizer and pesticide adoption, and a positive relationship between years in education and pesticide application; however, no relationship could be found between the age of farmers and technology adoption, and relationships between the distance of plots from the village and technology adoptions. Once technology is adopted, the level of technology application which is represented by technical efficiency has significant correlation with the number of family workforce members.

Annual crop area exploited. This factor does not affect technology adoption. Annual crop area exploited influences technology application positively; farmers who successfully expand their farms with wet paddy areas use more production inputs and apply more fermentation than the farmers without paddy crop plots. This is understandable since in general wet paddy area in the region has been exploited intensively by regularly applying production inputs in high doses, an unavoidable practice if the food requirements of the farmer's family are to be met. The farmers who also exploit the annual crop area have more ability in operating their farm than the farmers without paddy plots. The farmers who have fulfilled their basic family food requirements from their own farm have a better opportunity for spending their budget for purchasing production inputs.

Farm gross output. Farm gross output has a positive relationship with pesticide adoption and technology application. The larger farmers tend to adopt more pesticide than the smaller farmers. Farm gross output in a previous year has also a positive and significant correlation with the technical efficiency of cocoa production. The higher the gross output of the previous year, the higher the ability to purchase production inputs and apply fermentation.

The second, normative model used in the study is a linear programming model that focuses on the farm level activities based on different kinds of technologies. The farm condition is assumed to be stable, risk and time dimensions are not included in the model. Three main situations of farm activities are differentiated based on the contribution of the source of farmer income. Cocoa is cultivated as a single crop, cocoa and other perennial crops are cultivated as mixcrops on the same plots, cocoa plots are combined with annual plots, and cocoa and other crops are supplemented by off-farm activities. The main objective of farm households is to achieve an optimal farm gross margin that can be realized through the optimization of the gross margin of several crops described and off-farm activities. The technology used is divided into pre-harvest and post-harvest technology. Three levels of pre-harvest technology are used as the basis of analysis, extensive with no application of external inputs, intensive with a high level of inputs and semi-intensive with an intermediate level of inputs. Two levels of post-harvest technology are used, non-application and application of fermentation, which imply the direct and indirect sale of unfermented and fermented cocoa. A part of the family workforce works as a salaried workforce at other farms during the cocoa harvest and at other peak season periods; *i.e.* off-farm activity. Farms are subject to various constraints: the farm size exploited, the suitability of land used for different crops, the available family workforce and the seasonal peak requirement of labour for each activity.

The result of the optimization analysis shows that the best optimal farm solution is achieved in the farm situation with the most diversified activities. This is the case in the farm situation with mixed cropping of cocoa, wet paddy plots and off-farm activities. In this situation the farm gross margin obtained for each level of farm size is always higher than other types of farm systems. This achievement is possible since the optimal farm plan is generated by (1) making optimal use of the land available by application of crops' technology, both by a best single technology and the most appropriate combination of various technologies, (2) an optimal implementation of cocoa-processing technology through fermentation application, (3) an optimal employment of family workforce for both on-farm and off-farm activities. The best optimal gross margin obtained for a sole cocoa plantation is achieved on a farm size of 3 hectares with intensive cocoa treatment. For cocoa intercropping, the best result is obtained by intensive cocoa combined with hiring labour from outside farms.

The conclusions of the study are that in the last two decades the development of the farming system in the region, dominated by cocoa, has changed profoundly. This is due to the land suitability and the dynamic behaviour of indigenous and migrant farmers in adopting and making use of the technology and resources available. Farmers' decisions in adopting cocoa technology are determined by the origin of farmers, the number of neighbours known intimately, the level of education, the number of family workforce and farm gross output factors, while for application technology they were determined by the number of neighbours known intimately, education level, the number of family labour, annual crop area exploited and farm gross output factors. Fertilizer adoption is explained by the origin of farmers, the number of neighbours known intimately and the number of family labour. Pesticide adoption is explained by education level, the number of family labour and farm gross output factors. Herbicide adoption is affected by the factor's origin of. farmer. Fermentation adoption is affected by the number of family labour. Technology application is affected by the number of neighbours known intimately, education, the number of family labour, annual crop area exploited and farm gross output factors. The optimization analysis confirms that there is a room to optimize the existing cocoa farmers' practice of the region. Under various constraints of land, labour and crop production treatment, the optimal level of the farm margin may possibly be achieved by making optimal use of the land, introducing a more appropriate application of technology and employing family labour optimally, in both on-farm and off-farm activities.

Factors that are associated with farmers' decision making in adopting technology, have clarified our insight into farmers' appreciation of cocoa technology adoption. Farmers adopting technology when cultivating cocoa as a perennial crop are looking towards the long term objective and the long term investment, which is the average projected returns over a number of years will be the most significant farmer objective. However, many other aspects still contribute to cocoa development. *Firstly*, a comprehensive study of appropriate farming system models under the conditions of the region including the ecological evidence for promoting cocoa and perennial crops as a sustainable alternative. *Secondly*, the positive implications of technological adoption and application both at farmers and regional level need to be clarified to determine the optimal benefits. *Thirdly*, a study of integrated cocoa development that taking into account all agribusiness aspects is advisable. This study could identify the strong and weak points of the cocoa smallholder's bargaining position.

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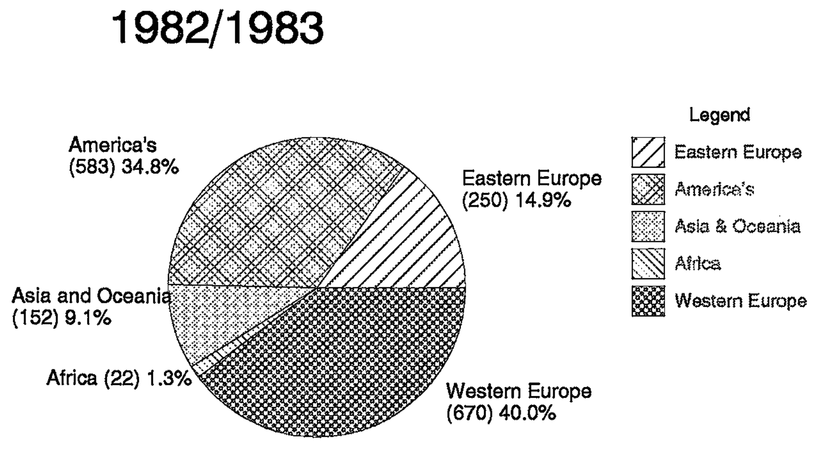
Cocoa pods

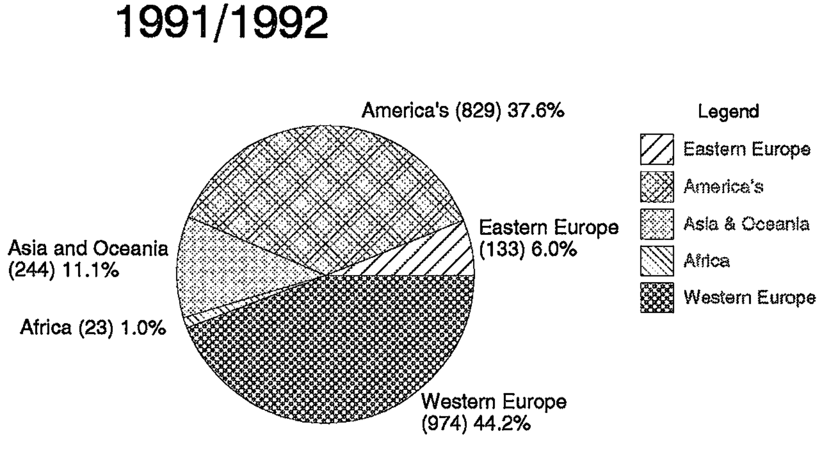
APPENDICES

Appendix 1.1 World Cocoa Production and Consumption during 1964 -1993

Data source :ICCO

Appendix 1.2 Final Consumption of Cocoa per Region in 1982/1983 and 1991/1992 (in x 1000 t and percentage)





