This is to certify that the

dissertation entitled

SYSTEM ANALYSIS APPROACH TO RICE THRESHING

TECHNOLOGY IN WEST JAVA INDONESIA

presented by

Handaka

has been accepted towards fulfillment
of the requirements for

Ph.D. degree in Agric. Tech. & Sys. Mgt.

Robert H. Wilkinson
Major professor

Date Oct 9 1991

PLACE IN RETURN BOX to remove this checkout from your record.
TO AVOID FINES return on or before date due.

DATE DUE	DATE DUE	DATE DUE

SYSTEM ANALYSIS APPROACH TO RICE THRESHING TECHNOLOGY IN WEST JAVA INDONESIA

By

Handaka

A DISSERTATION

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

DOCTOR OF PHILOSOPHY

in
Agricultural Technology and System Management

Department of Agricultural Engineering

1991

ABSTRACT

SYSTEM ANALYSIS APPROACH TO RICE THRESHING TECHNOLOGY IN WEST JAVA, INDONESIA

By

Handaka

In the dry season 1990, a farm survey and field experiments were carried out in Indramayu, West Java, Indonesia to evaluate the technical and economic factors of rice thresher mechanization. A system analysis approach was used to determine the optimum thresher size, the economic feasibility of engine-powered threshers and to estimate the agricultural labor available in Indramayu.

Engine-powered threshers produced losses 1.7% lower than that of manual threshing, and reduced total cost of harvesting and threshing, 2.78% lower than that cost of sickle harvesting and manual threshing. This cost reduction was to cover machine cost (2.32%) and thresher operator (0.46%).

Optimization results suggested that an engine-powered thresher size of 0.5 t/hr was optimal for farms less than 10 ha. Further, the results also indicated that subsidized credit made the larger thresher size more economically feasible. The profitability analysis of thresher ownership indicated that a local thresher made by artisan and priced less than Rp 1,550,000 was profitable with or without subsidy (BCR >1.0).

The population model indicated that during 1988-1998, agricultural labor force in Indramayu will increase by 0.4% annually and by 2008 it will decline by 1.3% annually. On the other hand, the non-agricultural labor force will increase by 6.6% annually.

The system approach techniques of the rice threshing mechanization provided a means of studying the influence of social-economic character of farms, government involvement and engineering technology on determining the level of rice threshing mechanization for small farms.

Approved:

Robert H. Wilkinson
Major Professor

R Dom Bennett
Department Chairperson

ACKNOWLEDGEMENTS

This dissertation would not have been possible without the help of many individuals and organizations in its preparation and finalization. Specially, I want to thank to:

Dr. Robert H. Wilkinson, my major professor, for his endless support and encouragement during the work.

Dr. Thomas H. Burkhardt, Dr. Thomas J. Manetsch, and Dr. Richard H. Bernsten the other members of the Guidance Committee, for their helpful suggestions.

Dr. Robert D. Stevens, my former guidance committee member, in providing suggestion during the preliminary study.

Many individuals in the Ministry of Agriculture, Republic of Indonesia, specially Dr. Soedjatmiko, Dr. Sutatwo Hadiwigeno, Dr. Faizal Kasryno, and the UNDP office in Jakarta who have made it possible for me to study at Michigan State University.

I would not have been succesfull without everlasting prayer and patience of my wife Endah Soeparti, my sons Nardipta Pratama and Mahendra Khrisna, during my 45 months absence from Indonesia.

TABLE OF CONTENTS

BIBLIOGRAPHY 220

BIBLIOGRAPHY 220

LIST OF TABLES

Table Page

LIST OF FIGURES

CHAPTER I

INTRODUCTION

1.1 Review of the Problems

Despite success in achieving rice self sufficiency, the problems of growth, equity and stability still dominate Indonesia's economic development agenda. The government is attempting to facilitate the nation's transformation, generation and adoption of technology to increase income, create employment, sustain agricultural production, and maintain a high level of economic growth. Since 1969, in four consecutive Five-Year Development Plans, the government has given priority to the Agricultural Sectoral Development including research, education, extension, agricultural technology, and institutional innovation.

In 1960 rice yields in Indonesia averaged only 1.7 t/ha, lagging behind Malaysia, the highest producer among the ASEAN countries, where yields averaged 2.0 t/ha. With the rapid adoption of Green Revolution Technologies in the late sixties, rice yields in Indonesia rose dramatically and surpassed those of Malaysia. By 1970, rice yields in Indonesia averaged more than 2.3 t/ha, making Indonesia's yields the highest among the ASEAN[1] countries. Since 1985, Indonesia's rice's yields have been the highest in the ASEAN region, averaging 3.9 t/ha (FAO,1987). By comparison, in Malaysia, rice yields averaged 2.8 t/ha, in the Philippines 2.7 t/ha, and in Thailand 2.1 t/ha. This tremendous increase enabled Indonesia to achieve rice self sufficiency in 1985, which transformed Indonesia from being the biggest rice importing country in the late 1970s to producing a slight rice surplus. Among the factors that contributed to this successful achievement was government investment in the agricultural sector, represented by agricultural expenditures of about two percent of the Gross Domestic Product (IMF,1987). Figure 1 shows the average rice yield in the ASEAN Countries.

As is common in developing countries, policy makers have raised concerns about the impact of new technology and rural employment, particularly on landless laborers and small land holders. Since more than 50% of the population is still engaged in agricultural activities, and each farmer cultivates less than 1 hectare of land (BPS, 1984), the strategy for agricultural development must be directed in to help the small farmers. Expansion of irrigation facilities, which has made possible double cropping of rice, has encouraged the use of high yielding rice varieties and

[1]ASEAN stands for Association of South East Asian Nations that includes Brainy, Indonesia, Malaysia, Philippines and Thailand

increased fertilizer consumption per hectare. Recent innovations such as herbicides in West Java and other rice growing areas in Java, have also increased labor productivity, as was the case in the Philippines, as reported by Smith and Duff (1981).

In the second half of the 1970s, Indonesia witnessed the rapid adoption of tractors for rice land preparation, primarily in West Java where more than 40% of the power tillers were in use. Sinaga (1979) reported that government credit and subsidies on tractors have a potential impact on labor displacement without any significant impact on increasing yield. Similarly, ten years earlier, Timmer (1984) reported that the introduction of large rice milling machine technology would displace rural labor, worsening income distribution, and widening the gap between the poor and the rich farmers. Regardless of whether these technologies are economically justified or not, the numbers of tractors and rice milling machines used in rice production are increasing drastically.

In Indonesia, farmers have harvested and threshed paddy using manual methods. Since 1985, engine-powered threshers were introduced and adopted gradually by the farmers, and now have become a new farm-input component of the rice production systems in Indonesia. The number of threshers (engine and pedal threshers) in 1988 has increased by 28.2% annually since 1981. The total number of threshers in 1988 was about 100,000 units (BPS, 1989). This figure indicates

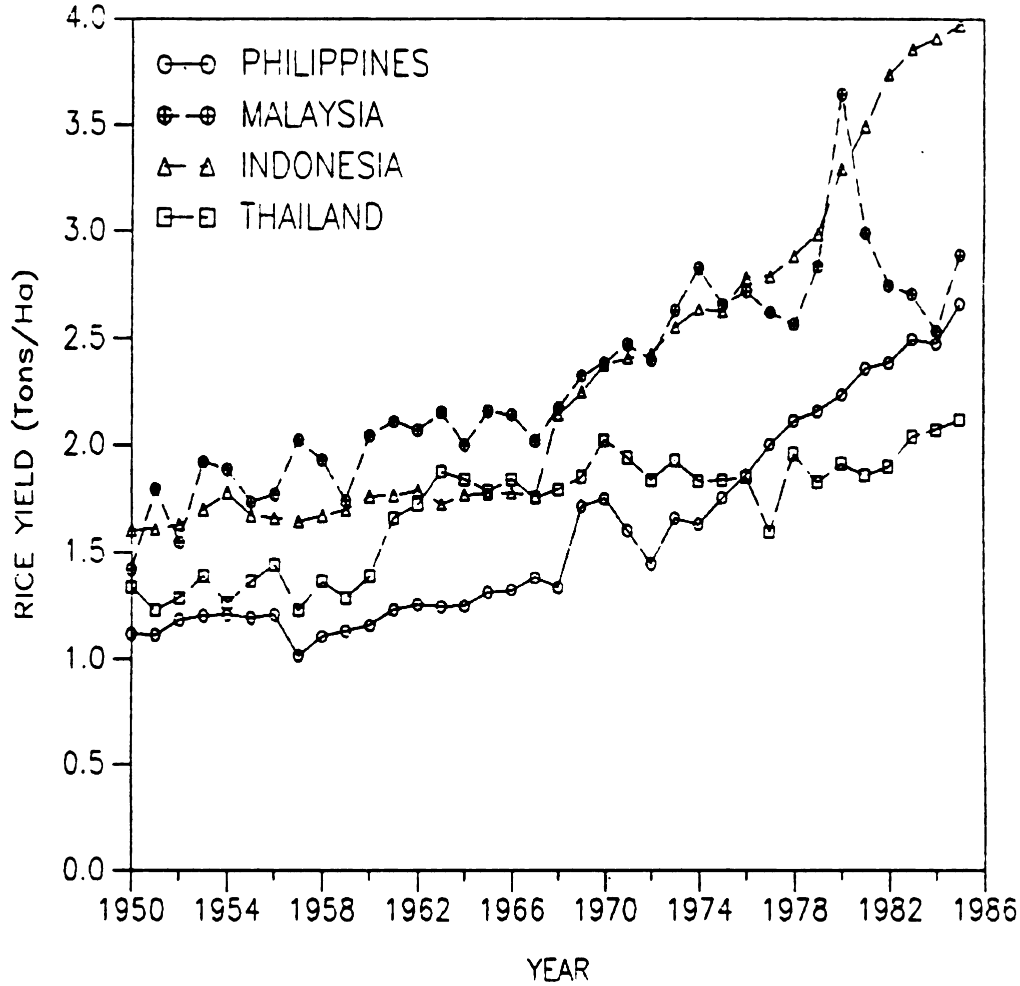


Figure 1.1. Rice Yield in the ASEAN Countries (1950–1985)

Source: FAO, 1987

the growing importance of rice mechanization, as well as efforts to reduce paddy post-harvest losses.

Various studies of rice post production losses have revealed that losses in harvesting and threshing operations ranged between 1 to 3% and 2 to 6% of the total pre-harvest yield[2] respectively (JICA,1982;BPS,1988). In West Java, Djojomartono (1979) estimated shattering losses associated with ani-ani harvesting (a small hand knife used for harvesting) ranged from 1.9% at the time of maturity to 2.% after nine days, and sickle loss ranged from 1.8% to 2.2% during the same time. Gaiser (1980), however, found that total cut losses (shattering and uncut losses) in Yogyakarta were 5.9% of the total yield, while threshing losses (hand-threshed) were 2.4%. The report of the joint survey between the Ministry of Agriculture, Bogor Agricultural University and the Central Bureau of Statistics (1988) indicated similar levels of the rice post-harvest losses throughout the country. This joint report that covered most of rice growing area from 15 provinces estimated that total rice post harvest losses equalled approximately 19% of the pre-harvest yield. Harvesting and threshing operations accounted for the largest share of the loss, with harvest losses at about 9.4% and threshing losses at 5.7% of the pre-harvest yield.

---

[2]Pre-harvest yield is defined as the yield before harvest operations, or the expected rice yield without any losses due to mechanical cutting.

Several studies (JICA and MOA, 1989), the FCRC(1988), and Hansen (1981)) indicated that the contractual labor system between harvest laborers and owner-operators had a significant impact on harvesting-threshing losses. Beside reducing grain loss, rice threshers have also had a direct effect on reducing the number of laborers required (Juarez, 1979; Smith and Duff, 1981, and Toquero, 1981). Because of the consequences of mechanizing rice threshing, there is a need to examine the technical and socio-economic aspects of this technology before it is widely introduced.

Previous studies revealed that many factors contribute to losses in field post-production and these vary from place to place, depending on differences in economic, technical and environmental conditions. Reliable data on the technology and economics of rice harvesting and threshing mechanization are very limited in Indonesia, as well as the agricultural technology and system management aspects of developing and implementing models that comprehensively integrate the technical, economic, and social factors.

This study used the systems approach methodology to analyze the mechanization needs for rice threshing technology, and to evaluate the technical and economic performance of alternative technologies that are, or could be considered to reduce harvesting and threshing losses.

Objective of the Study

This study used the systems approach methodology to analyze the technical and economic characteristics of rice threshing technology used at the farm level. The specific objectives of the study are as follows :

1. to identify the needs of mechanization technology for small farmers in order to reduce their grain harvesting and threshing losses.
2. to identify the most profitable utilization and ownership pattern for mechanical rice threshers, under the existing institutional arrangement between owner operators and harvest laborers.
3. to use a system simulation model to analyze and evaluate the alternatives to rice harvesting-threshing technology in point (1) and point (2).

1.3. Summary

The Problems, Objectives of Study, and Approaches.

The dramatic increase of Indonesian rice production that began in 1970 was the result of a complex national effort, involving the interaction of many different policies, government agencies, and levels of implementation (Timmer, 1985).

The key elements that contributed to increasing rice production includes transfer of technology, selection and provision of inputs, training and education for farmers, development of infrastructures, and pricing and marketing strategies (Robinson *et al.*,1987).

After great success in increased rice production, which finally made Indonesia self-sufficient in rice by 1985, a second problem appeared. The second problem was the rice grain losses, which amounted to 12-20%, according to many studies and surveys. The rapid adoption of modern rice production technology also increased the demand for selected farm mechanization, including rice mill machines, tractors, water pumps, sprayer technology and, recently, engine-powered threshers.

In Indonesia, traditionally, threshing has been one of the most labor intensive activities and is normally conducted by harvest-laborers. The consequences of the introduction of harvesting and threshing equipment, therefore, require a comprehensive study, particularly in accordance with the change of the harvest-laborer's income and their decrease in number.

This study is concerned with the following objectives:

1) the identification of the appropriate harvesting-threshing mechanization technology for small farmers
2) the evaluation of the profitability of alternatives rice harvesting-threshing systems and their prevailing harvest-laborer arrangement
3) the development of a model to evaluate the possible alternatives for harvesting-threshing technology for small farmers.

CHAPTER II

REVIEW OF LITERATURE

2.1 General Economy and Rice Production in Indonesia

Indonesia is predominantly an agricultural country with 56% of the economically active population working in agriculture. About 70% of this population is working in the food crop subsector. According to Stevens and Jabara (1988, p.49), two common measures of the structural change in economy are: (a) the proportion of income produced in each sector and (b) the proportion of the labor force in each sector.

Agriculture's contribution to the Gross Domestic Product (GDP) declined from 56% in 1965 to only 24% in 1985. Between 1965 and 1980, the GDP grew at 7.9% annually, while the agricultural sector grew at 4.3%. During the same period, the industry sector grew at 11%, the manufacturing sector at 12%, and the service sector at 7.3% annually. GNP per capita increased from \$100 in 1965 to \$530 in 1985 (World Bank, 1980, and 1987-1990). Table 2.1 shows a selected agricultural Economic Indicators of Indonesia from 1965 to 1985. This table indicates that implied per capita income in agriculture (based on 1985 US dollar) increased from \$164 to \$223, only 1.8% increase per year or 35.9% in

Table 2.1. Selected Agricultural Economic Indicators of Indonesia, 1965 -1985.

Row	Indicators	1965	1985
1	Population (million)	100.	166.4
2	Per capita income (1985 U.S Dollar)	208	530
3	Average annual change, (1965-1985)	4.8	
4	Share of labor force in agriculture[a] (percent)	71	57
5	Share of agriculture in GDP, current price (percent)	56	24
6	Share in labor force minus share in GDP[b]	15	33
7	Ratio of share in GDP[c] to share in labor force	0.79	0.42
8	Implied per capita income in agriculture[d] (1985 U.S. dollar)	164	223
9	Average annual change in per capita agricultural income, 1965-1985 (percent	1.5	

[a]Data for labor force are for 1980 instead of 1985
[b]Row 4 minus Row 5
[c]Row 5 divided by Row 4
[d]Assumes all GDP generated in agriculture accrues to the agricultural labor force. Calculated as Row 7 time Row 2.

Source: Carol F. Timmer and C. Peter Timmer,"Pattern of Agricultural Diversification in Asia" (Cambridge, MA: Harvard Institute for International Development, 1988).

20 years.

These statistics indicate the magnitude of the structural transformation of Indonesia's economy. This shift from a predominantly agricultural to a non-agricultural sector (industry and services) based economy suggest that the agricultural sector needs to become more productive and efficient in order to meet the food and fibre needs of the country.

Rice production has changed dramatically, due to the rice intensification program (BIMAS) that was initiated in the mid-1960s. The Green Revolution transformed the traditional method in agriculture to a more productive science-based approach in order to meet the increasing demand for rice. The introduction of the new high-yielding varieties of rice, the extensive adoption of fertilizer and pesticides, credit facilities, and improved farm management through intensive training and extension, have all contributed to increased rice yield. As a result average rice yield (milled rice) rose from 1.32 t/ha in 1965 to 2.48 t/ha in 1985, an 87.5% increase (Barker et al, 1985). In 1985 rice production reached it highest level of 25.86 million tons, changing Indonesia from being the largest rice importing country to a country with a slight surplus of rice.

Rice production increased from 9 million mt in 1967 to 11.5 million tons in 1968 and consistently increased every year since then. In 1972, production decreased due to the drought which affected the whole country. Between 1976-1977, production decreased again due to pest infestation (brown plant-hopper). In the early 1980s the government introduced the improved intensification program called INSUS to the farmers and it rapidly spread throughout the country, accelerating the increase in rice production. To facilitate extension efforts, farmers were encouraged to establish small farmer groups,(a village-based farmers group).

The historical sequence of increasing rice production suggests that farmers were responsive to participation in the mass intensification program. However, beginning in 1985, the rate of growth in rice production declined to only 1.6% in 1986. The problem of sustaining growth in rice production is an increasing concern.

2.2 Agricultural Mechanization

Adoption of modern rice production technology has also increased the demand for farm mechanization. Rice intensification has influenced labor use per unit of output and labor use per unit of land as well. These changes are attributed to the intensification of farming operations, and inputs applied to modern rice varieties. Pingali *et al.* (1987) observed that the transition from human energy to mechanical energy is only profitable at higher intensity farming systems. In some locations in Indonesia, increased demand for agricultural labor has lead to the adoption of mechanization technology (DGFCA, 1982). Kasryno (1986), indicated that increasing farm labor wages (nominal) is one factor responsible for increasing use of farm machines in West Java. In contrast, the real farm labor wages indicated no significant increase (CAE, 1989).

Soedjatmiko (1983) has classified agricultural mechanization in Indonesia by four stages. During the first stage (1950-1960), rather large scale machines, such as wheel tractors (larger than 25 Kw), water pumps, and large rice milling machines were imported and introduced . However, the lack of workers with the skills necessary for the high level technology, and poor management prohibited the adoption of this imported and sophisticated technology.

The second stage (1960-1970) was dominated by small scale farm machinery. Large scale rice milling technology was gradually replaced by the small scale rubber roller rice mills. However, owners of small scale rubber roller rice machines frequently were plagued with breakdown, which hindered further adoption due to lack of parts.

In the third phase (1970-1980), small farm machines gradually became popular. These machines were developed and extended through research, experimentation, demonstration, and extension. The establishment of cooperation among universities, agricultural research agencies and the Agricultural Engineering Division of the Ministry of Agriculture became an important link for further development. The Agricultural Engineering Department of

Gadjahmada University, the Bogor University of Agriculture and the Agricultural Engineering Division of the Ministry of Agriculture initiated a study on soil characteristics, tillage equipment, and irrigation pump in 1972.

The fourth phase, beginning in 1980 to date, represents the reorientation phase of agricultural mechanization. Mechanization specialists in the Ministry of Agriculture have used the systems approach as a tool for mechanization development planning. The needs for agricultural mechanization development has been identified as the fundamental step toward the "selective mechanization approach". In recent years, the nation's capability to design and develop agricultural tools and machines improved, as well as testing and evaluation. Transfer of technology was facilitated by aid from the international agencies (FAO, UNDP, IRRI, JICA, and the like) and the regional cooperation of RNAM and ASEAN. Expanded international cooperation has served to improve the capability of Indonesia to develop technology that is suitable for each locality. In the end of 1990, government established the National Center of Agricultural Engineering as subunit of the Agricultural Research and Development Agency of the country. The functions of the center are to :a) carry out a systems analysis study of agricultural engineering technology and its system management, b) design and modify agricultural tools and machines, and c) test and evaluate improved agricultural tools and machines.

These efforts have improved the national capability to develop a suitable mechanization technology, guided by the developmental strategy in *PELITA*[3]. The number of farm machines used in rice production (Table 2.2) is the indicator used to measure the growth of agricultural mechanization in Indonesia. Even though the figures cannot be used for a detailed analysis of mechanization, they can be used to measure the rate of mechanization technology adoption.

Table 2.2 indicates that from 1981-1989, adoption of the two-wheel tractor progressed faster than that of the four-wheel tractor. Most two-wheel tractors were found in Java (68%), even though individual farm lands were smaller than those outside of Java. Over the period, tractor use grew by 16.2% annually. The number of hand sprayers also increased significantly (13.4% per year), because they contributed significantly to controlling pest populations.

The number of threshers (power and pedal) increased at 28.2% annually. The thresher statistics show the growing importance of post harvest technology at the farm level for reducing post production losses and increasing return per

---

[3]*PELITA* stands for Pembangunan Lima Tahun or Five Year Development Plan. The three developmental goals are:(a) economic growth (b) equity or income distribution and (c) national stability.

Table 2.2 Number of Selected Farm Machine in Indonesia (1981-1988).