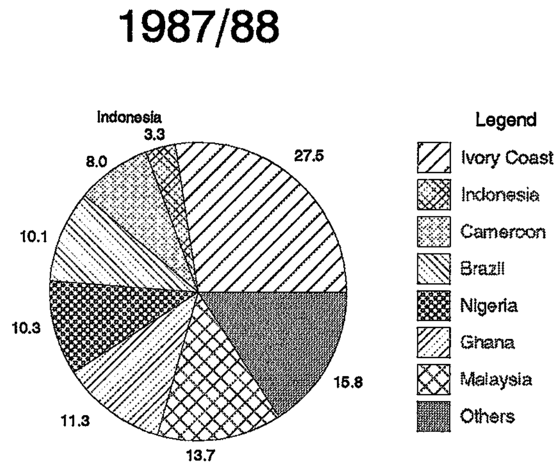
Data source : ICCO

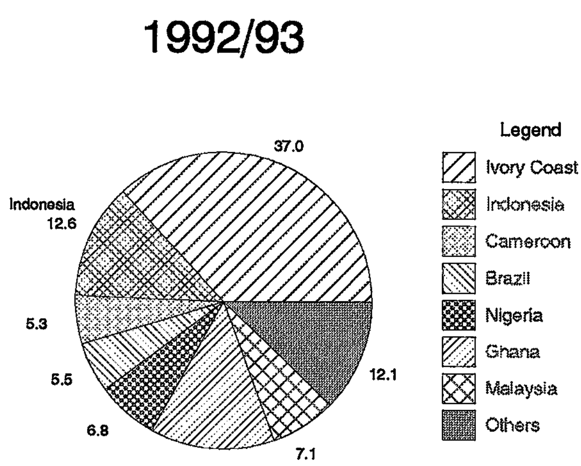
Appendix 1.3 Area and Production Growth of Various Tree Crops in Indonesia, 1968 - 1990

	Area (1000 ha)			Production (x 1000 t)		
Crops	1968	1990	Growth rate (%)	1968	1990	Growth rate (%)
Rubber	2,208.7	3,130.5	1.6	755.6	1,261.9	2.4
Coconuts	1,595.4	3,390.4	3.5	1,132.7	2,258.3	3.2
Oil-palm	119.6	1,126.7	10.7	181.4	2,412.6	12.5
Coffee	339.4	1,061.9	5.3	157.3	424.5	4.6
Tea	119.5	134.9	0.6	75.8	145.2	3.0
Cocoa	**12.9**	**345.0**	**16.1**	**1.2**	**113.8**	**23.0**
Clove	75.7	685.7	10.5	17.2	74.7	6.9
Pepper	42.9	119.9	4.8	16.7	70.4	6.8
Nutmeg	14.2	66.0	7.2	7.5	16.3	3.6
Cassiavera	25.4	81.2	5.4	2.5	5.8	7.3
Kapok	152.4	322.8	3.5	21.8	61.2	4.8
Cashew	58.4	281.1	11.0	9.1	29.7	8.2
Vanilla	6.3	12.5	4.7	.4	2.1	11.8
Others	115.2	182.1	2.1	340.2	540.7	2.1
Total	4,886.2	10,940.8	3.7	2,722.4	7,437.0	4.7

Source: Directorate General of Estates, Ministry of Agriculture, Republic of Indonesia, 1992

Appendix 1.4 World Market Share of Major Cocoa Exporting Countries (in percentage)





Data source: ICCO

Appendix 1.5 Indonesian Cocoa National Area, Production and Yield per ha, 1970 - 1990

Year	Area (ha)	Production (t)	Yield/ha (kg)
1970	12,110	1,738	143.5
1971	14,393	2,009	139.6
1972	17,130	1,801	105.1
1973	15,517	1,813	116.8
1974	17,563	3,191	181.7
1975	17,498	3,921	224.1
1976	15,341	3,909	254.8
1977	21,795	4,818	221.1
1978	25,759	5,496	213.4
1979	35,710	8,632	241.7
1980	37,082	10,284	277.3
1981	42,969	13,137	305.7
1982	48,429	17,260	356.4
1983	59,928	19,640	327.7
1984	78,519	25,502	337.5
1985	92,797	33,798	364.2
1986	98,115	34,327	349.8
1987	171,826	50,199	292.6
1988	253,104	79,335	313.4
1989	317,705	110,509	347.8
1990	345,005	113,786	329.8

Source: Statistical Estate Crops of Indonesia (1991)

Appendix 3.1 Agro-physical and Socio-economic Conditions of the Region Studied

1 Introduction

It is necessary to present background information if the area of study is to be comprehended in all its complexity. Presenting both specific and general characteristics of the area will facilitate the understanding of technology adoption processes in the region. The information consists of agro-physical and socio-economic aspects associated with technology adoption processes. Besides the presentation of actual conditions, the development process of several elements that compose the overall picture of the region will be presented.

2 Location of the research

The research was conducted in the Sub District (which is further called the region) of *Bupon* which is located in the Regency of *Luwu*[1], South-Sulawesi, Indonesia. The region covers a wide area on the plain which is located in the North-Eastern part of South-Sulawesi (*Figure 3.A*).

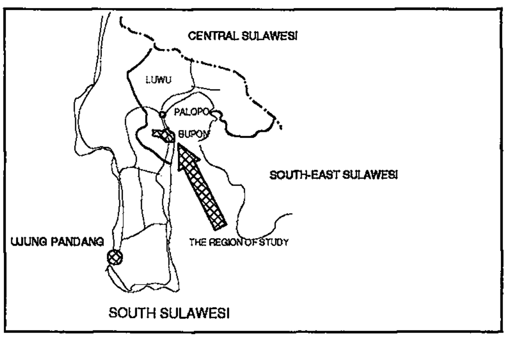


Figure 3.A Map of South-Sulawesi, Indonesia (Source: Regional Planning and Development Board of South-Sulawesi)

Luwu is the largest *Kabupaten* in South-Sulawesi with a total area of about 17,795 km², of which about 83% is primary and secondary forest. Statistical data shows that in 1993 only about 6% of the area had been exploited as dry land farms, which mainly consisted of plantation areas, and 5% as wet land farms (*sawah*). Except for new transmigration settlements on several locations, this region has not been exploited intensively in recent years. Agricultural and other raw material products that need to be sent to other regions are transported by truck over main roads or by ship through a small harbour with poor facilities. The region is connected with other places by main roads that are still in a good condition. Roads connecting one village to another are generally in a bad condition. It is difficult to visit certain villages that are located on the Western or mountainous regions particularly in the rainy season.

The region of *Bupon* that can be seen on the map presented in *Figure 3.B*, is located at about 400 km in a North-Easterly direction from Ujung Pandang, the capital of South-Sulawesi. It covers a wide fertile agricultural area that extends from the hill of *Latimojong* on the West to the sea shore on the East. The total area of the region is about 360 km² consisting of about 38% of agricultural land in cultivation. About 55% of the area is covered by secondary and primary forest vegetation that is located in the mountainous region in the West.