Year	Tractor (no.)		Thresher[a] (no.)	Dryer (no.)	Hand-Sprayer (no.)	Rice Mill (no.)
	Two-wheel	Four-wheel				
1981	4,845	3,859	15,149	111	382,373	49,368
1982	6,443	4,061	11,731	837	464,922	47,279
1983	7,642	4,074	23,657	1121	510,870	52,675
1984	8,881	4,122	34,442	975	652,206	46,360
1985	9,936	4,352	65,524	846	722,060	56,920
1986	10,219	4,175	82,146	1009	724,120	59,855
1987	13,610	4,048	100,128	1773	814,132	62,606
1988	16,804	na	103,019	1229	na	na
Growth (%)	16.2	0.5	28.2	8.5	13.4	4.5

[a]including pedal and engine-powered threshers.
Source : Central Bureau of Statistics, (1983-1989)

unit of land.

During the 1981-1989 period the number of rice milling machines increased by only 4.5% annually. By 1986 it was estimated that more than 97% of the rice production was processed by machine and that hand-pounding had almost disappeared (DGFA, 1987).

The farm mechanization development pattern in Indonesia likely followed Binswanger's generalization (1984), that rice processing machinery is adopted faster because it is profitable at a low-wage rate. This is followed by tractors for primary tillage when a new mobile power source became available. Yet, wide spread adoption of the rice milling machine and the small hand tractor gave rise to a serious debate about the pros and cons of mechanization on the end of the 1970s. The debate focused on potential labor displacement, and changes in income distribution among small farmers as consequences of widespread adoption.

Despite increases in rice production and significant growth in farm mechanization, researchers became increasingly aware of the need for production technology to reduce post-harvest losses. In Indonesia, agricultural engineers have already contributed by designing and modifying a lighter and smaller tractor and other machines in order to reduce the cost of rice production.

Although extensive adoption of the new improved production technology has increased farmers' yields, farmers have not extensively adopted improved post-production technologies which would reduce losses (Djojomartono, 1979). Some reports on post-harvest surveys (JICA, 1982;BPS, 1988; and MOA and JICA, 1989) also suggest that field post-production practices were largely responsible for the post production losses.

Esmay *et al.* (1984) argued that these losses were attributed to the biological characteristics of most new high-yielding rice varieties which shatter more easily. Djojomartono (1979), found that double rice cropping has shifted rice harvesting to the wet season when high rainfall occurs. This has greatly increased drying and handling losses.

2.3. The Economic Framework of Agricultural Development Theory

In developed countries, the ever increasing pressure of population growth and the need to feed people, induced a shift from resource-based agriculture to science-based agriculture. It was not until the middle of the nineteenth century that agriculture in the less developed countries (LDC's) also shifted from resource-based to science based agriculture. This slower progression in the LDC's is partly due to the low capacity of LDC's to generate new productive technology. In addition to farm mechanization, in Indonesia, the slow growth of mechanization was mainly due to factor costs.

The agricultural development theory provides a useful tool for problem solving analysis. Schultz, in Stevens and Jabara (1988, pp 70-78), argued that in many developing countries, traditional agriculture has already reached a point at which traditional inputs are most efficiently used. Additional traditional investment, would only marginally increase the income or the return, since traditional farmers are already trapped in a low level economic equilibrium.

Hayami and Ruttan (1984) developed an induced innovation model by treating technical change as an endogenous factor to the development process. This model argues that farmers will increase their investment if one of the following changes occur:a) increased productivity of the land, b) decreased cost of production, or c) increased product price. In other words, the important criterion is total net return of profit on this investment in new technology (Stevens and Jabara, 1988, pp. 83-84). Furthermore, the induced innovation model reveals that there are multiple paths of technological development that are guided by factor price. Suitable technologies (economically and ecologically) are a prerequisite for achieving sustained growth in agriculture. Hayami and Ruttan (1984, p.71) stated the following:

> "An essential condition for success in achieving sustained growth in agricultural productivity is the capacity to generate an ecologically adapted and economically viable agricultural technology."

Accordingly, the three factors that determine a countrys' capacity to generate a viable agricultural technology are the capacity of:(a) the agricultural research to produce new technical knowledge, (b) the industrial sector to develop, produce and market new technology, and (c) the farmers to use modern agricultural production factors effectively (Hayami and Ruttan, 1984, p. 60)

The government, the private sector, and the farmers all make important contributions to agricultural development. Research and development is needed to accelerate the generation of cost-reducing technology suitable for local agricultural conditions. The private sectors must produce and market new technology that seems marketable and appropriate to use, and the farmers must improve their capacity to adopt appropriate technology to increase their income.

The key to developing appropriate technology is the price of production factors in an open market economy, which reflects the scarcity of production factors. Timmer (1984), has shown that macro policies affect the technological choice of rice milling in Java and its effects on income and equity.

Viewing technical change as an indigenous factor, the induced development innovation model as proposed by Hayami and Ruttan (1984), provides a basis to interpret the process of technical change within the economy. Within this framework, technical change is a dynamic response to change in resource endowment. Four elements that affect the rate of agricultural development are : technology, resource endowment, cultural endowment and institution.

Regarding the process of technological change, Hayami and Ruttan (1985, pp. 260-262) distinguished three phases of technology transfer as follows:

a) **material transfer,** which involves the transfer or importation of new technology such as new varieties of seed, machines, pesticides, fertilizers and the like, and management practices associated with these materials. Local adjustment and naturalization of " transfer technologies" tend to occur primarily through trial and error.

b) **Design transfer,** which involves the transfer of information in the form of blueprints, formulas, journals and books, and related software. This implies that prototype machines may be imported for testing purposes to obtain copies of the design. Imported machines are tested, and modified to adapt them to local ecological conditions for different activities.

c) **Capacity transfer,** which occurs primarily through the transfer of scientific and technical knowledge.

Ruttan, furthermore stressed, that the objective of technology transfer is to institutionalize local capacity for creativity and diffusions of continuous flow of locally adapted technology.

Analysis of the historical development of mechanization in Indonesia, suggested the first phase of technology transfer has already occurred, mainly in Java and the major rice growing area like South Sulawesi, Aceh, Bali, and most Sumatera provinces. The second phase is currently evolving as indicated by the local production of many types of machine, such as tractors (less than 15 Kw), rubber roller rice mill machines, small engine-powered threshers, irrigation pumps, and hand sprayers. However, in this phase, sophisticated designs which have been borrowed from developed countries are still common. This has resulted in high-cost technology that is relatively expensive and unaffordable for the small farmers. Esmay (1988) argues that these imported designs seem to be too sophisticated for most farmers in Indonesia and may cause difficulties because small and medium blacksmith and local shops may have difficulties to develop and adapting these machines. Gifford (1981) observed that in the end of the 1970s the signs of the third phase, capacity transfer, have appeared in Indonesia, although product quality of some machine was considerably low.

Furthermore, Evenson (1984) stated that for both mechanical and biological technology, technology developers may expand the adaptability of technology, and recipients may accept and modify it to make it more suitable for local agricultural conditions. It is clear, therefore, that technology generation can be accomplished through the steps of material transfer, design transfer and capacity transfer as mentioned by Hayami and Ruttan (1985).

To reduce post-harvest losses in Indonesia, the government can make major contributions through its agricultural engineering research and development, extension, education, credit, subsidy, and implementation of the program and projects. Since there are many problems related to one another, this study focused on evaluating the alternative technologies that are, or could be considered, from the farmers' perspective.

2.4. Summary

Rice Production in Indonesia

The green revolution technology has driven rice production in Indonesia since the early 1970's. From 1960 to 1967, rice production grew at a rate of only 0.3% per year, but increased at 5% per year between 1968 and 1982. From 1982 to 1985 rice production increased at a rate of 4.5 % per year, making Indonesia self-sufficient in 1985 (FAO,1987; Timmer,1985).

Timmer (1985) found that two factors explained the growth in rice production:

1) a change in rice supply curve because of new technology (high yielding varieties, fertilizers and pesticides, irrigation improvement, and increasing numbers of knowledgeable farmers
2) a change in the rice supply curve because of improvements in government financial incentives for farmers to use inputs more intensively.

After the great success of increasing rice production, Indonesian farmers became highly dependent upon the availability of High Yielding Varieties, seeds, fertilizers, pesticides and irrigation. This new technology has been called the " seed-fertilizer revolution" (Robinson *et al.*, 1987). Government has made available the inputs necessary for the adoption of this new technology at affordable prices and on time, often under high subsidies for their distribution. Indeed, in 1985 Indonesian rice farmers produced the highest yields in the South East Asian region (3.9 t/ha), compared to Malaysia (2.8 t/ha), the Philippine (2.7 t/ha) and Thailand (2.1 t/ha). However, mechanization development in Indonesia grew slower than in other ASEAN countries. This slow growth rate was mainly due to low labor wages rates in agriculture.

Farm Mechanization

The adoption of the "seed-fertilizer" technology which increased yield, has encouraged farmers to adopt more mechanization technology. Since the end of the 1970s, the rubber roller mills became the most important machine for farmers; and small tractors, sprayers and water pumps began to spread widely in the major rice growing areas. At the end of 1989, almost all rice farms in the northern coastal plains of West Java provinces were prepared by using tractors, because of the decrease in animal traction, shortage in human labor in some area, and government subsidies which reduce substantially the cost of tractors.

In Indonesia, rice threshing by hand beating is predominant. However, in some regions, such as Aceh, North Sumatera, and West Sumatera, engine-powered threshers became increasingly popular following the national campaign to reduce post-harvest losses in 1985. Similarly the pedal-powered threshers became a popular technology among the farmers in Central Java, and Yogyakarta. It is not clear, however, whether adoption of this method is related to the expansion of ***tebasan*** system[4], since the pedal-operated threshers are currently widely used by the harvest-laborers in some areas of Central Java Yogyakarta, and East Java.

Economic Framework of Agricultural Mechanization

The growth of small farm mechanization in Indonesia has been carried out through the transfer of technology through adapted research, field tests, demonstrations, and extension. Until 1989, there was no institute responsible for conducting agricultural engineering research and directed to support agricultural mechanization. One institute, a small sub-ordinate of the Directorate General of Food Crop Agriculture is responsible for research, development, training and extension. Thus, international cooperation, (through the government and/or the private sector) has helped Indonesia improve her capacity to design, construct, modify, and test an improved and suitable technology for the small farms.

Most rubber roll rice mills, small tractors, water pumps, sprayers, and rice threshers are currently domestically produced by local manufacturers, some using

---

[4]***Tebasan*** is a harvesting system, under which the owner-operator sells the standing crop prior to harvest. The buyer then contracts the harvest laborers to cut the paddy and pays them a cash wage.

foreign designs and others using indigenous materials and designs. The price of these machines, however, are too expensive for farmers, and some times have a problem with poor quality.

To some extend, government involvement is required to develop suitable mechanization technology for Indonesia. This involvement includes:

1) the provision of credit for improving local-shop capacity.
2) the industrial extension to help local shops in manufacturing improved machines.
3) continuing research and development to generate new and cost-reducing technology.
4) promoting higher education in agricultural engineering to improve human resource capacity.

Price and labor wages are also two factors related to the rapid diffusion of farm mechanization. Farmers are usually motivated to select the most profitable system for them. Since the objective of the farmers is to increase return, the new technology must; 1) reduce the cost of production; 2) reduce grain losses; and 3) maintain grain quality.

CHAPTER III

PRESENT CONDITION OF RICE HARVESTING AND THRESHING IN INDONESIA

3.1. Harvesting Systems in Indonesia.

Harvesting systems prevailing in Indonesia were classified according to the institutional arrangement between harvest laborers and owner-operators. The four systems were:

(a) *Gropyokan* System (Free Harvest):

Under the "free or open system " any person may participate in harvesting. The laborer's wage is paid in-kind by a certain share, equal to 11% to 16% of the laborer's total harvest. This was the predominant harvest system which was used in almost 33% of the harvested area in Indonesia.

(b) *Ceblokan* System:

This is a contract based system. A laborer who wants to participate in the harvesting must also plant and weed the crop. Usually laborers are not paid for planting and weeding during the crop season, although half-day payment is sometimes given without any meals, as in the *Gropyokan* System (MOA and JICA,1989). The laborer's harvesting wages are paid in-kind, ranging from 11% to 16% of the harvest. This system is used in about 30% of the harvested area in Java. Between 15-20 laborers are usually assigned for every **bau** (parcel) of land equivalent to 0.71 hectares.

(c) *Tebasan* System:

Under this system, the owner-operator sells the standing-crop to the buyer, prior to harvest. The buyer (paddy/rice trader or broker) then contracts harvest laborers to cut the crop and pays them a cash wage. A laborer's wages varies between Rp 7.00 to Rp 15.00 per kg of cut-crop paddy. Adoption of this system is increasing throughout Java, with an estimated 24% of the farmers using this system (DGFA, 1989).

(d) Fixed Payment System:

Under the fixed payment system, the laborers are paid a fixed amount of money per (Rp/kg of paddy) by the owner-operator. This system is common in the outlying areas of Java (40%).

(e) Self Harvesting.

Under this system, the owner-operator and his family harvest the crop themselves.

Uncontrolled numbers of harvesters resulted in various kinds of losses to the farmers. Hansen (1981) noted that farmers who used the gropyokan system incur grain losses because:

> " the large number of harvesters cause more stamp-down loss, dropping loss, and left over, losses in carrying the rice from the field to the farmers house, losses occur through stealing or through real transportation loss, and finally, there are losses due to the distribution of shares and handling loss."

In Indonesia agricultural laborers commonly form groups to transplant paddy. This was taking place at the time of this study in Indramayu, West Java. Group harvesting arrangements were also common throughout East Java (MOA, 1987), Central Java (Diperta Jateng, 1990) and Yogyakarta (Diperta DIY,1990; and Endah Suparti, 1989). Laborer groups for harvesting are very rare in West Java, although the JICA study team found one such group in Karawang, 75 Km East of Jakarta (JICA and MOA, 1989) which consisted of 120 households (26% of all the households). The objective of the group was to reduce harvesting losses caused by too many harvesters and to limit the participation of harvester from other villages. The group consisted of two units; i.e, laborers for reaping and laborers for threshing. Using the *ceblokan* system, the laborers were paid 16.7% of the total production. The income is divided equally among the members to avoid competition among themselves.

In order to reduce harvest losses due to overcrowding, some farmers in Indramayu, West Java, have shifted to *ceblokan* systems which enable them to better manage and supervise harvesting. The landlords divided parcels of land equally between each of the laborers (including their families), and the laborers performing the task, receive 16.7% of the total production as payment. This means that every laborer (and their family) has the right to harvest land ranging in size from 350 to 475 square meters. Even though the *ceblokan* system is not predominantly practiced in the studied area, the use of this system is increasing. In the neighboring district of Subang, West Java, about 25 km to the West, Hayami and Kikuchi (1982), found that the *ceblokan* system has been adopted increasingly by farmers as shown (Figure 3.1.). In 1965 only 50% of the farmers had adopted the *ceblokan* system, but by 1975, more than 95% farmers has adopted this system. As these villages are close to each other, it is expected that in less than 10 years the ceblokan system will be adopted by most farmers in Indramayu District.

3.2. Harvesting Method

Before the adoption of high-yielding rice varieties in the late 1960s, harvesting was mostly done manually, using sickles. Currently, most farmers (84%) use sickles, either serrated or unserrated. Only a very small number (16%) still use *ani-ani* (small knives), mostly to harvest tall traditional rice varieties. The high-yielding varieties (HYVs) are well suited for sickle harvesting as they have short stalks, uniform-ripening panicles and they shatter easily (MOA,1989).

In addition, Hansen (1980) found, that farmers shifted from using the ***ani-ani*** knife to the sickle because: a) ***ani-ani*** harvesting is more time consuming; b) if laborers harvest in competition (***gropyokan*** system), the laborers tend to select only the panicle with the most rice; (c) if ***ani-ani*** are used in harvesting, the landlord must hire someone to clear crop residue, thus increasing the cost for the next cropping season.

Wet season harvests fall between January and the end of April, and the dry season harvest falls between June and August. Usually, the moisture content of paddy at harvest varies between 20-26%. After harvest the cut paddy is collected and placed in the field for threshing.

3.3. Threshing method

There were four common methods for threshing paddy in Indonesia:

1. Rubbing by feet on a mat
2. Beating paddy with a wooden stick
3. Beating paddy against a wooden (or steel) frame with or without plastic mat, and
4. Pedal or engine-powered threshers.

Among these four methods, beating paddy (number 3) was most widely practiced in Java. An estimated 42% of the farmers used the beating method, 26% the rubbing method, 13% used pedal threshers, and less than 8% used power threshers. The use of each method varies by region. Engine-powered threshers were most popular in Aceh, West Sumatera and North Sumatera. Pedal threshers were popular in Central Java, where about 70,000 units (more than 80% pedals) were in use. In contrast, in West Java, only 3,000 threshers are in use and an estimated 42% of these units were engine-powered threshers (a portable machine).

In Java, harvesting, threshing and cleaning were considered a single activity. In some places, separate wages were paid for harvesting and threshing. In-kind payment varies between 200 to 400 kg/ha (4 to 5% of the total product). Although cash payment for threshing varies depending on the institutional arrangement, the most common rate varies between Rp3.5 to Rp 5.0/kg of paddy.

3.4. Harvesting and Threshing Losses in Indonesia. Previous Post-harvest Survey.

Several surveys have estimated post-harvest losses in the provinces of West Java, East Java, South Sulawesi and Lampung. These studies were conducted by international institutes (JICA,1982; and JICA 1989), government agencies (MOA,1986; BPS,1988) and individuals (Eriyatno,1978; Djojomartono, 1979; and Gaiser, 1980).

Harvesting loss is defined as the loss due to scattered grain or uncut panicles during the harvesting operation. Threshing loss is defined as the loss due to unthreshed grain and grain scattered during the threshing operation. The results of each study are summarized in Table 3.1.

Table 3.1. Summary of Harvest Loss and Total Crop Losses Assessment under various studies, in Indonesia (1982-1989).

Name of Study	Year	Provinces (no)	Harvesting loss (%)	Threshing loss (%)	Total Harvest loss (%)	Total Crop losses (%)
JICA[a]	1982	4	6.4	4.7	11.1	22.4
JICA/MOA[b]	1989	4	3.5	4.6	8.1	13.6
BPS[c]	1987	15	9.2	5.9	15.1	19.5
DGFCA[d]	1988	3	3.9	3.4	7.3	14.5

[a]JICA, 1982. Rice Post Harvest Survey in Indonesia
[b]JICA/MOA, 1989. The Study on Improvement of Rice Post Harvest and Marketing in Farmers Groups.
[c]BPS,1987. Post Harvest Survey, Wet Season 1986/1987
[d]DGFCA/MOA,1988. Post Harvest Loss Observation in Lampung, East Java and West Java.

The JICA study (1988) compared losses using the *gropyokan* system versus the ceblokan system. The results indicated that the gropyokan system, practiced mainly in West Java resulted in higher losses than the **ceblokan** (Table 3.2.).

The Sukamandi Research Station (FCRC, 1989) also conducted a comparative study and obtained similar results, that the gropyokan system tended to have a higher grain loss during the harvest operation.

Regardless of the different methods used in loss assessment, Tables 3.1 and 3.2. show that harvesting and threshing operations make up a large share of total post-harvest losses. Assuming that the harvesting operation occurred at the peak harvest date, the level of losses are mainly associated with difference in:[5]

(a) **Method of operation:** harvesting by sickle or ani-ani, threshing by hand, pedal, or engine powered threshers.

(b) **Rice varieties:** most common varieties are Cisadane, IR-64, IR-36, IR-42 and Ciliwung

(c) **Institutional arrangement:** Labor employment system used: *gropyokan, ceblokan* or *tebasan.*

Table 3.2. Harvest losses between *gropyokan* and *ceblokan*, in Indonesia 1988/1989.

Item	West Java	East Java	South Sulawesi	Lampung
Variety	Cisadane	IR-36	IR-42	IR-64
Yield (mt/ha)				
Gropyokan	6.9	8.1	7.1	7.4
Ceblokan	7.5	8.4	7.2	7.9
Paddy Losses (%):				
Gropyokan	1.8	0.8	0.5	1.1
Ceblokan	1.1	0.8	0.5	0.8

Source :JICA, 1989.

[5] During the survey, most farmers harvest their crop at the peak season. The decision to harvest is made on the basis of more than 50% maturity, crop age and panicle color. The crops' moisture content slightly differ ranging, between 22-25%.

Paddy Losses.

Table 3.2 shows that across the rice varieties, paddy losses ranged from 0.5 to 1.1% in the *ceblokan* system. On the other hand the *gropyokan* system results in paddy losses of 0.5 -1.8%. This suggests that uncontrollable number of harvest laborers during harvesting and threshing resulted in higher losses. Although there is a difference in losses between the rice varieties and locations, there was no clear explanation about the contribution of these variables.

3.5. Summary

Harvesting and Threshing in Indonesia.

Five harvesting methods (including threshing) were prevalent in Indonesia's rice production system. These were: 1) the *gropyokan* (or "free-harvest") system; 2) the *ceblokan* system; 3) the *tebasan* system; 4) the fixed payment system, and 5) the self harvested system.

The *gropyokan* system allows all interested parties to participate in harvesting-threshing activities, leading to an uncontrollable number of harvest laborers. The harvest laborers earned wages of rate of 16.7% of the gross product.

The *ceblokan* system is being increasingly adopted number of farmers in West Java. About 90% of the farmers had already adopted this system by the late 1970s (Hayami and Kikuchi, 1982). The wage share of the harvest laborers, declined apparently because they had to plant and weed the crops without payment, in order to participate in harvesting and threshing. The wages of the *ceblokan* system are the same as *gropyokan*, 16.7% of the gross output.

In the *tebasan* system, the paddy buyers employed a team of harvest laborers and paid them at a fixed rate ranging from Rp.7.- to Rp 10.0/ kg of stalk paddy. The buyer then thresh the paddy using engine-powered threshers. In some areas in Central Java and Yogyakarta, the harvest-laborers equipped themselves with pedal-operated threshers.

A fixed harvesting system exists only on the outer islands, such as Kalimantan, and some in Sulawesi and a self-harvest system is primarily done by family owned very small farms.

In West Java, farmers have not adopted *tebasan*. At 1988 prices, the harvest-laborer in Indramayu, West Java receive wages about 16.7% of gross output, about 4-6% higher than harvest-laborer in Central Java and Yogyakarta (BPS, 1989). This suggests, that changes in the harvesting-threshing system in West Java, that reduce payment to the laborers would be opposed by the laborers. In Central Java and Yogyakarta, however, the use of pedal threshers by harvest-laborers reduced drudgery, and increased labor productivity (Farm survey, 1990). While small pedal-threshers were available in some areas of West Java, they did not find a ready market among farmers. Starting in 1985, engine-powered threshers were adopted by some farmers in West Java villages, but their diffusion was slower compared to the diffusion of small tractors. The harvest-laborers who used the engine-powered thresher, received payment at the rate of 13.9% of the gross product instead of 16.7%. The 2.8% was to be given to the thresher owner for threshing costs.

The handcut/hand threshed system dominated harvesting-threshing in West Java, even though the contribution to grain loss was still higher, compared to handcut-pedal thresher and the handcut/engine-powered thresher systems. Harvest laborers improved the handcut/hand-threshed system by using a polyethylene sheet to reduce scattered grain losses. The harvest-laborer arrangement system was apparently related to income gain for harvest laborer and plays an important factor in technology diffusion. Although the grain loss remain higher in hand-cut/hand-threshed technology, harvest laborers still preferred to use this method, for economic reasons.

Grain Losses related to harvesting-threshing system.

In Indonesia, the grain losses in harvesting and threshing were a major contributor to total rice post-harvest losses. Studies have found that the range of post-harvest losses was about 12-21%, where 3.4-9.2% was from harvesting and threshing. Pedal and engine-powered thresher reduce grain losses about 1-2%. This suggests that field losses can be reduced by improving suitable technology. The efficiency of the improved technology should be made compatible with the prevailing harvesting-threshing arrangement between harvest-laborers and owner-operators, so the users of this technology do not experience a financial loss.

CHAPTER IV

RESEARCH DESIGN AND METHODOLOGY

4.1. Framework of Analysis

This study draws on a combination of the following resources:

a. a review of general literature on farm mechanization, particularly post-harvest (harvesting-threshing) systems of small farmers.

b. a post-harvest farm survey in West Java.

c. field research experiments on harvesting and threshing in West Java, and

d. a visit to Central Java, an area that is more advanced in applying threshing technology.

The purpose of the literature review, farm survey, and field measurements was to generate a system alternative which minimizes grain losses, and provides a low or least cost alternative for providing threshing technology to small farmers, the village and the society, while not adversely reducing harvest laborer income.

The literature review provided a general picture of the rice production and rice post production systems of small farmers in Indonesia, particularly in Java. It also

provided a cross country comparison between Indonesia, and other Asian countries' experiences in extending mechanization technologies to small rice farmers.

The farm survey provided information about the characteristics of the small farms and their rice production systems in the study area. It also provided data: a) to assess field grain losses caused by inadequate harvesting-threshing technology; b) to examine the socio-economic feasibility of diffusing an alternative harvesting-threshing technology; c) to determine current thresher ownership patterns and utilization; d) to determine farmers' reasons for adopting or not adopting threshing technology, and e) to determine the labor contractual system that exists in the study area. Its main objective is to estimate the economic and social acceptability of alternatives to existing farm-level harvesting technology. The survey used a questionnaire to collect data on the above mentioned variables.

This study used field measurements to measure current harvesting-threshing system operations in the study area. Although numerous general studies of grain losses have been conducted in the country, current data on the economics of harvesting-threshing mechanization technology and its system management are limited. Therefore, this study, extends previous research on field post-harvest grain losses and validates these estimates.

The above steps were undertaken as part of the feasibility evaluation, as described in the systems analysis

methodology. The objective of the feasibility evaluation was to acquire a deeper, better understanding of the problem being studied through needs analysis, system identification and problem definition. Manetsch (1986) described, that the problem definition explains what system alternatives must be realized and what means are to be used in obtaining the desired objectives.

Finally a system simulation model was developed as a tool of analysis. Various combinations of values, which are generated from statistical analysis, were assigned to the design parameters. Controllable inputs of the model are to be used to generate a wide range of system alternatives. The black-box model representing the system model is shown in Figure 4.1.

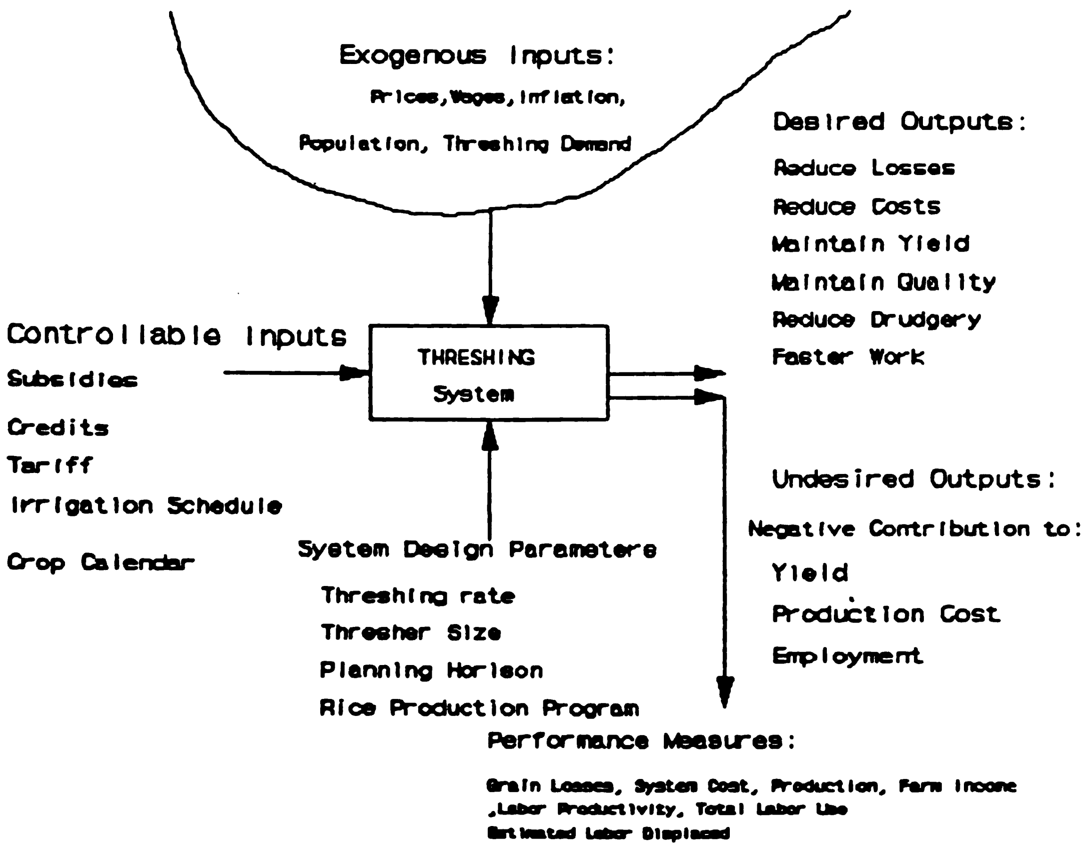


Figure 4.1. General Rice Threshing System

4.2. Farm Survey (Selection of Districts, Villages and Households.

District, Subdistricts and Villages Selection.

Indramayu district was purposely selected from among the major irrigated rice growing areas in West Java, based upon the following criteria; a) easy accessibility by road transportation; b) availability of secondary data describing each village; c) proximity of one village to another; and (d) type of harvesting-threshing technology being used in the study area. Within the district, several subdistricts were selected based upon irrigation facilities and levels of threshing technology used. A subdistrict with more than 50% irrigated rice farms was selected. The level of threshing technology was defined as the number of threshers being used by the farmers in the corresponding subdistricts/villages. Since current statistical data indicated that the total number of threshers used in West Java was limited to about 3,000 units and scattered throughout West Java province, the survey used an arbitrary number of 10 engine-powered threshers to select study subdistricts. A subdistrict with more than 10 units was considered to be a high level subdistrict/ village. Conversely a subdistrict or village with less than 10 threshers was considered a low level subdistrict/village. Based on these selection measurements, two districts, Gabuswetan and Anjatan, were chosen to represent a high level subdistrict and a low level subdistrict, respectively. Three villages were selected

from Gabuswetan. These were Gabuskulon, Babakan Jaya and Rancahan. Two villages, Anjatan Utara and Sukra, were also selected from Anjatan.

Household Sampling

Stratified random sampling was employed to select household samples. The household were stratified according to the following four categories, based on the type of technology used:

Strata-1 : Farmers using sickles/manual threshers (Manual Farmers, M-F).

Strata-2 : Farmers using sickles/engine powered threshers (Thresher-Owners, T-O).

Strata-3 : Farmers using sickles and hiring engine-powered thresher (Thresher- Hired, T-H).

Strata-4 : Farmers using sickles/pedal thresher (Pedal-Owner, P-O).

The total sample of 135 respondents was distributed across subdistricts as shown in Table 4.1.

Table 4.1. Selected district, subdistricts, villages and sample size of each strata in the study area, Indramayu, West Java 1990, Indonesia.

Subdistricts /Village	M-F	T-O	T-H	P-O
Gabuswetan:	30	30	30	NA
Gabuskulon	10	10	10	NA
Babakan Jaya	10	10	10	NA
Rancahan	10	10	10	NA
Anjatan:	15	5	12	13
Anjatan	15	5	6	8
Sukra	0	0	6	5
Total no. of Respondents	45	35	42	13
Total samples = 135				

NA: data not available
M-F: Manual-Farms; T-O: Thresher-Owner; T-H: Thresher-Hired; P-O: Pedal-Owner.
Source : Farm Survey, West Java 1990.

4.3. Field Research Experiments.

Harvesting losses

This study used the method developed by a joint Post Harvest Losses Assessment team[6]. Losses assessment in harvesting was measured by subtracting the yield of the standard plot (2.5 * 2.5 m^2) from the yield of the control plot (a size of 1 m^2). The standard plot, called an *ubinan* was a common plot that the Subdistricts Office used to

[6] In 1987, the Government of Indonesia established a joint Post-Harvest Losses Assessment Team which included researchers and scientists from the Ministry of Agriculture, Universities (Gadjahmada and Bogor University of Agriculture) and the Bureau of Statistics. This team was formed to organize the general survey of post-harvest losses throughout the country.

estimate rice yields by converting the plot yield to a per hectare value. The Central Bureau of Statistics used this ***ubinan*** method to estimate national production.

The control and the standard plots were randomly selected in the field. Stalk paddy from control plots was carefully reaped using scissors, to avoid scattering and falling grain, and put into a bamboo basket. The grain was then striped-off manually and weighed. The pre-harvest yield per hectare was then estimated by multiplying the weight of the control plot by 10,000.

The stalk paddy, in the standard plots was harvested by farmers using sickles. The rice grain was then striped-off manually from the straw and weighed. The yield per hectare was then calculated by multiplying this weight times a conversion coefficient of 1,600. The difference between the control yield and the standard yield is defined as the harvest loss, and expressed as the percent of pre-harvest yield. Mathematically it is formulated as follows:

$$YLD_c = 10000 * W_c \quad (1)$$

$$YLD_s = 1600 * W_s \quad (2)$$

$$HVL = \frac{(YLD_c - YLD_s)}{YLD_c} * 100 \quad (3)$$

Where

YLD_c : Yield of the control plot (kg/m^2)

YLD_s : Yield of the standard plot (kg/m^2)

HVL : Harvest loss as a percent of yield before harvest (%).

W_c : Weight of control plot (kg)

W_s : Weight of standard plot (kg)

One control plot was harvested in each rice field owned by a respondent farmer, and three additional plots were assigned as standard plots in the same field. Thus a total of four plots were used to estimate the harvesting loss in each field. Harvest loss measurements were taken from 4 fields, each containing 4 plots, making a total of 16 replications.

Threshing Losses

The stalk paddy harvested from the same field was threshed by two methods: hand-threshing (hand beating) and with an engine-powered threshers. Two types of engine powered threshers were used. The first was a commercial thresher commonly used by farmers in this region, and the second type was a modified TH-6 model developed by IRRI (International Rice Research Institute) Los Banos,

Table 4.2. Number of fields, plots and samples used in harvesting and threshing measurement in Indramayu, West Java, 1990, Indonesia.

Item	Number of fields	Number of Plots (Reps)	Number of Plots (Reps)
Harvesting	4	4	16
Threshing	4	12-15	126
hand-threshing[a]	4	12	48
engine-powered thresher (gasoline)[b]	3	12-15	39
engine-powered thresher (diesel)[b]	3	12-15	39

[a]Hand-threshing was manual threshing
[b]The experiment in one field was dropped because of engine failured and the rice field was too wet. Two types of threshers were used, gasoline and diesel.
Source : Field Experiment, West Java 1990.

Philippines. This modified machine was fabricated by the Agricultural Engineering Workshop of West Java Province. Table 4.2 shows a summary of field measurement of harvesting and threshing losses.

Grain output from three outlets was measured. These were a threshed grain, a blown grain, and an unthreshed (straw) grain. The threshed grain is measured from the main outlets, the blown grain measured at the blower outlet, and the straw grain is measured at the straw outlet.

Threshing performance of an engine-powered thresher was measured in terms of grain output per hour basis, grain content from straw output and grain content from blower output. Threshing efficiency, cleaning efficiency, separation loss, and threshing loss were calculated by measuring the grain at the main outlet, straw outlet and blower outlet. The grain-straw ratio was measured three time in each field.

Threshing loss was calculated based on the amount of grain measured at the blower and straw output, relative to the grain straw ratio. Twelve to 15 samples of bundled rice from each field weighing at least 15 kg were threshed by the engine power threshers, and the same number of about 10 kg samples were hand-threshed. Threshing time and grain moisture content were measured, and grain output at the main outlet, straw outlet, and blower outlet were collected and weighed to calculate grain output per hour, threshing efficiency and separation losses.

Grain purity and husked grain were analyzed in the Grain Testing Laboratory at the Center of Agricultural Engineering, Jakarta. Variables measured during each testing run were:

(a). weight of sample crop	(kg)
(b). moisture content	(%)
(c). threshing time	(min or sec)
(d). grain content at main outlet	(kg)
(e). grain content at straw outlet	(g)
(f). grain content at blower outlet	(g)
(g). fuel consumption	(ml/sample)

(h). husked grain (%)

Adjusted weight at 14% MC was calculated by using the following formula (JICA and MOA, 1989):

$$W_b = \frac{(100-mc)}{86} * W_{bmc} \qquad (4)$$

$$W_s = \frac{(100-mc)}{86} * W_{smc} \qquad (5)$$

Where :

W_b: Grain weight of blower outlet at 14% MC (kg)

W_s: Grain Weight of straw outlet at 14% MC (kg)

W_{bmc}: Grain Weight of blower outlet at current MC (kg)

W_{smc}: Grain Weight of straw outlet at current MC (kg)

W_{th}: Weight of Threshed Grain at main outlet at 14% MC (kg)

The threshing performance were calculated using the following approach (Thiersten *et al.*, 1987):

$$THL = \frac{(W_b + W_s)}{GSR} * 100 \qquad (6)$$

$$SPL = \frac{(W_b + W_s)}{(W_{th} + W_b + W_s)} * 100 \qquad (7)$$

$$EFF = \frac{W_{th}}{(W_b + W_s + W_{th})} * 100 \qquad (8)$$

$$CLEAN = \frac{C_g}{T_g} * 100 \qquad (9)$$

Where:

GSR: Grain Weight based on the grain straw ratio at 14% MC (kg)

THL: Threshing Loss (%)

mc: Moisture Content (wet basis) at threshing operation (%)

SPL: Separation Loss (%)

TEFF: Threshing Efficiency (%)

C_g: Weight of clean grain (g)

Th_g: Weight of threshed grain, a clean grain plus other material (g)

CLEAN: Percent of clean grain to output(%) (output were a mixture of paddy and plus chopped straw and other materials

4.4. Cost System

Annual Operation Cost

The cost of the hand cutting and hand threshing operations were directly calculated using the harvest share percentage. In the studied area, one harvest laborer was paid about 16.7% of his/her daily harvest.

The machine cost was estimated by calculating the fixed cost and the variable costs. The fixed cost includes depreciation (4-5 years) and interest rate, tax rate, insurance and shelter cost. In Indonesia, the tax rate, insurance rate and shelter rate were not usually included when calculating this cost. The interest rated were estimated as the average market rate (18%) found in the farm survey. The straight-line method was used to estimate depreciation. Total annual and per unit operational cost was determined by the following equations (Gupta, M.L, Gajendra Singh, and R.K. Gupta, 1986):

$$OPCOST=FCOST+VCOST \qquad (10)$$

OPCOST: Operation cost (Rp/year)

FCOST : Fixed cost, including the depreciation and annual interest rate, insurance rate and shelter rate .

VCOST : Variable cost, including the labor wage rate, fuel cost, lubrication cost, repair and maintenance cost.

Financial Cash Flow.

Cash flow analysis was performed to evaluate the financial feasibility of alternative threshing technology. The estimate cash flow is defined as gross benefit generated from on-farm and off-farm use of threshers minus the costs incurred for using the thresher, including investment cost and variable costs. The Net Present Value (NPV) method was used to evaluate the generated cash flow by using the following mathematical formula (Juarez, F, 1981, Gittinger, 1985):

$$NPV=-C+\frac{R_1}{(1+i)^1}+\frac{R_2}{(1+i)^2}+..........+\frac{R_n}{(1+i)^n}+S_n \qquad (11)$$

where :

C : the investment cost of the machine, engine attachment and other implements;

$R_1...R_n$: the stream of the net income in period 1,2...n

S_n: the salvage value at the end of its economic life

i : the discount rate

For the thresher owner, the benefits were the streams of income resulting from use of thresher, both on-farm and off-farm (custom service).

Benefits resulted from two sources (Juarez, 1981):

(a) gains from custom service, and

(b) gains from use (improved efficiency).

Gains from custom service are the cash (in-kind) payments made by the user to the owner of the thresher. In West Java, thresher renters are commonly harvest laborers who paid the machine owner a portion (10-16%) of the grain threshed (throughput). The use gains are the benefits associated with the lower field losses due to using engine-powered threshers, compared to hand-threshing.

$$R_t = NRF_t + NROF_t - MA_t + LS_t \quad (12)$$

where :

R_t = the total income from a machine investment, including both on-farm and off-farm use in period t.

NRF = the income obtained from on-farm thresher use of the thresher in period t. (In West Java, harvest laborers pay 2.7% of the gross product to the thresher owner)

$NROF_t$ = the income obtained using thresher for custom work in period t

MA_t = the repair and maintenance expenses in period t

LS_t = the benefit in terms of reduced in field losses from using mechanical methods of threshing, compared to the traditional method.

compared to the traditional method.

The following data are included in the estimation of cost and benefits: capital investment in the rice thresher; salvaged value (estimated as 10% of purchase price); quantity of paddy threshed on-farm (tons); quantity off paddy threshed off-farm (tons); custom charge; farm wages; oil/fuel price; repair and maintenance cost; and reduction on field losses.

Utilization Estimation under Uncertainty

Risk analysis method has been widely used a tool for analyzing investment decision under uncertainty. Buck (1982), argued that uncertainties are those elements of the future which cannot be perfectly predicted. In this study, examples of uncertain events include, timing of thresher breakdown, equipment utilization rates, weather, economic life, and accidents. Each of these examples shows a change in the environment which cannot be controlled or perfectly predicted. Also, the amount and timing of any one of these elements can affect the cash-flow of the investment and thus alter its financial return. Moreover, some of these elements are more unpredictable than others, and therefore contribute more uncertainty.

Sullivan and Gordon (1982) argued that a probability function for uncertain elements can be estimated and directly incorporated into the analysis of alternatives. This approach uses various statistical concepts and descriptive measures (e.g., expected value and variance) for summarizing uncertainty in the cash-flow analysis.

In this study a Monte Carlo technique is used to generate random outcomes for probabilistic factors so as to imitate the randomness inherent in the original problem. Assuming random variables of off-farm and on-farm income, and benefits and cost that associated with these variables follow the normal probability, the simulated outcome is based on Equation 13:

$$Y = Mean + (Rn * SD) \tag{13}$$

Where:

Y:	Outcome value
Mean:	Average value of variable
Rn:	Random normal deviate
SD:	Standard deviation of variable

Based upon the theory, the random variables (off-farm and on-farm use of thresher, flow of benefits, and cost of thresher) can be estimated, once the mean and the standard deviation of these variables are found. The NPV and other financial performance (BCR, IRR and BEP) will also be estimated using this probability approach. This approach is used in a mathematical model discussed in Chapter VI.

4.5. Summary

Framework of Analysis

This study draws on the literature review, a farm survey, field research experiments and a visit to the Central Java an area which is relatively more advanced in applying threshing technology. The purpose was to generate an alternative system which minimizes grain losses, and provides a least cost threshing alternative for the farmers.

The literature review discussed a general picture of rice production in Indonesia, and West Java, and agricultural mechanization in Indonesia. Finally, literature review presented the general framework of agricultural development theory with implication for agricultural mechanization.

The farm survey generated farm level data, which serve as the basis for estimating the economics of alternative threshing investments. The sample farms were categorized into four different farms types: 45 manual farms, 35 thresher-owners, 42 thresher-hired, and 13 pedal-owner farms. These farms were distributed across five villages in two subdistricts of Indramayu District, West Java, Indonesia. All of these farms and villages were in the major irrigation area.

The field research experiments to measure the harvesting-threshing system performance were discussed, including field measurements to estimate grain loss, threshing rate, threshing efficiency, and operation cost.

The Financial analysis method to estimate profitability using net present value technique were discussed. Parameters used in this analysis were taken from the farm survey.

The objectives of the study will be achieved through carrying out a technical and economic analysis of rice harvesting-threshing system, and by using a modelling and simulation technique.