[1] *In government administrative regulations, the Republic of Indonesia consists of 27 Provinces where provinces supervise about 300 'Kabupaten' (Regencies). Each Kabupaten supervises several 'Kecamatan' (Sub Districts), where the latter supervises several 'Desa' (Villages).*

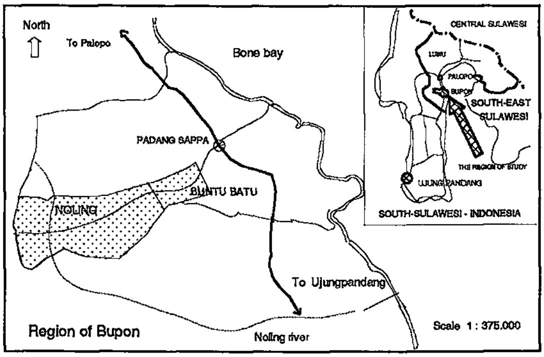


Figure 3.B Map of Bupon Region and Villages studied (Source: Bupon Sub-District Office)

The villages studied, *Noling* and *Buntu Batu*, are located at about 5 and 7 kilometres from the main road in a westerly direction and cover respectively about 2,200 and 950 hectares of agricultural area, including about 30 and 6 percent of forest area for each village. About 18% of the *Bupon* region, 59% of *Noling* and 73% of *Buntu Batu* villages are covered by cocoa plantations, which are cultivated by farmer smallholders. Meanwhile, in the *Luwu* region, only about of 6% is exploited for various tree crops, including the cocoa crop.

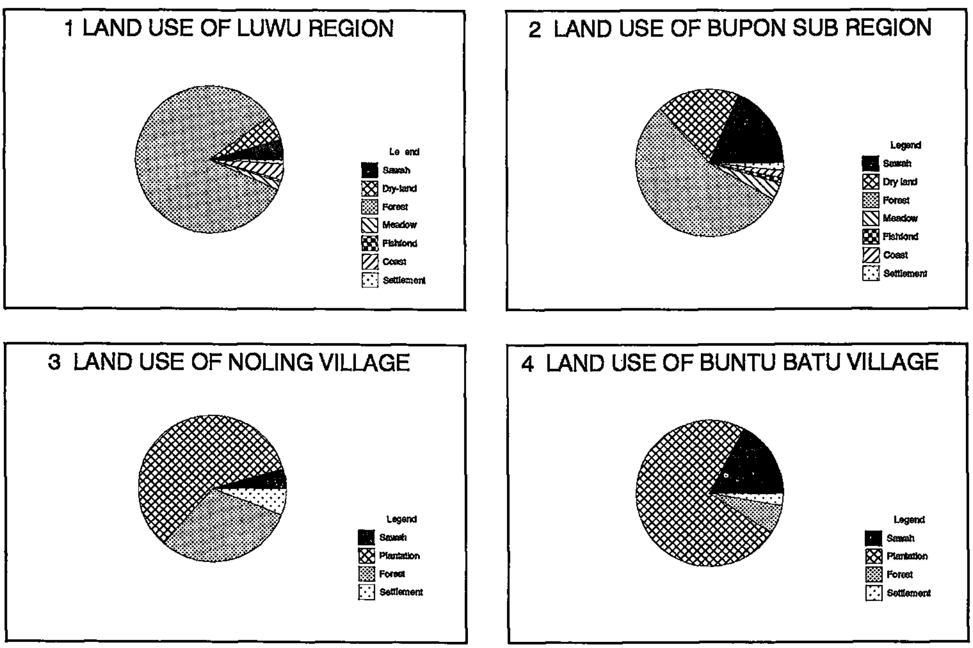


Figure 3.C Proportion of land used at each regional level, 1993. (Source: 1: The Ministry of Public Works; 2, 3 and 4: Monographs of villages, Bupon Sub-District Office)

The proportion of land used at each level of the region, as can be seen in *Figure 3.C*, shows a tendency, namely that the lower the level of the region the higher the proportion of available land used for cocoa exploitation, and otherwise, the lower the level of the region the lower the proportion of land reserves and forest. These conditions indicate that the cocoa crop has developed forcefully in the Southern part of the region.

3 Tropical forest and vegetation development

The scarcity of land for agricultural exploitation on the one side and the fast-growing population on the other has led to the forest area becoming the easier alternative for farmers in obtaining land for their farming exploitation. A lack of supervision due to a lack of forest supervisors and the pressure of fast population growth have caused a sharp decline in the forest area in the region. In 1992, only about 40 local supervisors supervised an area of about 1,235,000 hectares. Ideally, one supervisor would supervise about 2,000 to 5,000 hectares. This problem is accumulated by the expansion of farms and new settlement areas close to the forest region.

In 1988, there was still of about 1,480,000 hectares of forest area in existence, that means that during the last 5 years, it has diminished by about 20 percent. Even in the village of *Buntu Batu*, the proportion of forest in existence in 1993 was only about 6 percent of the total village area.

The diminishing forest area on certain hill and many plain regions has changed the picture of vegetation in the region. In the last 20 to 30 years the secondary, or even primary forest, was still the dominant vegetation of the region. However cocoa plantations, which are alternated by various other perennial crops and *sawah* area have changed the situation. In the area close to the coast, vegetation is dominated by coast plants and fish-ponds followed by coconuts, which are being interplanted by cocoa crop and *sawah* area. The sago palm which could once be found everywhere, has become scarce nowadays and the area has changed to cocoa or *sawah*.

4 Soil conditions

On the whole, the region is an agricultural area that consists of diverse kinds of soil with a relatively high level of fertility. This soil is covered by diverse vegetation, which is composed of the various perennial crops exploited, jungle and shrubs, and various annual crops cultivated on dry and wet field. The soil consists of Alluvial, Gley, Latososl, Regosol, Podzolic and Mediteranian types (RSGP Project, 1991). Cocoa is being cultivated on almost all the soil presented.

Two main types of soil, Alluvial and Podzolid, dominate almost the whole sub region of *Bupon*. The alluvial type covers the plain where it ranges from the coast of *Bone* bay in the East to the foot of *Latimojong* hill in the Western region. Alluvial soil, which is often namely recent deposits, can be found in two main soil types in the region, the greyish and brownish alluvial characteristics could be described as follows:

* greyish alluvial; this soil can be found in the plain region close to the sea at an altitude of 0-2 m above sea level. The drainage and the infiltration of water in this region are bad, and its soil characteristics are: (1) a soil texture of sandy clay, (2) a crumbly structure, (3) a pH of about 7.2 to 7.9, and (4) a main part of this soil is used for *sawahs* and fish ponds;
* brownish alluvial; This soil is the result of clay and sand sedimentation processes in an upland region. This soil can be found in regions with an altitude of 2-100 m. Its characteristics are: a sandy texture or dusty clay, a crumbly structure, a pH of about 6.5 - 7.2, a low drainage and water infiltration capacity. This soil is cultivated by planting cocoa, coconut, or other perennial crops.

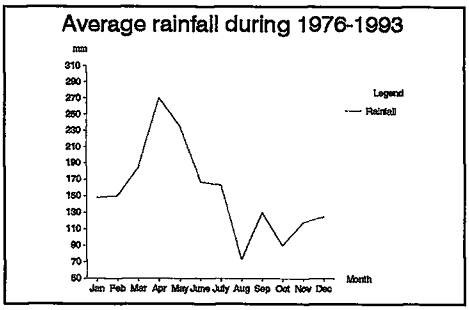
Another type of soil is yellow to brown podzolid which can be found on the upper land region at an altitude of 100 m above sea level. This soil is characterized by very poor mineral levels, especially Kalium, Calcium, Magnesium, etc; it has a rather low pH level because of washing processes; pH varies from 4 to 5.5, and it is very sensitive to erosion processes, therefore, this soil always needs to be covered by vegetation. In the

Bupon sub region, a large part of the soil is covered by a tropical forest and recently by cocoa plantations.