The first approach will be employed to study the existing harvesting-threshing system with respect to harvesting-threshing losses and the acceptance of new technology by the farmers. Techniques for assessing the technical performance of harvesting-threshing were reviewed, including efficiency of technology, grain loss, labor requirement, and cost incurred. The net present value technique was used for financial analysis. The results is presented in Chapter V of this study.

The second approach draws upon the literature review, survey and measurements to develop a village-based threshing model system. Various combinations of values will be assigned to the design parameters. Controllable inputs of the model will be used to generate a wide range of system alternatives. The system model and its application are discussed in Chapter VI of this study.

5.1

tha

tec

hav

tec

[illegible]

CHAPTER V

RESULTS AND DISCUSSION OF FARMS SURVEY AND FIELD MEASUREMENTS

5.1. Characteristics of Study Area

The following overview of the study area (demographic characteristics, rice area, production, general economy, and mechanization level) indicated how resources in this region have been used to increase rice production and the role of mechanization technology in the study area.

Population, rice area, economy and level of mechanization

West Java is one of the most populous provinces in Indonesia. About 33.5 million people, or 20% of Indonesia's population live in this area. Indramayu, the selected district, is located on the northern coastal area of this province and has about 1.4 million inhabitants.

In West Java, about 1.2 million hectares were in rice production, with about 10% of this area (116,000 hectares) in Indramayu District. The Jatiluhur Irrigation Scheme , which provides water to 250,000 hectares of rice area in the northern coastal plain, enables farmers to grow 1.6 rice crops per year.

In 1988, West Java produced 8.9 million tons of rice, while Indramayu produced about 1.0 million tons. In 1988, provincial yields averaged 4.58 t/ha, while Indramayu yields averaged 4.89 t/ha. West Java produced about 21.8% of the country's rice, making West Java a key rice production area. Thus, almost all national efforts to increase the production capacity of the farmers have been started in this region, including the BIMAS (Mass Intensification), the INSUS (Special Rice Intensification) and the SUPRA INSUS (Improved INSUS) programs. Because of the region's importance, any crop losses due to pest outbreaks, drought or floods, seriously threaten the supply of rice in the country.

In West Java, the rice mechanization level was considerably higher than the national average. Table 5.1, shows that 22% of the region's tractor population were in Indramayu. For other machines, the percent share ranges between 8 to 20%. In 1988, about 13% of the regions' rice threshers were in Indramayu. Of this total, 42% were engine-powered threshers, all with small and portable engines (5 HP). Engine-powered threshers have became popular among the farmers in Indramayu since 1985. Most were locally manufactured and some of them produced by village artisan in Gabuswetan Indramayu.

In 1988, JICA (Japan International Cooperation Agency) through the Ministry of Agriculture provided a grant to distribute rice threshers and rice winowers to the farmers in West Java (Diperta Indramayu, 1990). However, during our survey we found that 35 units of the 40 threshers were never distributed because of a lack of requests from farmers.

Table 5.1. General Economic Indicator of West Java and Indramayu, 1988, Indonesia.

Economic Indicators	West Java	Indramayu
Population (million)	33.5	1.364
Farm Households (percent)	na	42.9
Area of Wet Land Rice (ha):		
Technically irrigated	441,949	80,179
Semi technically irrigated	135,277	14,737
Non-Technically irrigated	322,807	3,341
Rainfed	277,994	12,221
Other	13,348	6,000
Total	1,191,375	1,164,478
Rice Harvested Area/year (ha)	1,904,614	186,036
Number of Rice Crops/year	1.6	1.6
Average Rice Yield (t/ha)	4.52	4.87
Rice Production (t)	8,973	932
Percent of Rice Production (%)	21.89[a]	10.39[b]
Number of Selected Farm Machines:		
Tractors	8,458	1,889
Hand Sprayers	170,000	20,514
Threshers (pedal and power)	3,837	513
Irrigation pumps	1,870	364
Rice milling Machines	18,011	1,317
Gross Domestic Product (%):		
Agriculture	23	52.9
Industry	19.6	5.2
Trade	21	24.1
Service	3.46	2.3

a: Percent of National Production
b: Percent of West Java Production
na: Data not available

Source : West Java and Indramayu Statistics, 1989

The regional economic statistics for West Java indicate that the agricultural sector dominates the region's gross domestics product (GDP). The agricultural sector accounts for about 23% of the region's GDP with 17% of this total coming from the food crops subsector. Following the agricultural sector, the trade sector accounts for about 22%, and the industry about 20% of the region's GDP. For Indramayu, the agricultural sector accounts for 52% of the GDP, the trade sector 24%, and industry and other sector contribute less than 5% (West Java Statistics, 1989).

Table 5.2. Village Characteristics, Indramayu, West Java 1990, Indonesia.

Subdistrict/ Villages	Rice Area (ha)	Population (people)	Farm Households (No.)	Threshers (No.)	Tractors (No.)
Gabuswetan:	12,057	95,327	10.046	134	207
Gabuskulon	639	6,155	2,641	16	13
Babakan Jaya	587	4,226	1,815	10	13
Rancahan	1,059	3,761	1,615	13	23
Anjatan:	12,648	152,837	17,341	5	250
Anjatan Utara	na	7,837	3,380	4	10
Sukra	na	6,673	2,865	1	15
All Indramayu	116,478	1,363,940	146,470	296	1889

Source : Agricultural Extension Office, Indramayu, West java 1990, Indonesia

Within Indramayu, the study subdistricts of Gabuswetan and Anjatan were the most populous areas, accounting for about 10-12% of the district total rice land in the district. These subdistricts were the major rice growing areas in Indramayu. Forty-five percent of Indramayu's engine-powered threshers were in Gabuswetan's subdistricts, averaging 5.5 units per village (about 500 ha per village). Although pedal threshers are found in some remote areas, they have not been used for a long time. On the other hand, in Anjatan, a neighboring village, the density of engine-powered threshers was far below Gabuswetan. This village averages only 0.16 engine-powered threshers and 0.5 pedal threshers per 500 hectares of rice land. All were government gifts to farmers groups. In both subdistricts the level of land preparation mechanization was high. More than 450 two-wheel tractors (25% of the total number of two-wheel tractors in Indramayu) were found in these subdistricts. Field observations during the farm survey indicated that more than 90% of the rice land was prepared by tractors. While some farmers still prepare their land manually for finalizing their field work, no farmers reported using animal power (BPP, 1990). Similarly Kasryno (1982) reported that about 80% of farmers already used tractors for land preparation in selected villages in West Java.

Both subdistricts have similar rice production and institutional support systems. Although tractor mechanization has been widely adopted since 1976 and rice has been milled by rice milling machines since 1970, the diffusions of threshers has been slower than both tractor and rice milling machines.

Through the government's massive campaign to reduce post harvest losses, launched in 1985, the hand-threshing method has been improved by encouraging farmers to use a polyethylene sheet to minimize the scattered grain. Today almost all farmers use this method to minimize grain loss. By 1990 the hand-threshing method still dominates the threshing operation. However, the grain losses remained very high (DGFCA, 1987).

Average land holding, tenancy and landless laborers.

The Agricultural Census of 1983 indicated that farms in the area are quite small and are cultivated by owner and tenants (Table 5.3 and 5.4). In Indramayu, 76,000 households owned farms averaging 0.72 ha in size. About 8,000 households owned an average of 0.80 ha/farm in Gabuswetan and 6,000 households owned an average of 1.14 ha/farm in Anjatan. In Indramayu, 11,000 tenant households farmed an average of 0.42 ha/farm, about 1,500 households cultivated an average of 0.44 Ha/farm in Gabuswetan and 1,300 households farmed 0.56 ha in Anjatan. The owner-tenant households held an average of 0.42 ha of farm land in Indramayu, 1.0 ha/farm in Gabuswetan and 0.84 ha/farm in Anjatan.

The number of landless laborers was about 216,000 in

Indramayu, about 21,000 in Gabuswetan and 26,000 in Anjatan. The ratio between the number of land-less laborer households and the farm operators households was 1.5 in Indramayu, 1.2 in Gabuswetan and 1.5 in Anjatan.

These land distribution statistics and estimated current population growth (2.3% annually) data, suggested that the small farms will dominate the future rice production system in West Java, and generally in Java. Under these circumstances, it will be difficult for small farmers with less than 1.0 ha to access a high-pay off input to increase returns, without any significant policy in the distribution of inputs. A technological package, that directly helps the small farmers will still be needed for the future rice crop production system.

Table 5.3. Number of land-Ownwer, Tenants, and Landless Laborers in Indramayu districts, 1990.

Distict/ Subdistricts	Land-Owner		Owner and tenants		Tenants		Landless	
	Number	Ha/ hh	Number	Ha/ hh	Number	ha/ hh	Number (person)	Number (house-holds)
Indramayu	76,831	0.7	51,862	0.4	11,268	0.4	216,527	72,000
Gabuswetan	8,141	0.8	4,808	1.0	1,564	0.4	20,892	6,900
Anjatan	6,446	1.1	7,534	0.8	1,770	0.4	25,561	8,500

*Assume 3 adult people for every household
Source : Agricultural Census 1983, West Java 1990, Indonesia.

Table 5.4. Number of farms and its size in Indramayu District, West java 1990, Indonesia

Size of Land (ha)	Indramayu		Gabuswetan		Anjatan	
	Number	%	Number	%	Number	%
< 0.19	50,918	25.0	3,805	29.0	3,872	25.0
0.2 - 0.39	40,006	20.0	2,679	20.0	2,918	19.0
0.4 - 0.59	40,372	20.0	2,194	16.5	2,287	15.0
0.6 - 0.79	28,777	14.0	1,655	12.4	2,071	13.6
0.8 - 0.99	20,427	10.0	1,324	10.0	1,726	11.3
1.0 - 1.9	15,551	8.0	981	7.4	1,388	9.1
> 2.0	8,778	4.0	709	5.3	965	6.3
Total Number of Farms	204,797	100.0	13,297	100.0	15,287	100

Source : Agricultural Census 1983, West Java 1990.

5.2. Socio-Economic Characteristics of Respondents.

The respondents were classified into four categories, namely Manual-Farmer (M-F), Thresher-Owner (T-O), Thresher-Hired (T-H), and Pedal-Owner (P-O). The statistical software package, SPSS-PC+ was used to analyze the socio-economic data collected during the farm survey.

Age, Farming Experience, and Education.

The Duncan Multiple Range Test (DMRT) indicated that average age of the respondents was not significantly different at α=0.05, ranging from 43 (Thresher-Hired) to 47 (Thresher-Owner and Pedal Owner). Most respondents have been farming since they were young. Their knowledge and their knowledged and experience was passed from generation to generation (Table 5.5).

Across the four strata, farming experiences range from 22 years (Manual) to 28 years (Thresher-Owner). Generally, the respondents have very little formal education. The Thresher-Hired averaged 3-4 years of education, the Thresher-Hired 5 years, and the Pedal-Owner averaged 6 years. The DMRT indicates a significant difference both in farming experience and education.

Table 5.5. Demographic characteristics of the respondents in the study area, Indramayu, West 1990, Indonesia.

Item	Manual-Farmers	Thresher Owner	Thresher Hire	Pedal-Owner
Number of Cases	45	35	42	18
Age (years)	44a	47a	43a	47a
Farming Experiences (years)	22a	28b	23a	23a
Education (Years)	4.9a	3.4b	3.8ab	6.3ac
Household members	4.1a	4.0a	4.0a	4.6a
Family Laborers:	1.6	1.7	1.7	1.1
Male	0.9a	0.8a	0.9a	0.7a
Female	0.73a	0.9a	0.8a	0.4a

DMRT: α=0.05; same letter = not significant
Source : Farm Survey, West Java,1990

Labor Availability

Across the four strata, the average number of family member per households participating in harvesting and threshing ranged from 1.1 (Pedal-Owner) to 1.7 (Thresher-Owner and Thresher-Hired) with the means no significantly different at α=0.05 (DMRT).

The Pedal-Owners were mostly key farmers in Anjatan village. Generally, they were wealthier and better educated than thus farmers in the other strata. Since they are wealthier and better educated, the number of their family members participated in harvesting and threshing was lower, compared to other strata, and most of their "family members" were permanent laborers.[7] In this particular case, there is little evidence that farmers adopted the threshers due to a shortage of family laborers.

Farm size, tenure status, rice crops, average yield, and irrigation status

Average farm sizes (Table 5.6) were significantly different across the four strata (DMRT, α=0.05), ranging from 1.1 hectares (Manual-Farmer) to 2.9 hectares (Pedal-Owner), while the Thresher-Owner averaged 1.6 hectares, and the Thresher-Hired's land averaged 1.4 hectares. Similarly average yield (wet season 1989) was not differed significantly between strata (DMRT, α=0.05), with the Pedal-Owner and Thresher-Hired producing the highest yields at 5.5 t/ha, followed by the Thresher-Owner (5.3 t/ha). The Thresher-Hired farmers produced the lowest yield at 5.2 t/ha. In contrast during the dry season in 1990, average yields of each strata declined. Yields for the Pedal-Owner

[7]Permanent laborer(s) is the laborer paid by the owner-operator permanently (including meal and clothes). Usually, the lived in the same house with their employer.

averaged 5.2 t/ha, the Thresher-Owner averaged 5.1 t/ha, and the Thresher-Hired averaged only 4.5 t/ha. The aggregate average yields of the wet season of 1989 was 5.3 t/ha and 4.7 t/ha during the dry season 1990.

Seasonal household production was computed by multiplying the yield average times the average farm size, while the annual production was computed as the sum of both wet season and dry season production. The highest total output was produced by the Pedal-Owner (31.2 t), followed by the Thresher-Owner (15.9 t), the Thresher-Hired (15.0 t) and the Manual-Farmer (11.5 t).

Most farmers planted varieties IR-64 (79%) and the Cisadane (13.2%). These varieties were the most popular rice varieties planted in the study area and throughout West Java.

Most of the sample farms (90%) were family owned land. Although rented-in, the rented-out, and the share-in opportunities were also available, few households utilized these tenurial arrangement[8]. Commonly, most farmers prefer to farm only their own land rather to rent-in or share-in, because the value of land is very expensive[9].

---

[8]rented-in:to rent a piece of land from some one else; rented-out: to rent a piece of land to some one else;share-in: to cultivate some one else's parcel with share in inputs and divides production with land-owner.

[9] During the interview, most farmers indicated that land value was very expensive ($500-$2500/ha).

Table 5.6. Average farm size, rice yield, production, rice variety, and Farm and Irrigation status in Indramayu, West Java, 1990, Indonesia.

Item	Manual-Farms	Thresher Owner	Thresher -Hired	Pedal-Owner
Number of cases	45	35	42	18
Average farm size (ha)	1.1a	1.6a	1.4a	2.9b
Average Yield (t/ha)				
Wet Season (1989)	5.16a	5.27a	5.45a	5.54a
Dry Season (1990)	4.5a	4.5a	5.1b	5.2a
Production (mt)				
Wet Season (1989)	5.7	8.5	7.6	16.2
Dry Season (1990)	4.9	7.2	7.1	15.1
Total	10.6	15.7	14.7	31.3
Rice Variety (%):				
Wet Season:				
Cisadane	16	23	5	8
IR-64	83	74	79	92
IR-42	0	0	3	0
Ciliwung	1	3	4	0
Other	0	0	9	0
Dry Season:				
Cisadane	51	55	47	73
IR-64	21	23	19	12
IR-42	9	1	17	0
Ciliwung	9	6	4	0
Other	10	15	13	15
Farm Status (%):				
Owned	90	92	88	96
Rented-In	6	8	3	0
Rented-Out	4	0	5	0
Share-in	0	0	4	4
Irrigation Status:				
Technically Irr.	98	92	97	100
Semi-Technically	2	8	1.5	0
Rainfed Irr.	0	0	1.5	0

DMRT; α=0.05; a value followed by same letter: not significant

Source: Farm Survey, West Java 1990.

In the study area, farmers cultivated both rainfed and irrigated land. A rainfed farm depends solely on rainfall. A semi-technically irrigated farm is irrigated by small tertiary ditches which convey water from surface ponds or small rivers. Usually these systems are constructed by village community. A technically irrigated farm is irrigated by water from a permanent irrigation structure (dam or reservoir with canals), constructed by the government and supervised by a village-based irrigation supervisor. Across the four strata, most farms (92%-100%) in the study area were technically irrigated, and only a few (0-8%) of the total number of farms were semi-technically irrigated.

Harvesting and Threshing Schedule

The cumulative percent of area harvested by each strata is plotted against the date of harvesting and threshing, both in the wet season and the dry season as shown in figure 5.1 and 5.2 . These figures shows, that Thresher-Owner and Thresher-Hired farmers in Gabuswetan and Anjatan completed their harvesting and threshing operation 1 week faster than other farmers (Manual and Pedal-Owner). Based on these figures we can conclude that engine-powered threshers have helped farmers to rapidly finish their work. If the number of harvest laborers in this village is limited, the thresher may reduce the delay in threshing and timeliness cost, and finally reduce the machine cost.

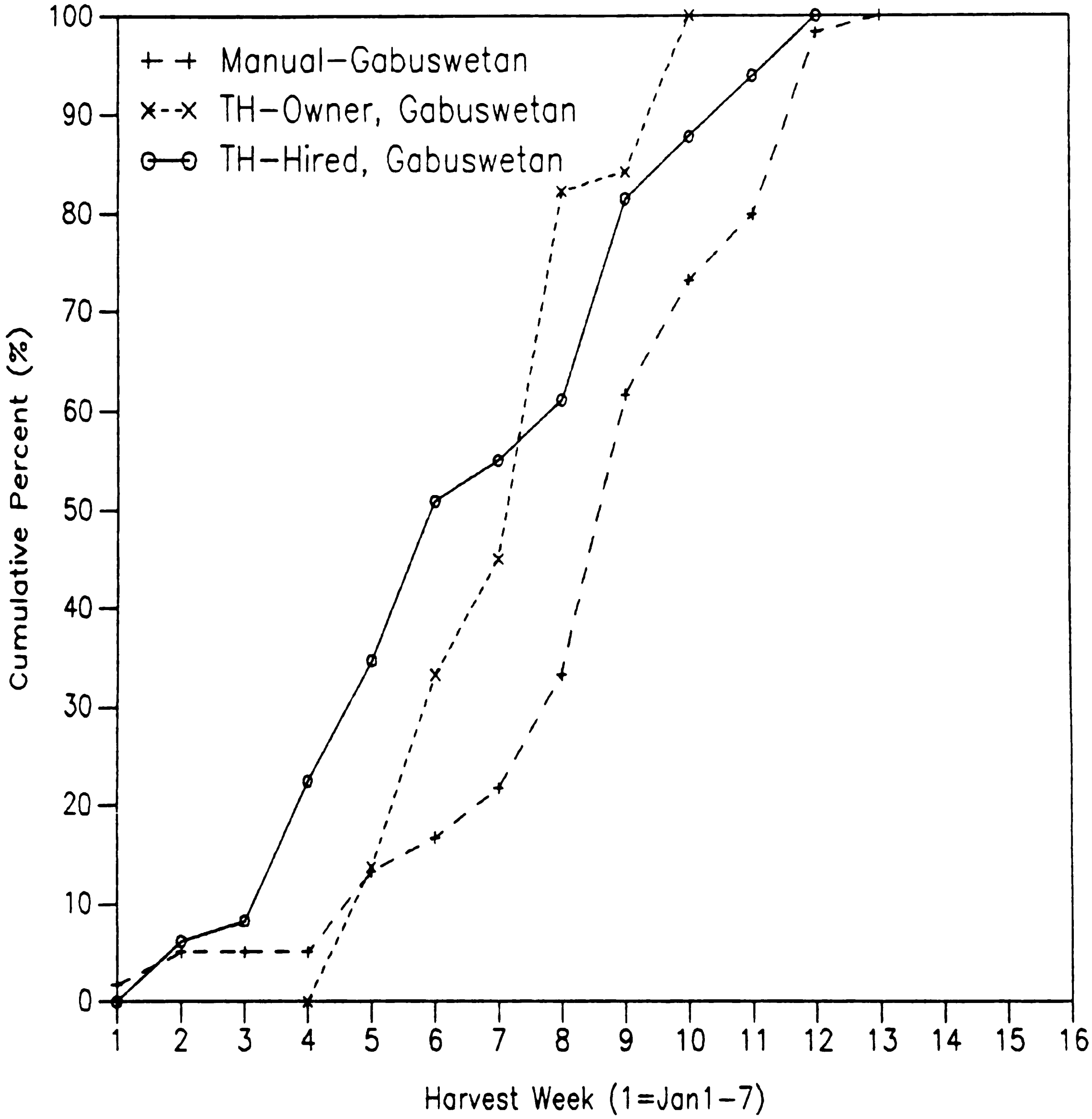


Figure 5.1. Percent Harvested Area Completed by each strata in Gabuswetan subdistrict

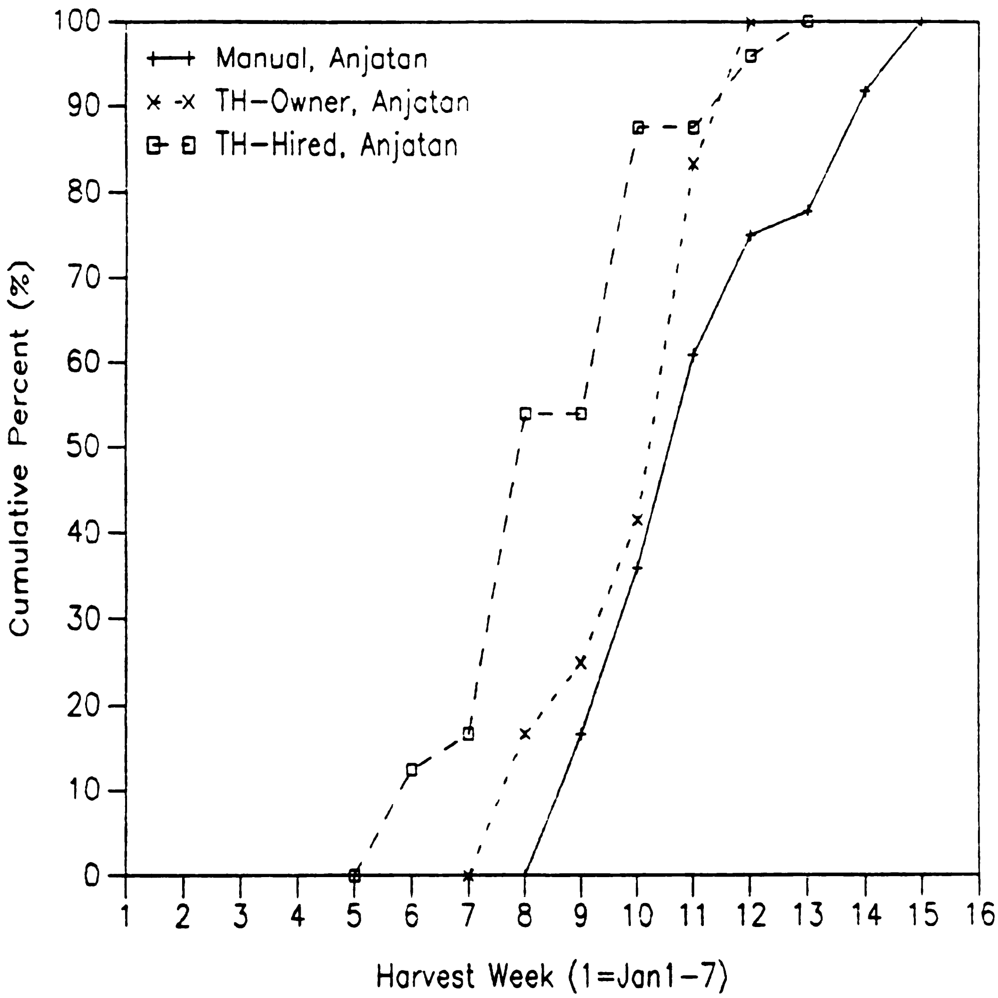


Figure 5.2. Percent Harvested Area Completed by each strata in Anjatan subdistrict

5.3. Financial Liability of the respondents.

Besides technology, credit has been one of the major factors contributing towards increasing rice production since 1970. Initially, government heavily subsidized inputs to make them affordable for most farmers. But since 1986, the government gradually reduced the subsidy for fertilizer and pesticides, following the ban of major pesticide types that were found to create new pest resistance. In addition the government also began to readjust the agricultural credit policy through Mass Guidance (BIMAS) because of the poor repayment capability of the farmers. Only selected farmers who have a good record could apply for agricultural credit. Since then a new credit policy has been offer through KUPEDES[10], with interest rate higher than BIMAS's credit (Robinson, 1987).