5 Climatic conditions

In general, the climatic conditions of the region can be characterized as a per-humid lowland tropical climate. To be precise, throughout the year it is frequently wet with only a rare excessively dry month. The phenomenon occurs since the region is a part of a wider region, in the North-East, of South-Sulawesi where two seasons coincide. When the rains set in the North, from October to March, a dry season hits the Southern region. Otherwise, from April to September when the rainy season hits the South, the dry season sets in the Northern region. A characteristic of this climate, particularly, the annual rainfall level as in *Figure 3.D*, shows that neither one of the months in a year is too dry. The most dry month is August with an average rainfall of about 70 mm. The average level of annual rainfall over the last 15 years has been about 2700 mm, with the number of rainy-days in a year running at about 120.

The average annual temperature of the region, is not too different from other regions. The minimum temperature is 23° C and the maximum temperature is 32° C. These climatic conditions are favourable condition for growing cocoa plants.



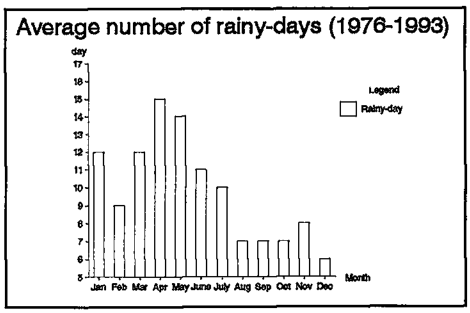


Figure 3.D Average annual rainfall and rainy-days during the last 15 years in the Bupon Region, South-Sulawesi (Source: Regional Public Work Services of South-Sulawesi Province)

6 Water resources

The availability of water, particularly for *sawah,* is an essential factor for rice production development. The water requirement for farmers who exploit cocoa plantations on dry land, is fulfilled by rain water. However, the needs of farmers to expand and complete their existing cocoa farming with annual crop plots tends to increase from time to time. This tendency has influenced the increase of water requirements as a convenient production factor. The geographical site of the region which is characterized by almost excessive rainfall throughout the year as described previously, is a favourable condition that provides benefits and enables farmers to make use of the water for their household and farming production.

The water requirements of farmers are fulfilled by (1) digging wells or deep water pumps, (2) surface water in the form of river and irrigation water, and (3) rain water. While the daily activities of farmer households are serviced by using well water. The presence of *Noling*'s river with its upper course located on the Western mountain, emptying into *Bone*'s bay on the East has brought various implications for daily farmers' activities in the region, which could be identified as follows:

(1) During a rainy season, which usually takes place throughout the year, the river of *Noling* will be flooded,

which has often damaged farms in the region. The floods eroded cocoa plantation areas which were located along-side of the river, particularly the part in a bend of the river. When the flood takes place for a longer period which usually occurs in a longer rainy season with a high rainfall level, the flood will inundate cocoa plantations, particularly on the lower part of a farm area which can damage cocoa plants, because of cocoa roots decaying. The minimal effects are, cocoa growth will be harmed and, as a result, there is a certain decrease in cocoa tree productivity in the following years.

(2) Another problem which emerged was the cessation of transportation and communication between villages and the farming areas located on the other side of the river. Farmers whose land was on that side usually walked across the river to transport and should production and production inputs since a bridge has not yet been installed. When there is no flooding, the river can to be traversed on foot. Flooding implied that all daily farm activities on the far side of the river had to be postponed, is sometimes for one or two weeks.

(3) Otherwise, the floods that occur every year were a benefit to farmers, as a result of an increase in soil fertility produced by sedimentation of soil mineral and humus.

(4) In the dry season certain inhabitants could earn an additional income by exploiting the riverbed sand that is sold as a construction material.

7 Development of support institutions

Farmers' organizations

Farmers' organizations were once organized, when the Coconut Smallholder Rehabilitation Project was still running well. But at present there are no activities anymore. In an informal way, farmers preferred using neighbourhood groups or ethnic groups as institutional tools to facilitate their contacts and communication amongst farmers. Meetings amongst ethnic and neighbourhood members were more frequent than in extension groups. The exchanges of information were apparently more frequent through ethnic groups than extension groups. Hence, the improvement of information mastery and farmers' technical knowhow was left far behind. The farmers who actually needed information, have to use their personal initiative, usually going to a more capable source of information elsewhere. Contacts with extension agents were too infrequent.

Research and extension institutions

Research institutions do not exist around the region. For food crops, research information could be received from the Food Research Station which is located about 300 km to the South of the region. Specifically for the cocoa crop, research information could be obtained from the Plantation Research Centre which is located on East Jawa or through the Regional Plantation Service in Ujung Pandang. By personal initiative, certain farmers usually contacted the research station to obtain actual information or advice on cocoa problems.

Initially, extension agents had the role of introducing and developing the cocoa crop in the region. They helped farmers to get F1 hybrid plant materials from research stations, organizing the cultivation of seedlings and teaching on cocoa technology. Unfortunately, in the subsequent development, its role has really declined. It has mis-apprehended farmers' needs for information. Seemingly, they thought that farmers could bring cocoa technical knowledge into practice perfectly. Obviously, farmers still have many technical gaps in their information. Around the region can still be found the Extension Service Centre and the Smallholder Coconut Development Project Unit. However, farmers are still not making proper use of these institutions.

Economic institutions and price development

The role of rural economic institution is apparently still too weak, although the cocoa business in the region is showing increased activity from year to year. Two rural banks have operated in the capital of the *Bupon* region.

However, most of the farmers have not yet made use of the banks as a business support. The necessities of capital and credit are served much more by other sources, such as traders, collectors or fellow farmers. Production inputs, such as fertilizer and other chemical products could easily be supplied by traders and private production input shops in the market, nevertheless this would be at a higher price.

The roles of exporters, traders and collectors in the cocoa business and marketing process are other aspects that might be underlined. They play a too dominant role in after-harvest activities. In the marketing and supplying process of production inputs they can determine the utilization level of production inputs. About six big collectors with about 100 sub collectors operate in the region who control the cocoa supply mechanism and marketing processes, included determining the price, quality, and quantity of cocoa that can be bought.

A cooperative does not function properly as a farmer instrument to facilitate the supplying of farmer necessities. Several cooperatives which were created a few years ago have no activities. They are generally lacking in capital, in management knowledge and in their capacity to compete with other private sectors.

The exchange value of farmers' revenue has increasingly decreased since prices of production inputs increase sharply from year to year. Meanwhile, the significant price increases for cocoa have rarely bees received by farmers, over the last few years. The price of cocoa in the farmer level in last 10 years tended to be in the similar level. When they occur fluctuations in cocoa prices, even more frequently inflict a loss upon the farmers. The reverse, during the last five years, the price of Urea, for example, has increased from Rp.120/kg in 1989 to Rp.240/kg in 1993, therefore, it has increased by about 100 percent. Similar rises have occurred in pesticide and herbicide prices. The other main problems of production inputs are their availability on the market at the appropriate time and quantity, which sometimes cannot be organized by suppliers.

The agricultural industry and the business of agricultural product processing are still not developed. Several home industries, such as a rice mill and a coconut oil processing plant have operated, but only on a small scale.

Appendix 3.2 Historical Development of the Region [2]

1 Stagnant agriculture

Until the sixties, this region was still a stagnant and traditional region which was characterized by a low density of population, extensive agriculture, and a non-exploited primary and secondary forest. The main livelihood of the inhabitants who lived in the region was formed by certain forest products, planting traditional annual crops, or exploiting sago palm trees. *Sawahs* that are generally located close by villages and/or main roads were left for a few years had become shrubs. When certain plots were still exploited, they were located at the sides of the main road. Perennial crops and tropical fruit crops that had previously given revenues for farmer households, had become shrubs again, sometimes they had even reverted to secondary forest.