The survey revealed that only 85 of 135 respondents (62%) provided their financial resources information, these were 21% (29 respondents) of Manual-Farms, 12% (17 respondents) of Thresher-Owner farms, 23% (31 respondents) of Thresher-Hired, and 6% (8 respondents) of Pedal-Owner farmers.

About 72% of the Manual-Farmers obtained credit from the government, while only 24% received credits or loans from landlords. Similarly for Thresher-Hired farmers, 71%

---

[10]KUPEDES is a program of general rural credit that offers loans up to Rp. 2 million at a flat rate of 1.5% per month on the original balance for working capital loans, and at 1% for investment loans (Robinson and Snodgrass, 1987).

received credit from the government, and only 23% percent received it from landlords, the rest (6%) obtained from others. On the other hand, 77% of Thresher-Owner farmers obtained financial aid from government source and 20% received aid from the landlords. All Pedal-Owner farmers obtained credit from government resource.

Financial liability obtained from the respondents indicated that most farmers had access to formal or non-formal financial resource (Table 5.7).

Across the four strata, the amount requested by respondents ranged from Rp 302,000 (Thresher-Owner) to Rp 470,000 (Pedal-Owner). These credits came either from the government (76%), the landlords (20%), the Middlemen and about 2% from other sources (relative, friends, etc). Most credit were used mainly for seasonal farm expenses (94-100%) and only a few farmers (2.4%) used the financial aid for purchasing an agricultural machine, while the rest of the farmers used the credit for family expenses.

Table 5.7. Financial Resources, Amount, Collateral Requirement, and interest rate, Indramayu, West Java 1990, Indonesia

Item	Manual-Farmers	Thresher Owner	Thresher Hired	Pedal-Owner
Financial Resources (%)				
Government Bank	72	71	77	100
Landlords	24	23	20	0
Middlemen	0	6	0	0
Others	3	0	3	0
Average amount (000 Rp)	363.2	302.9	382.5	470.6
Objectives (%):	A	B	C	D
Farm Expenses	94	100	100	100
Family expenses	1.5	0.0	0.0	0.0
Purchasing machine	3a	0.0	0.0	0.0
Others	1.5	0.0	0.0	0.0
Total (%)	100	100	100	100
Collateral Requirements (%):				
Personal Note	14	7	0	na
Land	70	20	0	na
Agr. Product	1.5	33	0	na
Building	3	0	0	na
Others	2	0	0	na
No Collateral	9.5	40	100	na
Interest rate and pay back period:				
Interest rate (%)	16.3	30.7	50.0	13.5
Payback period (month)	10.2	5.76	6.0	6.0

A: Government Bank; B: Landlords; C: Middlemen
D: Others (family and relatives)
na : data not available
[a]Credit used for buying tractors or sprayers.
Source: Farm Survey, West Java 1990.

A wide range of interest rates were available to farmers at the villages, ranging from 16.3% (government) to 50% (middlemen). The government's loans were more attractive to the farmers, because of their low interest rate. Since the official interest rate was set at 12% annually, the 4.3%

deviation that respondents reported was likely attributed to the transaction cost included when applying for this credit.

The private banks which were established at the end of 1980s are not likely reaching the village area. The existence of the non-formal financial market and the high real interest rate charges in this market indicate, that formal credits are limited, while the demand for credit is high. Generally, land is required as a collateral requirement for government credit which is relatively cheaper than other sources, therefore, large farmers have greater access to this credit.

5.4. Machinery Inventory

Machinery inventory varies between farm households. Back-Pack sprayers were the most frequently owned piece of equipment, owned by most thresher-owner (91%), 88% of the Thresher-Hired farms, 54% of the Pedal-Owner farms and only 7% of the Manual-Farms. Few farmers owned more expensive equipment, although tractors were owned by some Pedal-Owner farmers (15%), Thresher-Owner farmers (14%), Thresher-Hired farm (11%) and only 7% of the Manual Farmers. On the other hand, 4% of the Manual-farmers owned rice milling units compared to 2% by Thresher-Hired. No Thresher-Owner or Pedal-Owner farmers reported owning rice milling machines.

This machinery inventory data suggested that thresher user (owner and hired) operated more "mechanized farms"

compare to other farm types. Possibly, initial thresher owners have learning about the benefits of using machine from their tractor experience.

Most thresher-owner (85%) purchased their thresher by using their own saving, while only 15% were purchased by money that was borrowed from money lender or dealer. No credit was used for buying threshers. Seventy-five percent of the threshers were purchased after 1987, of those 25% were the used machine and the rest were new machines. All machines were reported in good condition and only a few had minor breakdowns.

5.5. Threshers Breakdown

Farmers were asked questions to assess the frequency of the machinery breakdown, delay caused by breakdowns, and the cost for repairs and maintenance (Tables 5.8 and 5.9). These questions assumed that delays in threshing repair due to the unavailability of parts, may delay the threshing operation, resulting in lower working days and greater losses.

Sixty percent of the thresher owners reported breakdowns (Table 5.8.). Forty-four percent of the major breakdowns were due to engine failure, and four percent were due to problems with the threshing machine (cylinder drum and its parts); with the rest being only minor breakdowns that did not delay the threshing operation.

The Thresher-owners indicated that failure with the thresher body and its parts (cylinder drum, concave and other body parts) was not a serious problem. This is likely true because there were at least four small workshops located in Gabuswetan subdistrict, with one workshop in Gabuskulon village, and three more workshops were about 2.5 -5 km from Gabuskulon village (Kandang Haur village). Existing workshops could meet most service needs, such as repair and maintenance, rebuilding and even making a bodies for threshers.

Table 5.8. Major breakdowns reported by thresher owners in each village, Indramayu, West Java 1990, Indonesia.

Item	Gabuswetan	Babakan Jaya	Rancahan	Anjatan
Breakdown experience (%):				
No experience	0.0	0.0	50.0	100.0
Yes	100	100	50.0	0.0
Cause of major breakdown (%):				
engine	66.7	100	40	0.0
threshing cyl.	16.7	0.0	10	0.0
other parts	16.7	0.0		0.0
Did the owner repair his thr.?				
Yes (%)	66.7	0	50	100
No (%)	33.3	100	50	0.0
Did break-down cause delay?				
yes(%)	83.3	33.3	30	0
no (%)	16.7	66.7	70	100
Total Days of delay	21.0	6.7	7.8	0.0
Cause of delay (%):[a]				
2.	33.3	0.0	0	0.0
3.	33.3	33.3	20.0	0.0
4.	16.7	0.0	10.	0.0
Part acquisition: for those w/delay				
no problem	0.0	8.3	36.0	20.0
substitute with locally made	12.0	0.0	4.2	0.0
order new parts	12.0	4.0	0.0	0.0
no action	0	4.0	0.0	0.0

[a]2: no time to bring to mechanic, 3: no mechanics; 4:others.

Source : Farm survey, West Java 1990, Indonesia

Table 5.9. Cost components of major engine-powered thresher breakdown in Indramayu, West Java 1990, Indonesia.

Item	Mean
Repairs by owner:	
spare parts cost (Rp)	7,600
labor cost (Rp)	0.0
transportation cost (Rp)	0.0
Repairs by mechanic:	
spare parts cost (Rp)	10,600
labor cost (Rp)	2,100
transportation cost (Rp)	0,400
Repairs by village shop/ dealer:	
spare parts cost (Rp)	7,600
labor cost (Rp)	1,100
transportation cost (Rp)	2,000

Source : Farm Survey, West Java 1990.

On the average, engine-threshers were broken 11.8 days per season, ranging from 6.7 to 20.9 days (Table 5.8). These breakdowns delayed threshing about 0.8 to 2.0 days/season. It seems that the these breakdowns did not affect the delay of threshing activity since harvest laborers remained available to do the threshing job. Sixty-three percent of the thresher owners reported no delay. These delays were not very significant for most farmers. The various causes of the delays reported by the thresher owners included: a)" no time to bring to mechanic" (8.3%); b) "no mechanics (20.8%), c) " other" (8.3%).

No farmers indicated that the delays in repairing their threshers were the result of "no parts available" or "insufficient money". Sixty-three percent of the respondents reported that the availability of parts was not a problem, since they usually replaced the defective parts with locally made parts. Four to 12% of farmers reported that they ordered parts from the dealer, if the parts were not available at the local dealer and only 4% reported no action. This case usually happened when the breakdown occurred at the end of the season.

The major repair costs were spare parts, followed by labor and transportation (Table 5.9). If the owner repaired the thresher by himself, the cost averaged Rp 7,600. By comparison, the cost of the repair, if done by a local mechanic or local dealer, ranged from Rp 7,600 to 13,160.

The availability of such workshops is one of the cost reducing factors that accelerates the diffusion of the thresher and is a stimulus to further thresher adoption.[11]

5.6. Average Farm Inputs and Rice Yields of Each Strata

Table 5.10 shows the average levels of farm inputs used by the farmers and the yields, both in the wet season 1989 and the dry season 1990. Due to the pest outbreak during the wet season of 1989, 20% of the respondents had abnormally low yields. In order to estimate the normal harvest data,

[11]Study of tractor mechanization in South Sulawesi and West Java (IRRI, 1981; and MOA, 1981) revealed that availability of rural workshops was one of the back-up supports required to keep tractors operating continuously.

Table 5.10. Average amount of inputs used by respondents in Indramayu, West Java 1990.

Season/Type of Inputs	Manual-Farmer	Thresher Owner	Thresher Hired	Pedal-Owner	All Far-mers
Wet Season:					
Parcel Size (ha)	1.1	0.9	0.9	1.5	1.1
Seed (kg/ha)	24.2	30.5	26.6	28.5	26.9
Fertilizer (kg/ha)					
Urea	226.1	272.1	244.8	231.3	243.9
TSP	139.1	170.7	171.4	162.3	159.7
KCL	80.0	67.9	108.3	91.4	89.1
ZA	-	50.4	92.3	7.7	52.6
Pesticides:					
liquid (l/ha)	19.8	18.0	15.4	16.8	17.7
solid (l/ha)	na	na	na	na	na
Yield (mt/ha):	5.16 a	5.27 a	5.50 a	5.54 a	5.33
Dry Season:					
Seed (kg/ha)	27.8	30.8	26.8	28.7	28.4
Fertilizer (kg/ha)					
Urea	217.5	253.7	237.7	233.2	235.2
TSP	138.0	135.5	164.2	129.9	144.4
KCL	66	71.8	95.3	90.8	81.1
ZA	na	na	na	na	na
Pesticides:					
liquid (l/ha)	19.8	17.9	15.4	17.0	17.8
solid (l/ha)	na	na	na	na	na
Yield (mt/ha)	4.49 a	4.49 a	5.08 b	5.19 b	4.74

[a]Data refers to the largest parcel. Same letter indicates no significant different (DMRT, α=0.05). na: data not available

Source : Farm survey, Indramayu, West Java 1990.

they were asked to estimate their normal wet season harvest and this estimate was used in the modelling.

In the wet season 1989, farmers planted an average of 26.9 kg of seed per ha, ranging from 24.2 to 30.5 kg/ha. There was no significant difference between Manual-Farm, Thresher-Hired and Pedal-Owner farms, however, the mean of seed per hectare planted by the Manual-Farms and the

Thresher-Owner was significantly different (DMRT at α=0.05).

The recommended fertilizers application rates per hectare were as followes: N (90-121 kg/ha); P_2O_5 (43 -50 kg/ha), K_2O_5 (20-33 kg/ha) and S (0-24 kg/ha). In the study area, farmers applied 243 kg/ha of Urea (118 kg of N), 160 kg of TSP (73.6 kg of P_2O_5), 89 kg/ha of KCl (40 kg of K_2O), and 52 kg of ZA (23 kg of N per hectare). Farmers seemed to apply more than the recommended rated of TSP and KCL, and the rate of application were higher during the wet season than the dry season.

To kill rice pest and control diseases, farmers applied liquid or solid materials. The amount of liquid materials usually range from 1.5 to 2.5 l/ha (depending on the intensity of the pest), and the rates for the solid material range from 10-15 kg/ha.

In the wet season 1989, rice yields were not significantly different between the strata. However, in the dry season 1990, the average yield between Manual-Farms and Thresher-Hired were significantly different (DMRT, α=0.05). Rice yields averaged 5.3 mt/ha during the wet season 1989, and 4.8 mt/ha during the dry season. The lower dry season yields were likely due to the lower application rate of fertilizer and pesticides in the dry season and a shortage of water.

5.7. Harvest Laborer Arrangement, and Utilization in Harvesting and Threshing Operations

Harvesting and threshing laborers included Hired laborers and family laborers. Hired laborers commonly came from both outside and inside the village. Table 5.11. indicates that 62 to 69% of the farmers only hired laborers from inside the village, 10 to 39% only hired laborers from outside the village, and about 19 to 23 % hired laborers from both inside and outside the villages. During the farm survey, it was found that about 30 to 40% farmers used the ***ceblokan*** system. Hayami Kikuchi (1982) found that this ***ceblokan*** system became widely adopted by farmers in the neighboring district of Subang (about 25 km from the study area), since 1975, where more than 90% of the farmers used the ***ceblokan*** system.

Table 5.11. Sources of Hired Laborers in Harvesting and Threshing operations in Indramayu, West Java 1990, Indonesia (in percentage).

Source of Laborer	Manual Farmers	Thresher Owner	Thresher Hired	Pedal-Owner	All Farmers
Farmers themselves	0	0	2.5[a]	0	0.6
Inside Village	64.5	62.9	69.0	61.5	64.5
Outside Village	15.7	14.3	9.5	38.5	19.5
Both Inside and Outside Village	20.7	22.8	19.0	0.0	15.6
Total	100.0[b]	100.0	100.0	100.0	100.0

[a]Indicates average permanent labor used by the Non-Owner Adopter farmers
[b]The sum is not 100%, due to rounding off numbers
Source : Farm survey, West Java 1990.

Assuming that pre-harvest labor requirements were the same in each strata[12], total labor used by the strata in the wet season was estimated in Table 5.12. During the wet season, total labor human requirements averaged 118 persons/ha for the Manual-Farmer about 6, 5 and 4 % more than the Thresher-Owner, the Thresher-Hired, and the Pedal-Owners, respectively. Most laborers used in harvesting and threshing operations were hired labor. Those were 95% on Manual, 94% on Thresher-Owner, 92% on Thresher-Hired and 99% on Pedal-Owner farms. This table also indicates that harvesting operation was the important source of income for rural laborers in West Java. Family

[12]This estimate was based on farm budget analysis of data collected for the Central Bureau of Statistics (CBS). Data taken from Anjatan subdistrict, which represented the major rice growing area in the northern coastal region of Indramayu.

laborers were required in this harvesting to supervise activity.

Laborers working for Manual and Pedal-Thresher farms did thresh the crop. In contrast, on Thresher-Owner (TO) and Thresher-Hired (TH) farms, threshing was done by the thresher operator. In this threshing hiring system (TO and TH), the engine-powered thresher system reduced labor requirements. In addition to that, harvest-laborers had to deduct 16.7% out of their harvest wages (2.78% of the gross product) for threshing costs. Consequently, total in-kind payment for harvest laborers was reduced from 16.7% of the gross output to only 13.9% of the harvest output.

Table 5.12. Average Pre-harvest and Post-Harvest Labor Used, Indramayu, West Java 1990, Indonesia.

Item	Manual Farmers	Thresher Owner	Thresher Hired	Pedal-Owner
Farms size (ha)	1.1	1.56	1.43	2.88
Pre-Harvest laborers (persons):[a]				
Family labor	36.94	36.94	36.94	36.94
Hired labor	31.35	31.35	31.35	36.9
Tractor[b]	15.05	15.05	15.05	15.0
Total pre-harvest	83.34	83.34	83.34	83.3
Post-harvest laborers (persons):				
family labor	1.8	1.7	1.7	0.3
hired labor	33.46	26.58	24.51	31.3
Total post-harvest	35.22	28.32	26.57	31.6

[a]Estimates based on the farm budgeting analysis of 20 farm samples in Anjatan ranging from 0.25 to 1.4 hectares.
[b]Tractor days is converted to persons by dividing the cost of land preparation by daily laborers wage.
Number of laborers (persons)= Tractor cost (Rp/ha) / Wage (Rp/person/day)

Source : Farm Survey, West Java, 1990.

5.8. Harvesting and Threshing Performances

Field experiments were carried out to measure the performance of each threshing method. Sixteen plots were used to measure harvesting losses, 70 replication samples were run to evaluate engine powered threshing performance, and 48 samples were used to assess the hand threshing method. Since the survey did not collect field data on pedal thresher performance, data from past survey were used as a proxy.

Harvesting loss assessment, hand-threshed performance, and engine-powered thresher performance, are reported in Table 5.13 through 5.14 respectively. All test performances are summarized in Table 5.16.

Table 5.13. Harvesting Losses, Indramayu, West Java, 1990a

Village	MC (%)[b]	Control Plot (mt/ha)[c]	Standard Plot (mt/ha)[d]	Harvest Loss[e] (%)		No. of Plots
				Avg[f]	SD	
Gabuswetan-1	25.90	5.65	5.37	5.0	0.4	4
Gabuswetan-2	23.50	5.11	4.76	6.8	1.8	4
Anjatan-1	22.90	5.45	5.05	7.4	3.2	4
Anjatan-2	22.50	5.70	5.37	5.8	1.4	4
Average	23.70	5.73	5.38	6.2	1.7	16

[a]Manual harvesting using sickles
[b]Wet basis
[c]Data taken from 1x1m plot size.
[d]Data taken from 2.5x2.5m, 4 replications
[e]Threshing loss not included
[f]average of 3 replications taken from each plot
Source : Field Research Experiment, West Java, 1990.

Table 5.14. Threshing Losses using Hand-Thresh (Manual-Threshing) in Indramayu, West Java, 1990

Village	Variety	MC[a] (%)	Threshing Rate[b] (kg/hr)	Threshing Eff.[b] (%)	Threshing Loss[b] (%)	Purity[c] (%)
Gabuswetan-1	IR-64	25.53	39.2 3.6 9.0	94.6 0.4 0.4	5.2 1.1 10.5	88.5 2.1 2.4
Gabuswetan-2	IR-64	25.53	39.1 7.9 20.3	95.7 0.9 0.9	2.2 0.3 11.62	87.1 4.2 4.8
Anjatan-1	Cisadane	25.40	45.8 4.9 10.7	95.0 0.2 0.2	5.0 1.3 26.7	87.1 4.3 4.9
Anjatan-2	Cisadane	24.50	49.2 3.9 8.0	94.3 1.1 1.2	5.4 0.3 4.6	88.5 4.3 4.9
Average		25.24	43.4	94.9	4.5	87.8

[a]Moisture content at wet basis
[b]Data taken from 12 replications. Numbers in cells indicate average, standard devition and coefficient of variance.
[c]Purity indicates percent of the clean grain
Source : Field Research Experiments, West Java, 1990

Harvesting loss using sickles ranged from 5.0 to 7.4% of pre-harvest yields, and averaged 6.2% with a standard deviation of 1.7% (Table 5.13). These estimates were similar to figures obtained in previous surveys conducted by the JICA (1982), MOA (1987), DGFCA (1988), and BPS(1989) which estimated harvesting losses ranging from 3.5 -9.2% of pre-harvest yields.[13]

Table 5.14 shows the performance of the hand-threshing method. Threshing was conducted at 25% moisture content during the harvest operation. The threshing rate averaged 43.4 kg/hr, ranging from 39.2 to 49.2 kg/hr. Threshing efficiency ranged from 94.3% to 95.7%, with an average of 94.9%. On the other hand threshing loss by the hand-threshed method ranged from 2.2% to 5.3% with an average loss of 4.5%. Paddy threshed by hand was not as clean as expected. Additional work was needed to remove dust and chopped stalk or other foreign materials.