The starting point of the reconstruction of agricultural development can be traced back to 1965. At that time inhabitants who had left their villages which was induced by a political insecurity, were starting to resettle. The 'Wet Land Development Project' of *Padang Sappa* was developed. Inhabitants that resettled were supervised in winning back their land. In 1967, after resettling around *Buntu Batu* village, farmers started exploiting annual crops such as tobacco, maize, beans and other food crops on dry land. Until the late seventies, farm systems were still dominated by annual crop exploitation. Farmers also produced perennial crop yields, such as coconut, fruits and various forest products.

2 Perennial crop development

In the mid-seventies, the Smallholder Coconut Development Project was introduced, by which farmers were assisted in developing their coconut trees by support from soft loan credit in the forms of provision of coconut seeds, production inputs, extension services and land certification. This project installed various infrastructures for supporting its activities in the region, such as constructing buildings and moving in extension agents. Initially, the project went well and showed good performance levels for several years, until the start of cocoa development by farmers at the end of the seventies. This project introduced the cocoa crop in the region for the first time by establishing cocoa hybrid seedling plots in the end of 1970's. That means that the first time is introduced to the farmers in the region that cocoa crop could be cultivated and its production could be traded. Previously, this crop was planted in the collection plants' plot near by the region in the village *Ponrang;* even in 1950's in the village *Siwa* that located about 80 km to the southern of the region, cocoa crop had been planted as backyard plants by certain inhabitants. At the time farmers did not yet know the economic advantages of this crop. When the seedling plots were introduced, most of the farmers responded unenthusiastically, although young plants and/or cocoa seeds were distributed free. Apparently, farmers were still traumatic with the case of castor-oil (*Ricinus communis*) crop, where a few years before this crop was cultivated widely by farmers (in order to fulfil the advice of state services), however when the yields were ready to sell there was no market available later for its production. This learning made more prudently farmers in choosing a perennial crop to be exploited. Notwithstanding they have the previously bad experience, some farmers remain try to cultivate little cocoa trees which later obviously became the sources of plant materials when the cocoa area expanded during the cocoa boom a few years later.

3 Annual crops development

Until the late seventies, annual crops remained the main source of livelihood of farmer families in the region, since the migrant farmers who settled earlier in the region had generally an experience in annual crop farms. In this new settlement, migrant farmers continued to cultivate tobacco, which was combined with other annual

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[2] *Sources of data and information are (1) Regional Planning and Development Board of Luwu Regency; (2) Bupon Sub District Office; (3) Regional Public and Work Services; (4) Padang Sappa Irrigation Project; (5) Regional Transmigration Office; (6) Regional Agrarian Office; (7) Regional Forestry Office; (8) Regional Food Crop Services; (9) Regional Estate Crop Services of Luwu Regency; and (10) Primary Data.*

crops such as dry land paddy, maize, various beans, legumes and other annual crops that can be of economic value to farmers' families. Paddy or *sawah* was mainly exploited by indigenous farmers. If the migrant farmers cultivated paddy or *sawah*, they occupied the *sawah* by sharing or renting from indigenous farmers. At that time the *sawah* was cultivated once a year remain.

Annual crops were exploited continuously until the era of cocoa development. Farmers cultivated these crops on the land that was being prepared for cocoa plantations. In the first year when engaging upon land clearance, making stakes and preparing holes for cocoa plants, food crops were exploited. During that year, shade plants either leguminous plants, mostly *Gliricidia maculata* and *Sesbania sp.*, or bananas were had also planted and the cultivation of seedlings took place too. Then, exploitation of food crops would be continued until the second or third year of cocoa growth depending on the availability of family workforce members and to what extent that intercropping anual crops influenced the growth of young cocoa.

The choice of annual crops varied from one ethnic group to another, which was related to their previous experience in exploiting crops in their original home region. Farmers who originated from the South of the region (*Soppeng, Bone*) generally cultivated tobacco and maize crops and those who came from the Western region (*Enrekang*) chose soyabeans for interplanting. Meanwhile, most of indigenous population planted rice, banana or other fruit trees as interplanting crops.

Nowadays interplanting annual crops with cocoa is not widely practiced anymore, since land clearance for new cocoa plantations is becoming increasingly rare. When farmers still exploit food crops on their dry-land, their production is usually only intended for home consumption. The annual crop that is exploited on separate plots is paddy of *sawah*. In 1993, farmers exploited this crop on about of 5% of the total area of *Noling*, 17% of the *Buntu Batu* villages, and 19% of the *Bupon* region. The average number of hectares exploited is too small, only about of 0.3 hectares per farmer household for two villages. Although the number of hectares exploited per household is too small, this crop does presumably play an extremely important role in maintaining farmer household strategies.

4 Irrigation development

An irrigation installation was constructed in the region in the mid of eighties. Its potential capacity to irrigate wet rice fields is about 12,600 ha, however, the hectares of *sawah* that could be irrigated in 1993 was only about 4,000 ha. The construction of many secondary and tertiary canals could not be continued since the land provided for canals and land reserved for *sawah* had been planted with cocoa. The canals therefore stopped on the border of cocoa plots. This problem arose due to the fact that at the time of construction the available land was being planted cocoa by farmers both indigenous and new arrivals, since a cocoa boom had taken place at the same time.

The existing irrigation in the region was not functioning optimally to provide irrigation water; several problems and constraints emerged later, such as: (1) due to the short time in which the irrigation system was installed, many parts of the irrigation construction did not function well anymore, which influenced the capacity of water distributed; (2) the synchronization between the canal drying periods and the times water was used by farmers was not running well. Farmers had difficulty in following the agreed water distribution time caused by the polyculture system. When a peak cocoa harvesting season occurs at the same time as the beginning of land preparing for *sawah*, farmers usually sacrifice one of their activities. Frequently, the farmers' preference was for land preparation for *sawah* being postponed for few days to adjust the availability of family workforce members; (3) the farmers usually cultivated fresh fish too between two rice planting seasons which could also influence water distribution mechanisms. This had the following implications that all mechanisms of water distribution would be disturbed; and (4) since the introduction of irrigation technology is quite new, various aspects are still not organized and arranged very well, such as the mechanism of water distribution amongst farmers and the maintenance of tertiary canals.

5 Land development

Previously, land could be occupied by farmers for free at least it could be exchanged for other resources owned by farmers. Without spending capital or money, farmers could occupy land by exploiting certain plots and after the next harvest they could receive their due through land sharing. Nowadays, that system is not found anymore, due to the increase in the economic value of land. Farmers, who wish to initiate a new farm business must spend certain amounts of money to buy or to rent the land needed.

The function of land in the cocoa farm business has become more important since its availability has become scarce. This situation has occurred particularly over the last 4-5 years. The increasing number of farmers interested in being involved in the business of cocoa farming on the one side and the scarcity of available land which is suitable for cocoa crop growing on the other has resulted in great competition for the land more suitable for cocoa exploitation.

Initially, if it is traced back to the beginning of the development of the region, in the late sixties, when land was still more easy to find, one could occupy a piece of land only by going to a local government official who would be a mediator with land owners. Land owners who are indigenous inhabitants who owned a great deal of land usually agreed directly to sharing their land since generally their land was still covered by shrubs or secondary forest. At the time, land was not paid for and the only capital brought by the arrivals was their family workforce and a little bit money to purchase rice, salt and tobacco during the first 2-3 months of exploitation.

In a relatively short period, the land function changed. Its economic values increased sharply and the price of a piece of farm land is almost too high for a beginner nowadays. In the last 4-5 years you could still start a cocoa business by renting a piece of cocoa plantation, and our money for renting can be returned after the agreed contract has finished. At present, the rent costs cannot be returned anymore. It seems to be impossible for a new farmer to buy or rent a piece of land with a low price. Even, if the land is rented, it must be for a longer period since if it is only for one or two years the cocoa yields cannot cover the cost of renting.

Finally, the control and ownership of land per farmer household are generally in a small piece. A few years ago when cocoa had not yet been developed, most of the indigenous farmers owned a large number of hectares of farm land. Because of the education costs of their children, housing construction costs, and other household consumption expenses, they sold part of their land to new comers. Farmers who have no land and work on other farmers' land tend to be increasing. The number of farmer owners and the farmers who had no land average out, at about 5,300 and 5,400 respectively.

6 Population and demographic development

By a favourable geographical environment and a high level of regional potentiality, which take the form of an excess of natural resources, the scarcity of population which is directly correlated to the source of workforce supply is a phenomenon, which could be a constraint on the economic development of the region. Population density was too low, only about 40 inhabitants per km^2 in 1993, which was too few compared with other regions, even compared with the average density of *South-Sulawesi* which is about 110 persons per km^2.

The level of population growth in *Kabupaten Luwu* varies for certain periods. In 1978-1982, the growth was rather high, approximately 7.7 percent. While between 1983-1986 it had diminished to the annual average level of 2.7 percent, and during the 1980-1990, the average growth was about 3 percent. The higher growth in 1978-1982 was caused by the fact that during that period the region had received a large group of transmigrants from Jawa and, then, had experience high population mobilities, of either groups or individuals, from other regions in *South-Sulawesi*. The transmigrants had generally settled in the Northern region with a low population density area.

It is interesting to briefly describe further transmigration aspects, since transmigration settlement provides workforces for many development and economic activities in the region. At the same time transmigrants will be transfer agents of technology for indigenous inhabitants. By their arrival, they introduced certain technology and new traditions which were not yet very familiar to local inhabitants. For instance, they introduced the plowing and preparing of the land for *sawah* by using animal traction, improving a mutual tradition amongst inhabitants which is called '*gotong royong*', modernizing and organizing village institutions by introducing the institution of a small community, namely '*Rukun Warga (RW)*' and '*Rukun Tetangga (RT)*' which means organizing certain members of the neighbourhood community, improving the traditional deliberation namely '*musyawarah*', creating a working group system, making a more healthy environment, and introducing the management and organization for water distribution of irrigation purposes.

Otherwise, besides these advantages, there were certain new problems for local inhabitants, *i.e.*, the new phenomenon of social jealousy. They considered that transmigrants had received better aid and treatment than local inhabitants. The aid was in the form of settlement areas and land clearance, house preparing and facilities, infrastructures, grants for certain periods, etc. This aid was not open to local inhabitants, although they also had the same socio-economic level, if not lower. To redress this imbalauce, since the Five Years Development Plan (*Repelita V*), 1989-1993, the government has completed its transmigration policies and implementation. The new policy stipulates that each location of transmigration must be reserved for at least 20 percent (in certain areas about 50 percent) for local inhabitants, which mens that they too could also have a chance to benefit from such facilities.

The historical transmigration settlement in the region can be traced back the late thirties. Around 1938 and 1939, the first transmigration group from Jawa, which was called the 'colonization group', was settled by Dutch Plantation owners as workforces for preparing land clearance and planting rubber and coconut plantations. They were settled in the various locations in the Northern region, such as in *Kecamatan of Tomani, Mangkutana, Wotu, Bone-Bone, Sukamaju* and *Lamasi*. Meanwhile the first transmigrant group consisted of 250 families or 1118 peoples, which was organized by the government, arrived in 1970, and was settled in the village of *Sidobinangun on Kecamatan of Bone-Bone*. To accelerate the rural development process of the region, the settlements were continued during the last five of *Repelita* (25 years). About 15.000 families or almost 70.000 people have settled in 45 settlement units. Their villages scattered over *Kecamatan of Bone-Bone, Masamba, Mangkutana, Sabbang, Malangke and Malili*, which were all located to the North of *Kabupaten Luwu*. Then, the second generation of these settlers became workers in various rural economic activities, particularly in cocoa exploitation activities in the region.

It is different in the Southern region, which initially suffered from the lack of population too, however, after the seventies, the population went up quickly due to the exodus of inhabitants from other *Kabupaten* in Central and Western *South-Sulawesi*. Therefore, this region was not allowed to be settled by transmigrants. This region was mostly settled by newcomers from *Kabupaten* of the Southern region. They occupied a wide fertile agricultural area from the mid sixties until the mid eighties. These arrivals became the main actors for development of the cocoa crop in the region. Obviously, they came to the new region when cocoa had not yet been introduced and they exploited annual crop plots. But, when the cocoa boom era arrived, the exodus of population from the South got underway, which can be seen in the increase of population in 1985 by about 23 percent. At present the growth of population has declined to about of 0.5 percent levels. The population densities of the *Bupon* region, *Noling* and *Buntu Batu* villages are about 180, 150 and 210 persons per km^2 respectively. The structure of population shows males and females average out and the number of workforce populations is about 46 percent of the total population.

Based on ethnic origins, the ethnic group the *Bugis* who came from the Southern region accounts for about 60 percent of the total population in the region. This ethnic group mostly has experience with tobacco farming and other annual crops. The second ethnic group is the native ethnic namely *Luwu*, which is characterized by a larger ownership of farm area and by mostly having a greater interest in their children's education. The third is a minority ethnic group that came from Western *South-Sulawesi* and generally has experience in paddy farming.

The supply of salaried workforces in the workforce market is provided by workforces who have come from

Southern, *Bugis and Makassar*, and from the North where the second generation of transmigration settlers from *Jawa* live. Salaried workforces are rarely available, especially when farm activities are on the increase, mainly in the peak season. During the last five years, the daily wage has increased 2-3 times. Actually, the daily wage is about Rp.3,000 to Rp.5,000, including lunch and a snack, depending on the kind of tasks. This wage level is equivalent to the price of 3-4 kilograms cocoa beans.

Appendix 4.1 Questionnaire

I General information
1 Number of the farmer
2 **Village**
3 Name of the farmer
4 **Origin**
5 Date of the first arrival in the village

II Relationship amongst group members (group elements)
Contact Group
6 Membership in the group
7 Meetings attended and their frequency

Neighbourhood group
8 Frequency of meetings with neighbours/acquaintances
9 Frequency of participating in group activities
10 Number of neighbours are known intimately

III Farmer characteristics
Experience
11 Previous experience
12 Date of the beginning be a farmer

Education
13 Level of education
14 Time of education
15 Courses that have been followed
16 Mastery of courses
17 Subject of courses
18 Frequency of courses
19 Media of other informal information received
20 Mastery of informal information

Age
21 Age of the chief of household

Cosmopolitanism
22 Number of visits to towns
23 Number of visitors that are contacted

Motivation
24 Motivation to involve in cocoa business

IV Household characteristics
Family number
25 Number of family members (list)
26 Number of children

Family workforce number
27 Number of active family workforce
28 Number of non active family workforce
29 Number of non permanent active family workforce

V Farm characteristics

Plot number exploited

30 Number of plots exploited

Hectares of farm exploited

31 Hectare of plots exploited (5 years)
32 Status of land occupied

Maximum distance of plots

33 Maximum distance of plots exploited from the village
34 Crops exploited in each plot
35 Type of exploitation

Off-farm activity

36 Kinds of off-farm activity
37 Period of off-farm activity
38 Number of workforce involved in off-farm activity
39 Salary and/or revenue from off-farm