Table 5.15 shows that the moisture content at harvest averaged 23.8%. The threshing rate of the engine-powered thresher ranged from 251.3 to 507 mt/hr with an average of 378.6 mt/hr. Threshing loss averaged 2.8% of the pre-harvest yield, while separation efficiency averaged 96.4%. Threshing loss is computed based on the amount of grain threshed relative to the grain-straw ratio (Eq.6) and separation

---

[13]Ani-ani (small knife) harvesting loss was not measured, because no sample farmers used this tool. Sample farmers have not used the ani-ani knives since high yielding varieties were introduced in the early 1970's.

Table 5.15. Threshing Losses of Engine-Powered Thresher in Indramayu, West Java, 1990.

Village	Variety	Machine Type	MC (%)	Threshing Rate[a] (kg/hr)	Threshing Loss[a] (%)
Gabuswetan-1	IR-64	Diesel	24.0	399.2 49.9 12.5	3.7 1.2 31.8
Gabuswetan-1	IR-64	Gasoline	24.4	382.1 44.6 11.7	1.7 0.8 23.0
Anjatan-1	Cisadane	Diesel	24.0	251.3 43.0 23.0	3.4 0.8 23.0
Anjatan-1	Cisadane	Gasoline	23.3	371.9 96.1 25.9	2.3 0.3 8,3
Anjatan-2	Cisadane	Diesel	24.4	359.2 35.2 9.8	3.8 0.3 8.4
Anjatan-2	Cisadane	Gasoline	23.1	507.8 0.3 0.1	1.9 0.1 2.6
Average			23.9	378.6	2.8

[a] Numbers in each cells indicate average, standard deviation and coefficient of variation. Data in Gabuswetan were taken from 15 replications, and 12 in Anjatan for each machine.

Source : Field Research Experiments, West Java, 1990.

Table 5.15. (Cont'd).

Village	Separation Eff. (%)	Scattered Loss[b] (%)	Cleaning Eff. (%)	Threshing Eff(%)
Gabuswetan-1	95.8 1.2 1.3	2.7	87.4 3.9 4.4	95.8 1.2 1.2
Gabuswetan-2	97.9 0.6 0.6	2.2	95.8 1.5 1.6	97.9 0.5 0.6
Anjatan-1	96.3 0.7 0.7	3.5	95.7 2.6 2.7	96.8 0.7 0.7
Anjatan-1	95.8 0.5 0.5	6.1	93.5 0.2 0.2	96.9 0.7 0.7
Anjatan-2	95.6 0.1 0.1	5.5	94.7 0.8 0.8	95.6 0.5 0.5
Anjatan-2	97.1 0.1 0.1	3.1	89.6 2.1 2.3	97.9 0.1 0.1
Average	96.4	3.8	92.8	96.7

[b] The scattered grain was collected and weighted after all replication were done for 1 machine, then its average was calculated.

Table 5.16. Summary of Field Losses Experiments, Indramayu, West Java, 1990.

Item	Unit	Manual-Threshing	Engine-Powered Thresher	Pedal-Thresher[c]
Field Capacity:				
Harvesting[a]	kg/hr	29	29	29
Threshing[b]	kg/hr	43	378	85
Losses:				
Harvesting[c]	%	6.2	6.2	6.2
Threshing	%	4.5	2.8	4.5
System	%	10.8	9.1	10.8
Efficiency:				
Threshing	%	95.9	96.7	na
Separation	%	na	96.7	na
Cleaning	%	87.8	92.8	na

[a] Recalculated from Eko (1989);
sickle harvesting capacity = 179.9hr/ha at 5.3 mt/ha.
[b] Both manual (43 kg/hr) and powered-thresher (378kg/hr) were taken from survey. Pedal thresher (85 kg/hr) was taken from Test Report (MOA,1989)
[c] Adopted from BPS and MOA (1988)
na: data not available.
Source: Field Research Experiments, West Java, 1990

efficiency is computed based on the weight of threshed grain relative to the sum of the threshed grain plus the scattered grain (blown grain) and the grain output from the straw outlet (Equation 7).

Cleaning efficiency ranged from 87.4 to 95.8% with the average of 92.8%. On the other hand threshing efficiency ranged from 95.8 to 97.9%, with the average of 96.7%. Separation efficiency and husked grain are used to evaluate the thresher performance. Compared to the design parameter established by Singhal and Thierstein (1987), these test results suggest that separation efficiency was 1.3% lower than the recommended level. Husked grain was not measured during the grain test, since the drum's speed was set at the recommended level (500-550 rpm). Factors affecting the separation efficiency include the setting of the adjustable gate and the blower speed.

The summary of the system performance is presented in Table 5.16. The alternative threshing system included Hand Thresh, Engine Powered Thresher, and Pedal Thresher. Across the three methods, the system capacities ranged from 43.0 kg/hr (Manual) to 378 kg/hr (Engine-Powered Thresher). Harvest rate was 29 kg/hr for all strata. The system losses include harvesting loss and threshing loss. Harvesting loss ranged from 5% to 7.4% with an average of 6.2%. Manual-Threshing had an average loss of 4.5%, ranged from 2.2% to 5.4%, and Pedal-Thresher was estimated at 4.49% as reported by CBS (1988).[14] Engine Powered Thresher gave the lowest loss (2.5%).

Across the three systems, the Sickle-Harvesting and Engine-Powered Thresher gave the lowest losses (9.1%), followed by both Sickle-Harvesting/Pedal-Threshing and Sickle-Harvesting/Manual Threshing (10.8%).

Rice Post-Harvest study by the Central Bureau of Statistics (CBS, 1988) revealed that losses by Manual-Threshing averaged 5.34%, Pedal-Threshing 4.49% and Powered-Threshing 4.89%. Both studies (CBS and this study) suggested that the difference in loss between manual threshing and engine powered thresher was too small and likely insignificant. Regarding this low threshing performance of engine powered threshers in reducing the grain losses, two important improvements may be useful. The first is to improve the skill of thresher operators through proper training programs and the second is to improved and modify thresher design to obtain an optimum design of engine-powered thresher.

---

[14]Pedal-Threshing loss was not measured since no farmers used this method. As proximate data collected by CBS (1989) was taken for comparison.

5.9. Cost and Return

In the study area, total harvesting and threshing costs were the same across all strata, equal to 16.7% of the gross product. For Manual-Farmers, all of this share went to the harvest laborers. In the Thresher-Owner and Thresher-Hired, only 13.9% of the gross went to harvest labor, and the rest (2.77%) went to the machine owner and operator. Of the 2.77%, 2.31% went to the machine owner and the 0.46% to the thresher operator. The harvest laborers on pedal-owner farms, received the full 16.7% because no fee required for pedal thresher (no pedal threshers were rented out).

However, during a field trip to Sukohardjo, Central Java (dry season (1990), the study team observed that 4-5 harvest laborers typically used a pedal threshers to thresh the crop and they were paid Rp 15.00/kg of rice. Similarly, in Kulon Progo (Yogyakarta province), harvest laborers who used a pedal threshers received 10-12.5% of the gross product.

The distribution of costs to the laborers, machine owner and the operator is shown in Table 5.17. Assuming that grain losses were not included in the calculations, and aggregate yield level (5.34 ton/ha) applied to all farmers, the harvest laborers' share to production was highest for the Manual-Farmers and the Pedal-Owner farmers (16.7%), followed by the Thresher-Owner farmers and the Thresher-Hired farmers (13.9%). In contrast, labor productivity is lowest for Manual farmers (3.16 kg/mhr).

The thresher owners earned the highest net returns (before deducting pre-harvest labor costs), equal to 4.57 mt/ha. In contrast, Manual-Farmers, Thresher-Hired and Pedal-Owner farmers, all earned net return of 4.45 mt/ha, about 2.8% less than the Thresher-Owner farmers.

Table 5.17. Average Yield, Cost Distribution to Harvest Laborers, Machine Owner, Operator, and Labor Productivity.

Item	unit	Manual	Thresher Owner	Thresher Hired	Pedal Owner
Average yield[a]	mt/ha	5.34	5.34	5.34	5.34
Labor use	mhr/ha	282.0	227.0	212.0	249.0
Cost of harvesting and threshing:					
harvest	kg/ha	891	742.50	742.5	891
	Rp[b]	187,110	155,925	155,925	187,110
machine[c]	kg/ha	0.0	148.50	148.50	na
	Rp[b]	0.0	31,185	31,185	na
thresher operator[d]	kg/ha	0.0	24.75	24.75	na
	Rp[b]	0.0	5,197.5	5,197.5	na
Total Cost	kg/ha	891	891	891	891
	Rp[b]	187,110	187,110	187,110	187,110
Labor productivity[e]	kg/mhr	3.16	3.93	4.19	3.57
Laborer share	%	16.70	13.90	13.90	16.70
Return to land cultivator	mt	4.45	4.57	4.45	4.45

[a]Assume yield are the same across all strata (5.34 t/ha)
[b]Paddy price Rp 210./kg
[c]2.77% of the gross product
[d]0.46% of the gross product
[e]Harvest-Threshing laborer share divided by number of laborers
na: data not available
Source : Farm Survey, West Java 1990.

5.10. Cost and Return Analysis of the Engine-Powered Thresher.

Off-farm and On-farm use.

Thresher-owner farms earned income from both on-farm and off-farm use. Average on-farm use was 5.66 t during the wet season, and 6.8 t during the dry season. By using a custom charge rate (2.3%-2.7%) of the gross product, an average off-farm throughput was 57.67 t in the wet season, but fell to 65% (37.52 t/season) in the dry season (Table 5.18). This suggests that in the wet season, threshers were more in demand than in the dry season. The high demand for thresher use in the wet season was due to two reasons:a) in wet season, rice field was still wet, which made it difficult to thresh paddy. Farmers then threshed their paddy at house, b) to reduce losses due to wet field.

Total revenue in the wet season 1989 was Rp 369,728 and Rp 229,659 in the dry season. The cost associated with threshing performance include: fuel, oil, lubrication, repair and maintenance and operator cost. Based on these direct expenses, total cost of operation was Rp 170,353 in the wet season and Rp 99,958 in the dry season.

Table 5.18. On-farm and Off-farm Thresher Use in Indramayu, during Wet Season of 1989 and Dry Season of 1990.

Item	WS-89	DS-90	Total
On-farm uses (ton):			
Mean	5.66	6.81	12.47
SD	6.66	9.70	
Revenue[a]	0.16	0.18	0.34
Off-farm uses (ton):			
Mean	57.67	37.52	95.19
SD	15.33	8.23	
Revenue[b]	1.60	1.04	2.64
Total Fuel Consumed (l):			
Mean	164.53	85.89	250.42
SD	51.16	28.25	
Rp/Season[c]	77,329.0	40,368	117,697
Total Oil Consumed (l):			
Mean	2.53	2.07	4.53
SD	1.82	1.57	
Rp/Season[d]	7,590	6,210	13800
Total Lubrication (Rp):			
Rp/Season[e]	2,500	2,500	5,000
Total Repair & Maintenance			
Mean	20,4200	8,400	28,8200
SD	25,0200	13,700	
Rp/Season			
Operator Cost (Rp/Season)[f]			
Mean	61,178	38,001	99,179
SD	17,475	13,743	
Total Revenue (Rp/season)	369,728	229,659	599,387
Mean	105,612	83,060	
SD			
Total Cost (Rp/season)	170,353	99,958	270,311
Mean	44,211	36,525	
SD			

[a]Based on 2.78% of the gross output; [b]Based on 2.78% of the gross output;[c]Average price at the village level (Rp350-500)/l; [d]Average price at village level (Rp 3000/l); [e]Estimated at 1.2%/100 hr of the purchasing price (Rp950,000);[f]Based on 0.46% of the gross output* Rp210/kg.

This calculation seem to be favorable for the thresher owners. Of those total operating cost (Rp.2510/kg), 44% was for fuel cost, oil cost (5%), lubrication cost (2%), repair and maintenance cost (12%) and operators (37%). With average revenue Rp. 5567/kg, the thresher owners gained Rp.3057/kg. However, by calculating the private profitability of owning engine-powered threshers we can estimate the "real" economic performance of the investment. In this calculation, different scenarios were used to find the sensitivity of economic performance under various assumptions.

Five scenarios were used to estimate the profitability level under different price, costs and custom revenue. The price of the thresher was varied according to the price set by the rural shop (village artisan), and the manufacturers. The cost and custom revenue were set at three different values. These were at average, and with or without increase of cost and revenue. Interest rates were set at 12%, 18.5% and 24%.

Scenario 1 used the average prices, labor wages, cost and revenue during the survey period (June 1990). Scenario 2 used the estimated thresher price in 1990 (Rp. 950,000) with the 1990 costs and custom revenue. Both scenario 1 and 2 were computed at 12% interest rate. Scenario 3 based on the price of a domestically manufactured machine (Rp.1,550,000), 5% higher in cost and custom revenue, and an interest rate of 18.5%. Scenario 4 was the same as Scenario 3, but the price of thresher and revenue were assume at the 1990 level.

In scenario 5, the price of thresher (with engine) was increased to Rp 2,550,000, interest rate was 24%, and the cost and custom revenue flow increased 5% per year. The summary of this sensitivity analysis is performed in Table 5.19.

Under Scenario 1, the thresher was an attractive investment. The NPV was Rp 967,000, the Benefit-Cost Ratio (BCR) was 1.65 and the Internal Rate of Return (IRR) was greater than 50%. Under the Scenario 2, the BCR decreased to 1.40 as the price increased from Rp 675,000 to Rp 950,000. Under Scenario 3, the BCR declined to 1.06 due to a higher interest rate (18.5%), and assumed higher cost and revenue (5%). Still the IRR was greater than the opportunity of cost (28.60%). Under Scenario 4, the BCR fell to 0.98 with assumption price, interest and the cost are hold constant as about in scenario 3, but assuming no change in revenue. Under this scenario, the IRR (15.6%) was less than market interest rate (18%). Scenario 5 represents the most pessimistic scenario. If price of thresher is increased to Rp 2,550,000, the interest rate was substantially higher than the market rate (24%), and cost and benefits were 5% above the current levels, purchasing thresher was clearly unprofitable (BCR=0.83, IRR<12%)

The above analysis indicates that at current technical capacity, the profitability of engine-power thresher depends highly on the purchase price and interest rate (opportunity cost of money). The purchase price of the thresher depends upon the type (village product or manufacturers product) and the source of power. Village products are cheaper than manufacturer's product. During the survey period, village product was Rp 950,000 to Rp 1,000,000/unit, compare to manufacturer product which cost Rp 1,550,000. Unit cost (Rp/hp) of Gasoline engine was cheaper than diesel engine. From an engineering point of view the gasoline engine was relatively easy to maintain, however, it required higher fuel cost than diesel engine. If subsidized credit is available for purchasing a thresher, the thresher is quite profitable (Scenario 1). Reducing the price of threshers can be made possible by reducing the size of power source or reducing the weight of thresher. This implies that engineering research in this field is a necessity in order to generate the cost-reducing technology.

Table 5.19. Private Profitability Analysis of Engine-Powered Thresher Under Different Scenarios, Indramayu, 1990.

Item	1	2	3	4	5
Assumption:					
Price (Rp)	675,000	950,000	1,550,000	1,550,000	2,550,000
Interest Rate (%)	12	12	18.5	18.5	24
Cost	current	current	5% higher	5% higher	5% higher
Revenue	current	current	5% higher	current	5% higher
Economic Performance:					
NPV (Rp)	966,722	709,199	148,054	-43,193	-516,366
BCR	1.65	1.40	1.06	0.98	0.83
IRR (%)	>50	>50	28.60	15.60	<12

5.11. Thresher Adoption History.

Before 1975, pedal threshers were introduced into this study area, but they were not widely adopted by the farmers (Table 5.20). On the other hand, engine-powered threshers have been available since 1985 through demonstrations by extension office or promoted by dealers or distributors. Since there are a few shops available in Gabuskulon village, thresher promotion was faster in Gabuswetan subdistrict than for other villages. Farmers obtained information about threshers from various sources. Most farmers (44-74%) got information from friends or from extension workers (24-39%). Pedal owners heard engine-powered thresher information from the extension workers (93%).

Table 5.21a shows why some farmers do not buy or use a thresher. Most manual farmers claimed that they did not have enough money to buy a thresher (60%), while only a few (9%) said that threshers were not available. This answer was likely biased because there were many thresher in this village. The remaining farmers said that a thresher was not profitable (14%) or that their land was too small (17%). Thirty-six percent of the farmers did not rent a thresher because labor was still abundant.

Table 5.20. Engine-Powered Thresher's adoption history in Indramayu, West Java 1990.

Item	Manual Farmer n= 45	Thresher Owner n=35	Thresher Hired n= 42	Pedal Owner n=13
The year respondent first see /heard engine powered-thresher				
before 1985	7 (15)	8 (23)	5 (12)	3 (23)
between 1985-1990	38 (85)	27 (77)	37 (88)	10 (77)
Source of Information				
dealer	12 (27)	6(17)	1 (2)	1 (7)
extension worker	14 (31)	9(26)	10 (24)	12 (93)
friends	19 (42)	19(54)	31 (74)	na
others	na	1 (3)	na	
Where did respondent first				
see?:	22 (49)	15 (43)	25 (60)	8 (62)
field	4 (8)	8 (23)	na	5 (38)
dealer office	6 (13)	5 (14)	7 (17)	na
extension office	7 (16)	na	1 (2)	na
demonstration	6 (13)	7 (20)	9 (21)	na
other				
The year respondents first see pedal				
thresher:	18 (40)	14 (41)	15 (36)	na
before 1975	13 (29)	5 (14)	15 (36)	na
between 1975-1980	14 (31)	16 (45)	12 (28)	na
after 1980				
Source of Information:				
friends	25 (56)	20 (57)	20 (48)	na
extension worker	7 (16)	7 (20)	13 (31)	na
village artisans	8 (18)	8 (23)	7 (17)	na
Others	5 (10)	na	na	na
Where did the respondent see?				
field	25 (56)	20 (57)	20 (48)	na
demonstration	18 (40)	12 (34)	13 (31)	na
extension office	2 (4)	13 (37)	7 (17)	na

na =data not available; percentage is noted in parentheses
Source : Farm Survey, West Java 1990.

Most Thresher-Owner farms reported (Table 5.21b), that they bought a machine to make a profit (46%) and to reduce losses (43%). Thresher-Hired farms used thresher to increase work rate (93%) and to reduce losses (35%). Reducing cost was not as important as reducing losses, since only 7-12% of Thresher-Owner and Thresher-Hired farmers claimed that a thresher reduced costs. The cost analysis, however, suggested that the cost of a thresher decreased 2.78% in Thresher-Owner farms, but remained the same in Thresher-Hired farms (Table 5.17).

Finally, 63% of the thresher owner claimed that in retrospect , buying a thresher was good decision, while the rest (37%) felt it was a poor decision.

Table 5.21a. Manual-Farmer respondents' reasons for not using or buying thresher ,Indramayu, West Java 1990.[a]

Item	All Villages
Reason for not buying a thresher:	
no money	60
not available in vlg.	9
not profitable	14
too small land	17
Reasons for not renting a thresher:	
not available in vlg.	19
not available when needed	20
too expensive	25
many laborers	36

[a]not included Sukra village in Anjatan
Source : Farm Survey, West Java, 1990

Table 5.21b. Thresher-Owner and Thresher-Hired farmers' reasons for using a thresher, Indramayu, West Java 1990.[a]

Item	Thresher Owner n= 35 (%)	Thresher Hired n=42 (%)
Did respondent consult someone before buying:		
not consult anyone	9	na
family member	31	na
dealer	9	na
extension worker	6	na
other thresher owner	37	na
Reasons for using/ buying thresher:		
make a profit	46	na
reduce cost	7	12
reduce loss	43	36
faster work	4	95.1
Was buying thresher a good decision? :		
yes	63	na
no	37	na

[a] Only for engine-powered thresher, since all pedal thresher were gift from government.
na = not applicable

Source : Farm Survey, West Java, 1990.

5.12. Conclusion

Results of Farm Survey and Field Measurements

Farmers in Indramayu District, generally, have experience in using high-pay off inputs in rice production. More than 90% of survey farmers, reported that they used high-yielding varieties, fertilizers, pesticides and other chemical products to increase rice production. Irrigation water, available throughout the year in Indramayu and most in the northern coastal area, has made it possible to grow two rice crops every year, and hence increase land productivity. The rapid adoption of this bio-chemical technology, supported with irrigation facilities and government extension programs has enabled farmers to produce high rice yield.

Tractor mechanization for land preparation and rice milling unit in rice processing represented additional technological progress. During the study survey (dry season 1990) more than 90% of farmers used small tractors for land preparation and no one used hand pounding to process rice. One stimulus to this rapid diffusion of tractor mechanization was the scarcity of labor in the peak season. Another factor was the decrease in the availability of animal power for agricultural work, which was reported at 2.6% per year in 1978. Observations during the survey suggested that the rate of decrease is even higher currently.

Farms in Indramayu (and West Java), were generally very small. Sixty percent of the farms were less than 0.5 ha, 28% between 0.5 ha to 2.0 ha and only 12% were more 2.0 ha. With current population growth (2.0%), the farms in this area (and in Java) will remained small farm systems. Yet, it is nearly impossible to generate adequate on-farm income only from such small holding. It is expected, that the number of landless households will increase. The landless households earned income mostly from on-farm activities, such as planting, weeding, and harvesting and threshing. Among these on-farm sources, harvesting and threshing were the most attractive activity that provided the largest income for the landless laborers. On average, laborers from one family (husband and wife) earned about 16.7% of the gross throughput (30 to 45 kg of paddy) which was equivalent to Rp.6000 to Rp.9000 per day. Based on 1990 prices and assuming an average yield of 4.5 mt/ha/season, in Indramayu, the harvest laborers' share/1000 ha was equivalent to 751.5 t/season or 1500 t/year. This was equivalent to Rp 150 million/season or Rp 300 million/year.