Production process

40 Crops exploited over the last 5 years
41 Crop production over the last 5 years
42 Kinds of production (5 years)
43 Production consumption (5 years)
44 Production sold (5 years)
45 Price of production (5 years)
46 Kinds of activity of production process (5 years)
47 Period of each activity (5 years)

Workforce used

48 Number of workforce used of each activity (5 years)
49 Workforce status of each activity (5 years)
50 Salary of workforce of each activity (5 years)

VI Technology adoption

51 Production inputs used of each crop (5 years)
52 Volume of production inputs used of each crop (5 years)
53 Price/unit of production inputs (5 years)
54 Other expenses of each activity (5 years)
55 Total expenses of each activity (5 years)
56 The reason for using/non using fertilizer
57 Problems faced in fertilizer application
58 The reason for using/ non using pesticide
59 Problems faced in pesticide application
60 The reason for using/non using herbicide
61 Problems faced in herbicide application
62 The reason for practicing/non practicing fermentation
63 Problems faced in fermentation application
64 First information of production inputs and fermentation received
65 First application of production inputs and fermentation
66 General other information

Appendix 4.2 Characteristics of Variables

(1) Origin of farmer (ORIGIN). This variable is based on information from ethnical groups. It distinguished two ethnical groups, migrant and indigenous farmers. The first group dominates the village of *Bupon* which mostly cultivated cocoa with the sole crop system. The second one, indigenous farmers dominantly housed in the village of *Buntu Batu* and grown cocoa on a mixedcrop system, which is the dominant style in the area. The origin of farmers is a dummy variable with the value 1 if farmer is migrant and 0 if indigenous.

(2) Number of neighbours known intimately (NEIGHB). This variable defines the level of social interaction between farmers, measured by the number of neighbours and acquaintances who are known intimately. About 70% of farmers recognized and met their neighbourhood community members frequently. About 53% of the farmers followed neighbourhood activities regularly.

(3) Years in education (EDUCT). The variable based on the level of education will differentiate the ability of farmers to grasp information that they have received, which will finally determine their ability to select appropriate technology at an appropriate level. The levels of education applicable to farmers are illiterate, primary, secondary and high school, and even university level. About 60% of the farmers has only had an education up to primary school level. Education is designed into two dummy variables, ECUCT1 and EDUCT2. EDUCT1 is the variable high educational level with the value 1 if farmer has years in education six or more than six years and 0 otherwise. EDUCT2 is variable literate farmers with the value 1 if farmer is literate and 0 if he is illiterate.

(4) Number of family workforce (FAMLAB). The variable number of family workforces is based on the variability of the family workforce size per farmer household ranging from one to ten persons. The average size of family workforce is four persons. The average of an active permanent workforce was about 2.4 persons per family.

(5) Annual crop area exploited in 1992 (ACHAD). The annual food crop area exploited in 1992 is a dummy variable which is based on the difference of annual crop exploitation. The value is 1 If farmer exploits annual crop plots and 0 if he does not exploit.

(6) Farm gross output in 1992 (FAGROS92). The variable farm gross output in 1992 is based on the variability of farm gross output in that year which ranging from a maximum of 16.62 million to a minimum of .17 million Rupiahs, with the average of about 4.61 million Rupiahs.

(7) Farm gross output in 1993 (FAGROS93). The variable farm gross output in 1993 is based on the variability of farm gross output in 1993 which ranging from a maximum of 27.25 million to a minimum of .84 million Rupiahs, with the average of about 5.17 million Rupiahs.

(8) Farm hectares exploited in 1993 (FAMHA93). The variable farm hectares exploited in 1993 is based on by the variability of farm area exploited in 1993 which ranging from a maximum of ha to a minimum of 16.05 ha to a minimum of .50 ha. The average farm area exploited in 1993 is 2.99 ha.

(9) Labour employed in 1993 (LABOR93). The variable labour employed in 1993 is based on by the variability of labour cost used in 1993 which ranging from a maximum of 7.29 million Rupiahs to a minimum of .5 million Rupiahs, with the average of 1.92 million Rupiahs.

(10) Fertilizer adoption in 1993 (FERTID). The variable fertilizer adoption in 1993 is a dummy variable which is based on the difference adoption of fertilizer in 1993, with the value 1 if farmer adopted fertilizer and 0 otherwise.

(11) Pesticide adoption in 1993 (PESTID). The variable pesticide adoption in 1993 is a dummy variable which

is based on the difference adoption of pesticide in 1993, with the value 1 if farmer adopted pesticide and 0 otherwise.

(12) Herbicide adoption in 1993 (HERBID). The variable herbicide adoption in 1993 is a dummy variable which is based on the difference adoption of herbicide in 1993, with the value 1 if farmer adopted herbicide and 0 otherwise.

(13) Fermentation adoption in 1992 (FERMED). The variable fermentation adoption in 1992 is a dummy variable which is based on the difference adoption of fermentation in 1992, with the value 1 if farmer adopted fermentation and 0 otherwise.

(14) Fertilizer application in 1993 (FERTI93). The variable fertilizer application in 1993 is based on by the variability of amount of fertilizer application per hectare in 1993 ranging from a maximum of 2,000 kilograms to a minimum of 550 kilograms. The average amount of fertilizer application per hectare in 1993 is 355 kilograms.

(15) Pesticide application in 1993 (PESTI93). The variable pesticide application in 1993 is based on the variability of amount of pesticide application per hectare in 1993 ranging from a maximum of 12.75 litres to a minimum of .10 litres. The average amount of pesticide application per hectare in 1993 is 2.82 litres.

(16) Herbicide application in 1993 (HERBI93). The variable herbicide application in 1993 is based on the variability of amount of herbicide application per hectare in 1993 ranging from a maximum of 12.00 litres and a minimum of 2.25 litres. The average amount of herbicide application per hectare in 1993 is 5.10 litres.

(17) Fermentation application in 1992 (FERME92). The variable fermentation application in 1992 is based on the variability of amount of cocoa fermented per farmer in 1992 which ranging from a maximum of 11150 kilograms to a minimum of 850 kilograms. The average amount of cocoa fermented per farmer in 1992 is 710 kilograms.

Appendix 6.1 The Formulation of Linear Programming in a General Model

The solution that should be attempted by the linear programming technique relates to a basic problem that is called the primal problem. For each primal problem there is a corresponding dual problem which yields additional information to decision makers. The nature of the dual problem depends on the primal problem. If the primal problem is a maximization problem, its corresponding dual problem is a minimization problem. Similarly if the primal problem is a minimization problem its dual problem is a maximization problem (Paris, 1991; Koutsoyiannis, 1979). According to Paris (1991), in general, theoretical linear programming model could be formulated by defining

c_j ≡ unit net revenue of commodity j
b_i ≡ total available quantity of input i
a_{ij} ≡ amount of input i necessary for the production of one unit of commodity j
x_j ≡ level of commodity j produced using the *jth* technological process
y_i ≡ shadow price of input i

The general formulation of a primal LP problem can be specified as follows (TNR = total net revenue):

$$\text{maximize TNR} = \sum_{j=1}^{n} c_j x_j$$

$$\text{subject to} \quad \sum_{j=1}^{n} a_{ij} x_j \leq b_i, \qquad i = 1,2,3,\ldots,m$$

$$x_j \geq 0, \qquad j = 1,2,3,\ldots,n$$

Formulation of dual problem is

$$\text{minimize TC} = \sum_{i=1}^{m} b_i y_i$$

$$\text{subject to} \quad \sum_{i=1}^{m} a_{ji} y_i \geq c_j, \qquad j = 1,2,3,\ldots,n$$

$$x_i \geq 0 \qquad i = 1,2,3,\ldots,m$$

By arranging all the information of the primal and the dual problems in a single array (Goldman and Tucker, vide Paris, 1991) the symmetric duality of a general LP problem can be presented as follows

≥ 0	x_1	X_2	...	X_n	< 0
y_1	a_{11}	a_{12}	...	a_{1n}	b_1
y_2	a_{21}	a_{22}	...	a_{2n}	b_2
...	...	...	...	...	...
y_m	a_{m1}	a_{m2}	...	a_{mn}	b_m
$\geq$	c_1	c_2	...	c_3	$\leq$

The primal problem can be read by multiplying the variables x_j to the coefficients in the corresponding columns. The same way, the dual problem can be identified by multiplying the y_i variables across the corresponding rows. The inequality in the upper-left corner represents the non-negative of both primal and dual variables. The inequalities in the upper-right and down-left corners represent the primal and dual constraints. Latest, the inequality in the down-right corner represents the relationship between the primal and the dual objective functions.