New harvesting and threshing technologies that decrease the demand for labor in Indramayu or West Java will consequently reduce laborers'income. This study suggested that the use of engine-powered threshers in Indramayu has decreased the share of paddy going to harvest laborers from 16.7% to 13.9% of the gross product. However, income per laborer increased 8%, from 25.45 kg/laborer to 27.5

kg/laborer. Returns to land operator (thresher-owners) was 2.6% higher (4.57 t/ha), compared to manual, thresher hired and pedal farmers (4.45 mt/ha). On the other hand, when using an engine-powered thresher total harvest-threshing labor productivity increased from 3.16 kg/mhr for manual-farms to 4.19 kg/mhr for thresher-hired farms.

Grain losses were higher in sickle/hand-threshed system (10.8%), compare to sickle/engine-powered threshed system (9.1%). Pedal-operated thresher, according to CBS Survey (1987) can reduced by losses 0.85% compare to hand-threshed system.

Although improved threshing technologies such as pedal and engine-powered threshers were available to the farmers, the diffusion rate of this technology was much slower than for tractors. The profitability analysis of engine-powered threshers using current utilization capacity suggested that the engine-powered thresher investment was profitable (BCR>1.0) only if price was less than Rp.1,550,000.

These results suggest that slow progress in diffusing engine-powered threshers in Indramayu and West Java was due to both a social concern about reducing the harvest laborers' share to production and the low profitability of the thresher custom hiring system. Harvest-laborers frequently refused to use an engine-powered thresher, because it reduced their income. Therefore, this reduced threshing capacity utilization.

The harvest-laborers arrangements that have evolved in

Central Java and Yogyakarta provide an alternative option for increasing the diffusion of machine-threshing in West Java. In these provinces, the harvest laborers' team owns the thresher and used it to perform their work. If harvesting and threshing arrangement remain the same (16.7%), the harvest laborers received the same output. Adoption of this system in West Java would both serve to maintain laborers income and reduce losses, benefiting both farmers and harvest laborers.

Developing cost-reduction technology that does not reduce the incomes for laborers is a challenge for developing countries with labor abundant such as Indonesia. A new harvesting-threshing system alternative is needed to help farmers reduce in-field post harvest losses, while minimizing the reduction of harvest labor income. Since the price of thresher and labor wage rates are dominant variables in this system, the government policies that lead to the generation of labor-saving technology should be based upon the needs of the larger part of the rural society. Subsidies for mechanization are only justified in the short time in order to initially introduce technology so users can learn about its benefits and its contribution to overall rice production. Once the learning process has provided enough proof for the farmers, the government should let the market forces determine the rate of adoption.

Agricultural engineering research in Indonesia must be continuously working to develop a lighter thresher per horsepower or to improve existing traditional pedal thresher in order to reduce costs of threshing. From the social viewpoint, size reduction is a positive trend for the labor abundant country like Indonesia, that needs a balance between employment growth and productivity.

CHAPTER VI

MODELING AND SIMULATION

6.1. Introduction to the problem situation

Resources, Technology and Institutions

Chapters 2 through 5 discussed the relevant theory and evidence of agricultural development and their relationships to farm mechanization development in West Java, Indonesia. This discussion focused on three components of induced innovation development (resource endowment, technology, and institution) as proposed by Hayami and Ruttan (1985).

The agricultural census of 1983 revealed that farms in Indramayu, West Java are quite small. Of 200,000 farms, 79% were less than 0.8 hectares. Further, this study found small, uneven and fragmented parcels of land in a typical study area of Indramayu. With the population growing at a at a rate of 2.3% annually, and the tradition of dividing the land among the family members, the average farm size will decrease in the future.

According to census data, Indramayu has more than 210,000 landless laborers equal to 16% of its total population. The average number of landless laborers was estimated at 2.1 /ha of rice land. With no further increases in yield and therefore production, the return to the laborers will decrease, because of the natural increase in population. In this situation of scarce land resource and abundant labor, the high pay-off inputs are necessary to increase return and land productivity or labor must find other forms of employment if it is available.

The green revolution technologies offered high pay-off inputs for the farmers in Indramayu, West Java, with small land holdings. In the 1960s, they still used very traditional farming practices, including the traditional rice seed varieties, manure fertilizers, minimum pest control practices and limited irrigation facilities. These traditional practices were resource-based. This traditional agricultural technology was developed from the experiences of enthusiastic people who lacked knowledge of science and industrial technology. Accordingly, the knowledge for producing rice has been passed on verbally and by demonstration from one generation to the next (Stevens and Jabara, 1988 p.60).

By the early 1970s, the green revolution rapidly changed their rice production practices and introduced them to new scientific-based technologies. Rice yields increased from less than 2.0 t/ha in the 1960s to 5.3 t/ha by 1985. Simultaneously, the number of rice crops harvested per year increased from 1.0 to 1.5 due to improved irrigation facilities.

Even though there was an abundance of laborers in the rural area, Indramayu recorded many small farm machines in use. The number of tractors in this area was about 25% of the total West Java tractor population, where the proportion of rice area was only 9.7% of the rice area in the West Java. Other indicators of the farm mechanization level are the district's share of back-pack hand sprayers (12%), engine-powered threshers (13.3%), small irrigation pump (19.5%) and rice milling machines (7.3%).[15]

During the 1970s, the small scale rice mechanization and its economic consequences were the main issues of rice mechanization development in Indonesia, especially in West Java. Sinaga (1977), argued that the rapid diffusion of small-scale mechanization was the result of the capital-labor distortions caused by the large subsidies for farm mechanization.

Yet, the adoption of farm machines has been encouraged through extension and demonstration, and diffused rapidly from farmer-to-farmer through their learning experiences. Factors contributing to the rapid diffusion of tractors were the decreasing numbers of traction animals, and a shortage of laborers for land preparation during the peak season.

The rapid increasing of small tractor mechanization in West Java suggests that wages for laborers increased over time. The Agro-Economic Survey (1988)[16] reported that in

---

[15]Number in parentheses represent the percentage of total number of West Java farm machines.

[16]Center of Agro Economic, personal communication, 1989.

West Java from 1980 to 1987, the nominal wages for laborers in land preparation increased at 17 % per year.[17] Assuming that the share of the harvest laborers in Indramayu held constant at 16.7% of the gross output, and the yield increased due to the progress of technology development, the harvesting wages (including threshing) increased at 9.9 %, annually[18].

In 1985, a government program introduced an improved threshing method using plastic sheets to minimize scattered grain. In 1986, a few farmers, who farmed at least 1.5 hectares of rice land, adopted small engine powered threshers. These small machines were manufactured locally, either by domestic manufacturers or by local black-smiths. Compared to the Japanese design, these domestic machines were cheaper.

These great changes in rice production and agricultural mechanization were the results of complex national efforts, involving the interaction of many different policies and activities of government agencies (Timmers, 1985). Furthermore, Robinson *et al*. (1987), indicated that the key factors in these dramatic changes were transfer of technologies, selection and provision of inputs, training

---

[17] General Price Index between 1981 to 1988 increased from 534.1 to 1242 indicated the average annual increase of 12.5%.

[18]Harvest laborers wage share , WAGE (t) is estimated of 16.7% of yield at year (t) multiplied by price of paddy at year (t). The growth is calculated as GROWTH= ((WAGE(t)-WAGE(0))/WAGE(0) *100%

and education for farmers, development of infrastructures, and pricing and marketing strategies.

This study survey in the dry season of 1990 in Indramayu, West Java, revealed that in the wet season of 1989, thresher utilization was 63.33 mt/thresher with a standard deviation of 11.8 mt. In the dry season 1990, utilization decreased to 44.33 mt/thresher with a standard deviation of 9.0 mt. The custom charge for threshing was about 2.78% of the gross output or about Rp.4850/mt, while the wage for the operators (2-3 men per machine) was about 4.6 kg/mt of the gross output. Common harvesting and threshing costs in West Java varied between 10.0% to 16.7% of the total gross output. Assuming that grain losses were not computed in the calculation, the percent paid to harvest laborers was reduced from 16.7% to only 13.9% of the gross output for farms using engine-powered threshers. For farms using manual methods and pedal-operated threshers, the amount of the harvest shared remain constant (16.70%). However, the survey showed that the return to land owner, was 2.7% higher on thresher-owner farms, than on manual, thresher hired or pedal-operated thresher farms.

Under current utilization levels, subsidized interest rates, and the average price of Rp.650,000, thresher investment is profitable with a Net Present Value (NPV) of Rp.966,000 annually and a Benefit Cost Ratio (BCR) of 1.65. However, by altering the price, the opportunity cost of money, and the utilization levels of threshers, the economic performance of threshers decreased. At Rp.950,000, the NPV of threshers decreased to Rp.709,000 and the BCR decreased to 1.40. At an intermediate price of Rp.1,550,000, an 18.5% interest rate and 5% increase in costs and benefits, the NPV decreased to Rp.148,000 and the BCR to 1.06. Furthermore, figuring the most pessimistic situation (at the highest possible prices, a 24% interest rate and 5% change in cost and benefits), threshers would not be profitable.

The traditional harvesting and threshing system requires a total of 35 laborers/ha. When the thresher was adopted, 26 to 28 laborers/ha were required, a 20% reduction. Farmers in Indramayu very rarely used pedal threshers, unlike farmers in Central Java. At the time of this study only two options existed, hand threshing or engine-powered thresher methods. However, the pedal thresher appears to be a possible alternative, if improvement were made in both its design and its utilization management.

Farm survey and field measurements suggest that there were significant grain losses during the field harvesting and threshing operations. Harvest losses contributed 6.3% of the pre-harvest yield and threshing losses contributed to 2.8 to 4.5% . Although farmers are aware of these field losses, they do not pay much attention to them. The in-field loss of harvesting and threshing varied according to the method used. Sickle-Harvesting and Hand-Threshing systems produced total losses of 10.8% of the pre-harvest yield, while Sickle-Harvesting and engine-powered threshing systems produced losses of 9.1% of the pre-harvest yield.

Previous post-harvest surveys in 15 provinces revealed that harvest loss ranged from 8.4% to 10.8% depending on location, rice variety, method of harvesting, and harvest time (CBS and MOA, 1987). The survey also showed that threshing loss ranged from 4% to 6.4% depending on the rice variety, and method used.

The study observed that the post-harvest equipment provided as a grant to the farmers was under utilized. There was an indication that in Gabuswetan village, and most probably throughout Indramayu District, the demand for engine-powered threshers was lower than the grantee expected. Although the special offer was made to the farmers to adopt and use the engine-powered threshers without purchasing them, only a few farmers agreed to accept this offer (Diperta Indramayu, 1990)[19]. Furthermore, the grantees apparently faced difficulties in maintaining the minimum utilization level, because many people still used the more laborious traditional methods, which provided the greatest income for the laborers. Finally, estimates of seasonal capacity utilization suggested that in the dry season, the off-farm capacity only reached 65% of the wet season.

The engine-powered thresher had a positive contribution to yield by reducing grain losses at least 1.7% below the traditional method. Other benefits accrued to the engine-

---

[19]Personal communication with Diperta Staff during the survey (July, 1990)

powered thresher were that it increased labor productivity and return to thresher-owner (2.75% higher than non thresher-owners) and reduced cost of total harvesting (including threshing) by 2.7%.

The previous studies (JICA, 1987; FCRC, 1988) revealed that the labor-contractual systems in harvesting (*gropyokan* and *ceblokan* systems) contributed significantly to total losses. In the *gropyokan* (open harvest system), the losses were due to the uncontrollable number of laborers working in the field. The ceblokan system seemed to reduce total losses by limiting the number of harvest laborers participating in the operation. However, Hayami and Kikuchi (1981) estimated that the harvest-laborer share of total production decreased if weeding and planting times were imputed into their wages. The change in the harvesting system in a village in West Java suggested that the shift from *gropyokan* to *ceblokan* increased exponentially overtime with $R^2 = 0.98$.

A change in harvesting-threshing technology in a village in Indramayu, West Java, is likely to induce change in the institutional arrangement between the owner operator and the harvest laborer. Hayami and Kikuchi observed that the *ceblokan* system applied in a village in West Java reduced the number of harvest laborers and allowed only laborers inside the village to participate in the harvest operation. This study, however, suggests that the use of engine-powered threshers induced the owner to rearrange the harvesting and threshing wages. The total costs of harvesting remain the same, 16.7% of the gross output, but the laborers have to pay 1/6 of this part for threshing costs. This rearrangement reduced the share of laborers from 16.7% to only 13.9% of the gross output.

Based on the problems identified, an appropriate threshing technology should meet the following criteria:

1). A rice threshing mechanization system is required for the small farmers in West Java.

2). The system should include an optimum size thresher which can be owned and operated by an individual farmer or by a group of farmers, and used by other farmers through a hiring system contract.

3). The system must be profitable, or at least operate at its break-even level under the existing custom rate and labor arrangement system.

4). The system must produce fewer grain losses than those by the current traditional losses.

5). The system also should maintain the laborer income and use as much as possible for a labor-saving technology, until a significant increase occurs in the cost of labor relative to capital.

6.2. The Conceptual Model

The general concept of the model is illustrated in figure 6.1. This conceptual model was developed to represent the actual harvesting and threshing system in West Java. The objective of this model is to indicate the model components, the linkages between components and the objectives or performance measures of the system model. This model includes the following variables:

1). Population, 2). Crop 3). Technology, 4). Government Policies, 5). Institution 6). Culture, 7). Weather/Irrigation, and 8). Rice land available. Each of these variables are represented by a circle, and the linkages are represented by arrows.

Population provides laborers to crop production activities. Weather and Irrigation facilities are major factors affecting the rice land area. They determine the cropping pattern and its harvesting schedule. The government plays an important role on price of technology (seed, fertilizers, pesticides, tools and equipment) through credit, subsidies, tariff and import taxes. Institutional arrangement in harvesting and threshing, land ownership pattern, farmers associations, dealership and other and cultural behavior also contribute to the acceptance and diffusion of harvesting and threshing technology. These components link together to produce rice yield, crop losses and total rice production. The performance measures of the system include: a) system costs, b) labor utilization, c) system capacity, d) system losses, and e) income or return to laborers and land operators.

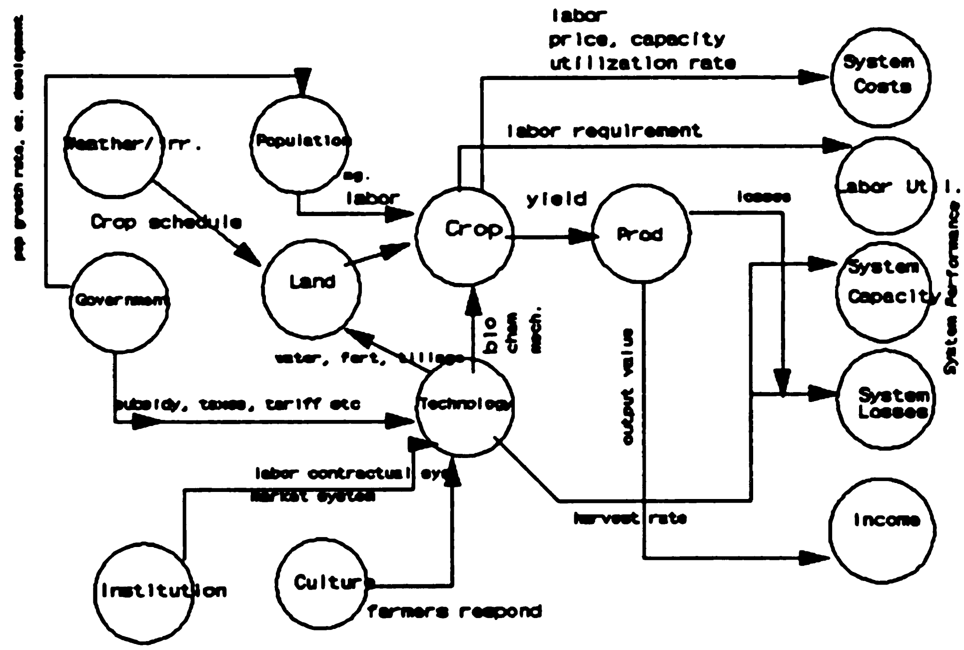


Figure 6.1 Conceptual Model of Harvesting-Threshing Technology in West Java, Indonesia.

The simulation model was also developed to determine the system behavior by altering system components one at a time. The simulation model was also useful to determine the most sensitive component to the system. To determine the objectives of the system model. Four subprograms were developed as follows:

1. Subprogram OPTIM determines the optimum size of the thresher, fixed costs, operational costs, system costs and system hours and the least cost system . This subprogram is based on inputs such as price, labor wages, working hour, threshing capacity, and fuel, oil and repair and maintenance costs found in the farm survey. This program, written in FORTRAN language, was developed by Gupta and Sing (1986) and applied for West Java situation.
2. Subprogram BENCOS that was developed in this study, generates the cash flow for the optimum size of thresher, computed by subprogram OPTIM. A Monte-Carlo method is applied in this program, using the statistical parameters estimated using survey data (means and standard deviation of variables such as seasonal off and on-farm income). The Net Present Value (NPV), Benefit Cost Ration (BCR) and Internal Rate of Return (IRR) are the specific outputs of this subprogram.

3. Subprogram SEAVAL produces a seasonal distribution of harvest rate, production rate, and the required number of harvest laborers[20]. SEAVAL also can be used to estimate the demand for threshers. This program requires inputs such as yield, starting and ending dates of harvest, total area of harvest, and harvest labor rate (persons/t). Subprogram SEAVAL is used to estimate the total product harvested, in-field grain losses, total labor used and required.
4. Subprogram LABOR produces labor supply estimates upon population parameters such as birth rate, death rate, age and gender distribution, and the labor force participation rate. A BOXC-TRAIN sub-program as introduced by Manetsch (1989) was used to facilitate the labor generation, and supplied to the SEAVAL sub program to compare the labor seasonal requirements.

[20] Seasonalization will be generated by SEAVAL subroutine as introduced in Manetsch (1986).

6.3. SUBPROGRAM OPTIM:

The optimization program, developed by Gupta *et al.* (1986), was applied to determine the optimum size of threshers based on the annual cost equation using the optimization technique developed by Hunt (1977). The annual cost of threshing includes fixed costs and variable costs which vary with thresher capacity (CAPTH) in term of mt/hr. It is assumed that price of thresher proportional to the size of thresher. Depreciation was determined by using the straight line method. Since insurance, shelter, and tax are not commonly considered in Indonesia, these components were not considered in the equation. Rewriting the mathematical formula developed by Singh and Gupta, the cost components are as follows:

1. Depreciation cost per year:

$$DEP=\frac{PUCTH*CAPTH*(1-SVF)}{ELTH} \quad (17)$$

where :

DEP = Depreciation in (Rp/year)

PUCTH = Price per unit capacity of thresher (Rp/(ton/h)

CAPTH = Threshing rate (t/h)

ELTH = Expected life time of thresher (years)

SVF = Salvage Value Factor of Thresher (decimal)

2. Interest Cost per year:

$$IRT=\frac{PUCTH*CAPTH*(1+SVF)}{2}*IR \qquad (18)$$

Where :

IRT = Cost of Interest per year (Rp/year)

IR = Interest rate per year (decimal)

3. Labor Cost per year:

$$LABOR=\frac{AUC*YC}{CAPTH}*LCTH \qquad (19)$$

where :

LABOR = Labor cost (Rp/year)

AUC = Area under crop (ha)

YC = Harvested Yield of Crop (t/ha)

LCTH = Total labor cost of threshing, (Rp/h)

4. F

Whe

FUE

ETH

EPT

SFC

PFU

5.

Wher

OIL

CRPS

POIL

4. Fuel Cost per year:

$$FUEL=\frac{AUC*YC}{CAPTH}*\frac{ETH*CAPTH}{EPTS}*SFCPS*PFUEL \quad (20)$$

Where:

FUEL = Fuel Cost per year (Rp/year)

ETH = Energy required for threshing operation (kWh/t)

EPTS = Efficiency of power transmission system (decimal)

SFCPS = Specific Fuel Consumption of power source (l/kWh)

PFUEL = Price of Fuel (Rp/l)

5. Oil cost per year :

$$OIL=\frac{AUC*YC}{CAPTH}*\frac{ETH*CAPTH}{EPTS}*\frac{SFCPS*ORPS*POIL}{100} \quad (21)$$

Where :

OIL = Oil Cost (Rp/year)

ORPS = Oil requirement of power source, expressed in % of fuel consumption

POIL = Price of oil (Rp/l)

6. Re

Wher

RAM

RMFT

7. P

P

powe

engi

Where:

PSC

PSCPH

determ

6. Repair and Maintenance Cost (RAM) per year:

$$RAM=\frac{AUC*YC}{CAPTH}*\frac{RMFTH*PUCTH*CAPTH}{10000} \tag{22}$$

Where:

RAM = Repair and Maintenance Cost (Rp/year)

RMFTH = Repair and Maintenance factor for thresher, expressed as % of purchase price per 100 h of operation.

7. Power Source Cost per year:

Power source cost determine the cost of engine which powered the threshers. The power source may be gasoline engine or diesel engine.

$$PSC=\frac{AUC*YC}{CAPTH}*PSCPH \tag{23}$$

Where:

PSC = Power Source Cost (Rp/year)

PSCPH = Power source cost per hour (Rp/h), which is determined as follows :

$$PSCPH=\frac{(PPS*(\frac{(1-SVF)}{ELPS}+\frac{(1+SVF)}{2}*RI)}{AUPS}+\frac{RMFPS*PPS}{10000} \quad (24)$$

Where:

PSCPH = Power Source Cost (Rp/hr)

AUPS = Annual use of power source (h/year)

PPS = Price of power source (Rp)

ELPS = Estimate life of power source (year)

RMFPS = Repair and Maintenance Factor of Power source, (decimal)

9. Timeliness Cost per year:

$$TMLNS=\frac{AUC*YC}{CAPTH}*\frac{YLTH*AUC*YC*PC}{(WHDTH*2)} \quad (25)$$

Where:

TMNLS = Timeliness cost (Rp/year)

YLTH = Yield loss due to delay in threshing operation, (kg/kg-day).