Appendix 6.2 Input-Output Table of Cocoa and Other Crops' production Techniques

Activities	Extensive	Semi-intensive	Intensive
1 Sole Cropping Cocoa			
(1) Inputs			
a. Fertilizer, Urea/TSP/KCl (kg)	0	500 (200/125/175)	1000 (400/250/350)
b. Pesticide (kg/lt)	0	5	10
c. Herbicide (kg/lt)	0	5	0
d. Small materials (unit)	1	2	2
e. Fermentation box (unit)	0	1	1
f. Labour (man-day)	125	235	292
- Fertilizing	0	28	28
- Weeding	50	20	20
- Pruning	25	30	30
- Pest control	0	24	24
- Harvesting	30	58	94
- Fermentation	0	36	36
- Drying	20	39	60
(2) Output (kg ha^{-1} $year^{-1}$)			
- Cocoa yield (beans)	500	1000	1500
- Fermented cocoa (beans)	0	1000	1500
2 Intercropping Cocoa with Coconut			
(1) Inputs			
a. Fertilizer (kg)	0	750	1500
b. Pesticide (kg)	0	15	20
c. Small materials (unit)	1	4	4
d. Fermentation box (unit)	0	1	1
e. Labour (man-day)	150	300	400
- Fertilizing	0	33	34
- Weeding	50	20	20
- Pruning	25	30	30
- Pest control	0	24	24
- Harvesting	55	118	196
- Fermentation	0	36	36
- Drying	20	39	60
(2) Output kg ha^{-1} $year^{-1}$			
- Cocoa yield (beans)	500	1000	1500
- Fermented cocoa (beans)	0	1000	1500
- Coconut (copra)	300	600	1000
3 Sole Cropping Coconut			
(1) Inputs			
a. Fertilizer (kg)	0	500	1000
b. Pesticide/herbicide (kg/lt)	0	5	10
c. Small materials (unit)	1	2	2
d. Labour (man-day)	50	80	125
(2) Output kg copra ha^{-1} $year^{-1}$	600	1000	1500
4 Rice			
(1) Input			
a. Fertilizer (kg)	-	200 (100/50/50)	800 (500/100/200)
b. Pesticide (kg/lt)	-	2	4
c. Small materials (unit)	-	1	2
d. Labour (man-day)	-	100	250
e. Tractor (unit)	-	1	2
(2) Output, rice unhulled (kg ha^{-1} $year^{-1}$)	-	3000	8000 (2 harvests/year)

Appendix 6.3 Crop Calendar and Labour Requirements for Cocoa Farm per Activity per Month (man-day)

Activity \ Month		1	2	3	4	5	6	7	8	9	10	11	12	Total year
(1) Sole Cropping Cocoa														
Fertilizing	A	0								0				0
	B	14								14				28
	C	14								14				28
Weeding	A	25								25				50
	B	10								10				20
	C	10								10				20
Pruning	A	12.5								12.5				25
	B	15								15				30
	C	15								15				30
Pest control	A	0		0		0		0		0		0		0
	B	4		4		4		4		4		4		24
	C	4		4		4		4		4		4		24
Harvesting	A			5	5	5	5	5	5					30
	B			9	10	10	10	10	9					58
	C			15	16	16	16	16	15					94
Fermentation	A			0	0	0	0	0	0					0
	B			6	6	6	6	6	6					36
	C			6	6	6	6	6	6					36
Drying	A			3	3	3	4	4	3					20
	B			6.5	6.5	6.5	6.5	6.5	6.5					39
	C			10	10	10	10	10	10					60
(2) Intercropping Cocoa with Coconut														
Fertilizing	A	0								0				0
	B	16.5								16.5				33
	C	17								17				34
Weeding	A	25								25				50
	B	10								10				20
	C	10								10				20
Pruning	A	12.5								12.5				25
	B	15								15				30
	C	15								15				30
Pest control	A	0		0		0		0		0		0		0
	B	4		4		4		4		4		4		24
	C	4		4		4		4		4		4		24
Harvesting	A	3	2	2	7	7	7	7	7	7	2	2	2	55
	B	5	5	5	14	15	15	15	15	14	5	5	5	118
	C	9	9	9	23	24	24	24	24	23	9	9	9	196
Fermentation	A			0	0	0	0	0	0					0
	B			6	6	6	6	6	6					36
	C			6	6	6	6	6	6					36
Drying	A			3	3	3	4	4	3					20
	B			6.5	6.5	6.5	6.5	6.5	6.5					39
	C			10	10	10	10	10	10					60
(3) Sole Cropping Coconut														
Fertilizing	A	0								0				0
	B	2.5								2.5				5
	C	3								3				6
Harvest and other	A	5	5	4	4	4	4	4	4	4	4	4	4	50
treatment	B	7	7	6	6	6	6	6	6	6	6	6	7	75
	C	9	10	10	10	10	10	10	10	10	10	10	10	119
(4) Rice														
All treatment	A	-	-	-	-			-	-	-	-			-
	B	30	20	20	30			-	-	-	-			100
	C	30	30	30	35			30	30	30	35			250

Note: A - extensive treatment; B - semi-intensive; C - intensive

Appendix 6.4 Input and Output Unit Price on the Regional (Bupon) Level, in Rupiah, in 1993

	Description	Unit	Price
Input			
	1 Fertilizer		
	- Urea	kg	250
	- TSP	kg	350
	- KCl	kg	350
	2 Pesticide/herbicide	kg	20,000
	3 Small material	unit	10,000
	4 Fermentation box	unit	50,000
	5 Labour wage		
	- average year	man-day	2,500
	- peak period	man-day	5,000
	- non-peak period	man-day	3,000
	6 Tractor (hire)	unit	100,000
Output			
	1 Cocoa (beans)		
	- Non-fermented	kg	1,500
	- Fermented	kg	1,800
	2 Coconut (copra)	kg	800
	3 Rice (unhulled)	kg	250

CURRICULUM VITAE

The author of this dissertation was born on 28th August 1943 in Siwa/Sengkang, South-Sulawesi (Indonesia). He accomplished his agricultural engineer at the Faculty of Agriculture of the Padjadjaran University, Bandung, in 1974. From 1974 to 1989 he worked at the Directorate General of Estates, Ministry of Agriculture to manage the tree crops' development. He became involved in many activities of tree crops' development project, particularly in development systems and procedures, and project supervising. From 1989 to 1991 he obtained his 'Diplôme d'Ingenieur d'Agronomique Tropicale' in agronomic development at Ecole Superieure Agronomie Tropicale, Centre Nationale d'Etude d'Agronomique Region Chaude (ESAT-CNEARC) in Montpellier (France). From 1993 he studied at Department of Management Studies, Wageningen Agricultural University. To accomplish his Ph.D, he focused his research on decision-making processes of cocoa smallholder.