WHDTH = Working hours per day for threshing operation (h/day)

PC = Price of crop (Rp/mt)

The sum of the cost components derived from Equations 1

through 9 is the annual cost of a thresher subject to CAPTH as follows:

10. Annual cost of thresher :

$$AC=f(DEP, ITR, LABOR, FUEL, OIL, RAM, PSCPH, TMLNS) \quad (26)$$

Since all cost equations are subject to CAPTH, the optimum size of thresher can be determined as follows:

$$\frac{d(AC)}{d(CAPTH)}=0 \quad (27)$$

therefore :

$$(CAPTH)_{opt}=(AUC*YC*(LCTH+PSCPH+YLTH*AUC*YC*PC*\frac{0.5}{WHDTH})^{(0.5)}$$

$$*(PUCTH*\frac{(1-SVF)}{ELTH}+(1+SVF)*(\frac{RI}{2}))^{(-0.5)} \quad (28)$$

In order to find the Break-even level of the threshing operation when compared to the custom rate of threshing

(traditional system), the thresher must work for a given time period. The minimum working period was determined as follows:

$$WHRC=\frac{(AFC-AUC*YC*(CRTH-OCTH))}{(CAPTH*(CRTH-OCTH))} \quad (28)$$

Where:

WHRC = minimum working hours of the thresher for custom work to make the cost of threshing at least equal to custom rate (traditional threshing), (hr/year)

AFC = Annual fixed cost of thresher (Rp)

CRTH = Custom rate of thresher (Rp/t)

OCTH = Operating cost of thresher (Rp/t)

Selection procedure and program logic for optimum selection of threshing system are shown in Figure 6.2.

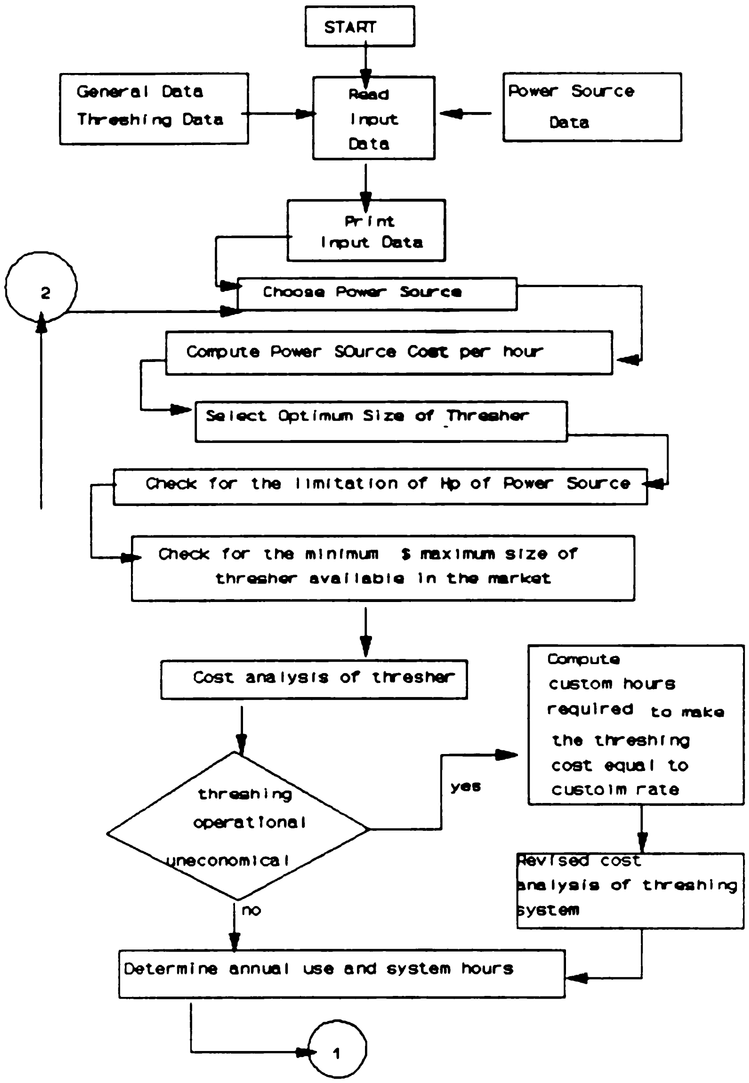


Figure 6.2. Selection Procedure and Program Logic for Optimum Selection of Threshing System (Adopted from Gupta *et al.* 1986).

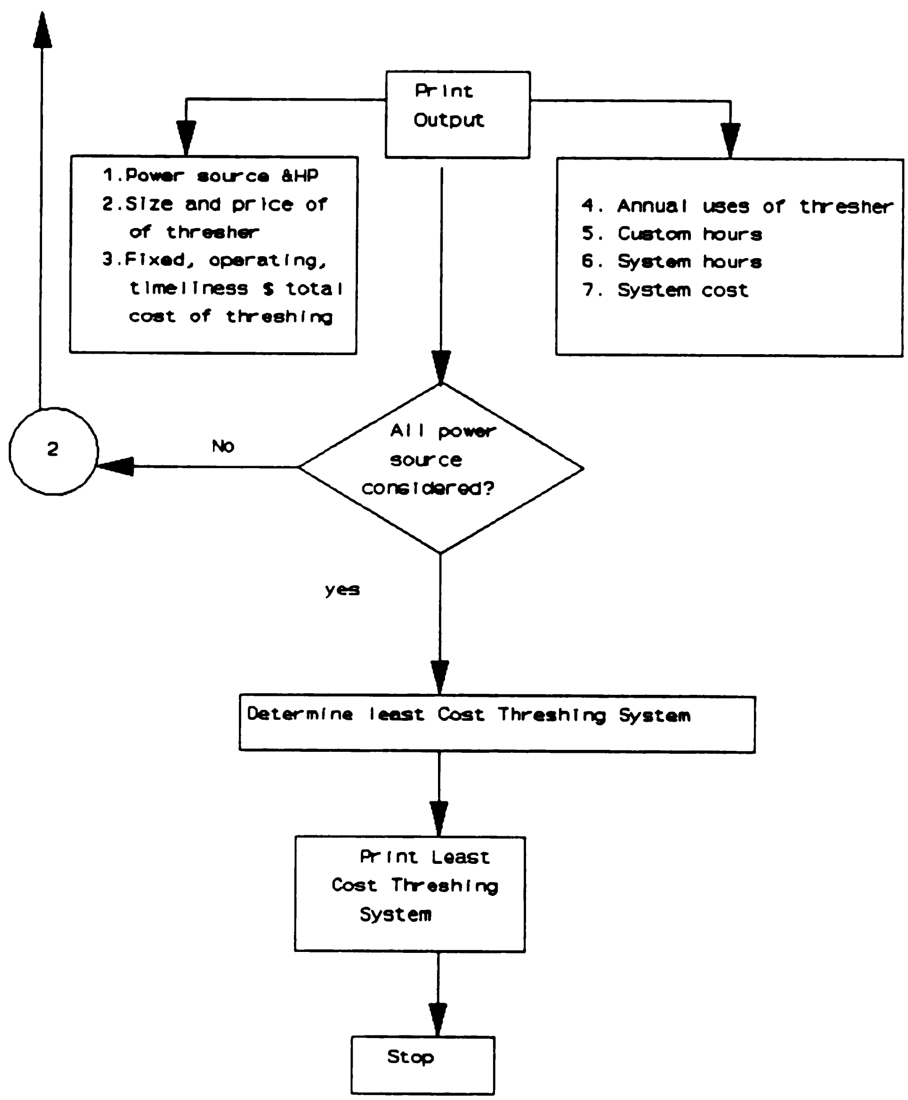


Figure 6.2. (Cont'd)

6.4. SUBPROGRAM BENCOS

Once the optimum size has been determined, the profitability of each threshing system will be evaluated based on the actual capacity of the thresher (the off- and on-farm thresher utilization). The specific subprogram called BENCOS was developed to perform the cash-flow analysis of optimum size thresher.

The Central Limit Theorem of statistics states that the probability distribution of a variable which is the sum of a number of other variables approach the normal distribution as the number of variables in the summation increases (Manetsch, 1989). Post-harvest study by Ilangantileke (1978) assumed that labor availability for harvesting operation followed a normal distribution. The farm survey of this study used sample size of 35, a sufficient size for normal assumption. Based upon these assumptions in the subprogram BENCOS, the flow of benefits and costs will also follow a normal distribution (Gaussian). It is assumed that variability of off-farm and on-farm utilization are affected by weather, demand for thresher and the reliability of thresher. These seasonal variations are represented by their means and standard deviations. The probability density function of the normal distribution is given as,

$$f(x) = \frac{1}{\sqrt{(2*\sigma_x^2)}} * e^{\frac{-(x-\mu_x)^2}{2*\sigma_x^2}} \tag{30}$$

Where, μ_x = the mean or expected value of the random variable X and

σ_x = the standard deviation of X

The following method was used to compute normal random variables with a specified mean and standard deviation (Manetsch, 1989).

1. A uniform random variable (0,1) was generated using function RAND provided by MS-FORTRAN
2. A standardized normal random variable Y_i was generated where,:

   Y_i = FNL (NMLVAL,0.,.025,40,R_i)
3. FNL is a sub program which constructs a piecewise linear approximation for the inverse normal cumulative distribution function, using the array NMLVAL. The array NMLVAL contains the ordinates of the inverse normal cumulative distribution, (Manetsch and Park, 1989).
4. A normal random variable X_i was computed with the desired mean μ_x and standard deviation σ_x from equation (31).

The standardized random variable was transformed into a normal variable having a desired mean and standard deviation using equation (31) as follows:

$$X=\sigma_x * Y_i + \mu_x \tag{31}$$

where variables μ_x and σ_x are the mean and standard deviation of variables that derived from the farm survey in Chapter V. The sum of on-farm and off-farm utilization was made equal to X_i and convert to REV of the main program. REV and OPCOST, the revenue and cost of operation were computed by equations (32) and (33),

$$REV=((SDTONS*Y_i)+ATONS)*CCHARGE*PC \tag{32}$$

$$OPCOST=((SDTONS*Y_i)+ATONS)*OCTH \tag{33}$$

where,

REV	=	Total revenue generated from on and off-farm utilization of thresher (Rp/year)
OPCOST	=	Operational Cost per year (Rp/year)
SDTONS	=	Standard Deviation of annual thresher utilization

ATONS = Average annual utilization of thresher (tons/year)

CCHARGE = Actual custom charge for using thresher (percent of thresher capacity, kg/tons)

PC = Price of Rice (Rp/ tons)

Y1 = Standardized random variable generated by function RAND

OCTH = Operating cost (Rp/t)

6.5. Seasonal Distribution of Harvesting.

The seasonal output of rice production is generated by a function subprogram called SEAVAL. The output is harvested at different points of time during the harvesting period and has significant implication upon labor demand as well as on employment (Haque, 1977; and Korean Agricultural Sector Study Team, 1972) as shown in Figure 6.3.

Mathematically, output is distributed over the harvesting time period by a function sub-program called SEAVAL[21]. The curve in Figure 6.3 represents the harvest rate at different times of the harvest between the starting time T1 and the ending time T2. The mathematical function is generated is such a way as to make the area under the curve between T1 and T2 equal to the output and equal to zero elsewhere. The conservation flow concept is used in

---

[21]The mathematical function SEAVAL is derived as
SEAVAL= D*(1-Cos(W.t)
where D = 1/(T2-T1) and W = 6.28319
(Manetsch, 1989; Haque, 1977)

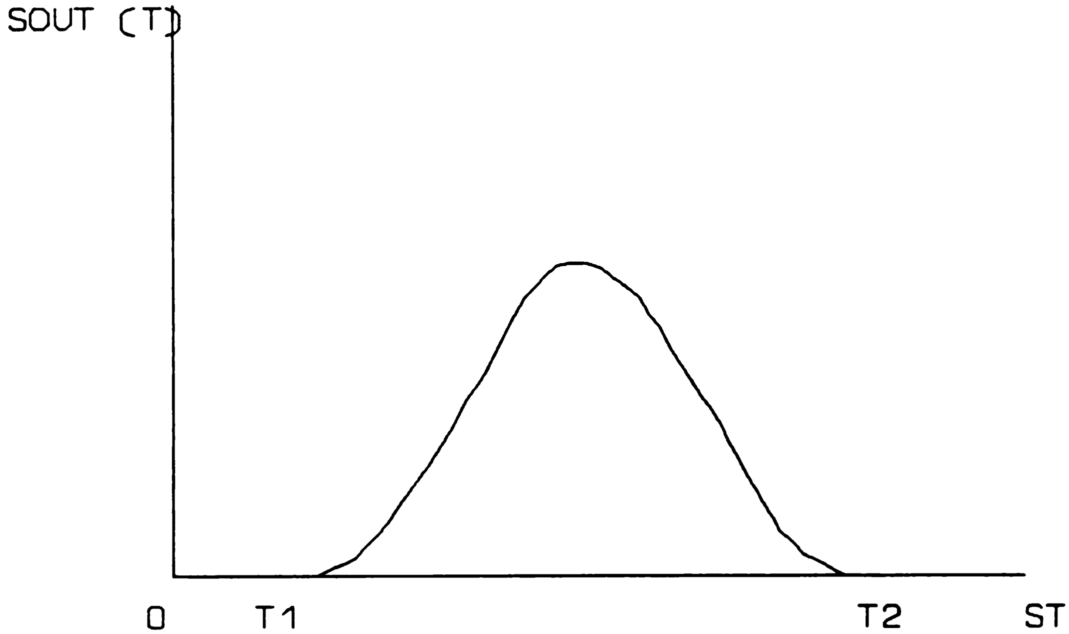


Figure 6.3 Seasonal Distribution of Harvest

this approach.

The harvest rate at time t is equal to a seasonal harvest output (SOUT) and mathematically defined as:

wher

ocr

fol

S

$$SOUT_t = OUT * SEAVAL \tag{34}$$

where;

OUT = desired yearly output (ha)

SEAVAL is a seasonal output that generated by the following function subroutine (Manetsch, 1989):

```
          FUNCTION SEAVAL (ST,T1,T2)
          IF (ST.LE.T1) GO TO 1
          IF (ST.GE.T2) GO TO 1
          T =ST-T1
          D = (T2-T1)
          W =6.28319*D
          SEAVAL = D* (1.-COS(W*T))
          GO TO 2
  1      SEAVAL =0.
  2      CONTINUE
         RETURN
         END
```

where,

T1 = starting time of harvest

T2 = ending time of harvest

ST = 1, it indicates the distance between Jan 1 to Jan 1 of the following year (one year)

The rate of output is then calculated using Equation (35) as follows:

$$ROUT(t) = SOUT(t) * YIELD \tag{35}$$

ROUT = Rate of output (t/dt), and dt is a small incremental time that set to be 0.01 or equal to a half week. One year is equal to 100 dt.

SOUT = Seasonal output (ha/dt)

YIELD = Yield of rice (t/ha)

The number of laborers required for harvesting is equal to the rate of output (t/dt) multiplied by the unit of laborers (person/t), as follows:

$$RLABOR(t) = ROUT(t) * LABYLD \quad (36)$$

Where,

RLABOR = Number of people required for harvesting at time dt

$$BLABOR(t) = AGLAB(t) - RLABOR(t) \quad (37)$$

where,

AGLAB(t) = Number of people available for labor during rice harvest at time dt

ABYLD = Labor per unit of product (person/t)

BLABOR = Number of people unused (unemployed) at time dt (people)

AGLAB (t) was computed by LABOR subroutine or by using the statistical data available.

The starting time and ending time of harvest were set based upon the harvesting schedule found in the farm survey. Data input used for simulation was derived mainly from the information taken from the farm survey and other data that applied to the region.

6.6. Labor Supply Model.

The human population is modeled to estimated the supply of harvest laborers based on age, gender distribution, and percent of labor participation in agricultural work. This model was designed for Indramayu districts. A subroutine called BOXC (Llewelyin, 1966) was used to facilitate the population model. This BOXC Subroutine is written in a FORTRAN code as follows:

```
    CALL BOXC(TBRTH,BOUTFM,POPFM,NCOUNT,NOCY,LT,SUMIN)

     -----

    SUBROUTINE BOXC(BINR,BOUTR,TRAIN,NCOUNT,NOCY,LT,SUMIN)
    DIMENSION TRAIN(1)
    NCOUNT = NCOUNT + 1
    SUMIN  = SUMIN + BINR
    IF (NCOUNT.NE.NOCY) GO TO 1
    BOUTR =TRAIN(1)/FLOAT(NOCY)
    DO 3 I =2,LT
 3  TRAIN (I-1) = TRAIN(I)
    TRAIN(LT) =SUMIN
    SUMIN =0.0
    NCOUNT =0
 1  RETURN
    END
```

The initial values of NCOUNT and SUMIN were set equal to zero. The actual arguments in the CALL statement are TBRTH, BOUTFM, POPFM, NCOUNT,NOCY,LT,SUMIN and the formal arguments in the SUBROUTINE statement are BINR, BOUTR, TRAIN, NCOUNT, NOCY, LT, and SUMIN. TBRTH is the input rate, BOUTFM is the output rate, and POPFM is the array of population, LT is the length of population array.

The population was arranged by each 2 years age cell from 0 to a maximum 80 years old (0-1,2-3,4-5,6-7, ...79,80), therefore, LT was equal to 40. The NOCY variables is the number of simulation cycles per index or update. In this model, the population will change every 200 cycles or every 2 years.

The population parameters such as birth rate, death rate, sex and age distribution, and the estimated percent of the population active in agriculture, were estimated from national population data published by the Central Bureau of Statistics. The minimum age for laborers was set to be 15 and the maximum age of laborers was set to be 64. This assumption followed the population parameters defined by the World Bank (World Bank, 1988).

6.7. MODEL INPUTS

6.7.1. Input for OPTIM subprogram

Input data required for the OPTIM subprogram were arranged as follows:

1. **General Data :**

   a. Area under crop, assuming that all land area is under double rice cropping per year.

   b. Yield of rice crops (Tons/ha)

   c. Interest rate (decimal)

   d. Estimated salvage value, as a portion of the purchase price (decimal)

   e. Shelter charge (assumed as 0 for West Java case)

2. **Thresher Data :**

   a. Price of per unit capacity of threshers (Rp/ton-hr).

   b. Minimum thresher capacity available on the market (tons/hr).

   c. Maximum thresher capacity available on the market tons/hr)

   d. Type of thresher

   e. Maximum annual utilization of thresher (hr/year)

   f. Expected life time of thresher (years)

   g. Energy required per ton of paddy (Hp-hr)[22]

   h. Labor cost for threshing (Rp/hr)

[22] Adopted from study conducted by Ramos (1981).

i. Repair and maintenance factor (decimal)

j. Timeliness Cost Penalty (Kg/ton-day)

k. Custom rate of threshing (Rp/ton)

3. **Power source data:**

a. Power source name

b. Horse power of power source (HP)

c. Price of power source (Rp)

d. Expected life time of power source (years)

e. Annual utilization of power source (hours)

f. Rate of insurance of power source (decimal)

g. Repair and maintenance factor as a portion of the purchase price (decimal)

h. Specific fuel consumption (l/hr)

i. Oil consumption factor (decimal)

j. Price of fuel (Rp/l)

k. Price of oil (Rp/l)

l. Efficiency of power transmission (decimal)

The following are the outputs of the model:

1. Optimum size of thresher (ton/hr)
2. Price of Thresher (Rp)
3. Fixed Cost of Thresher (Rp/year)
4. Operating Cost (Rp/year)
5. Timeliness cost (Rp/year)
6. Cost of Threshing (Rp/ton)
7. Annual Utilization (hr/year)

8. Working hour required (hr/year)
9. System Hour (hr/year)
10. System Cost (Rp/year)

6.7.2. Input for BENCOS subprogram:

Inputs required for BENCOS subprogram are as follows:

1. Total Investment (Rp)
2. Interest rate (decimal, 0.12 to 0.30)
3. Price of thresher (Rp)
4. Price of engine (Rp)
5. Expected service life of thresher (years)
6. Expected service life of power source (years)
7. Custom charge per ton (decimal, 0.01 -0.04)
8. Fuel price (Rp/l)
9. Operator Cost (Rp/t)
10. Oil price (Rp/l)
11. Price of paddy (Rp/t)
12. Interest rate alternative (for IRR calculation)
13. Number of simulation (integer minimum 1)

Outputs of the BENCOS subprogram:

1. Thresher utilization in Wet Season (ton)
2. Thresher utilization in Dry Season (ton)
3. Annual Utilization of Thresher (ton)
4. Net Annual Benefits (Rp)
5. Net Present Value (RP)
6. Benefit Cost Ratio (Decimal)

7. Internal Rate of Return (%)
8. Average and Standard deviation of (1) to (7)

6.7.3. Inputs for the LABOR subprogram:

The following were inputs for the Labor subprogram:

1. Birth rate (0.0xx) of female 15-24 years old
2. Birth rate (0.0xx) of female 25-34 years old
3. Birth rate (0.0xx) of female 35-45 years old
4. Death rate (0.00x)
5. Number of simulation years (integer)
6. Time increment (DT =0.01)
7. Percent of agricultural labor force to total labor force (decimal)

The following were outputs of the labor simulation:

1. Number of population
2. Number of labor force (15-64 years old)
3. Growth rate of population age 15-64 years old
4. Growth rate of non-agricultural labor force
5. Number of agricultural labor force
6. Number of non-agricultural labor force
7. Percent of agricultural labor force
8. Percent of non-agricultural labor force

6.7.4. Inputs for the SEAVAL subprogram

The following were inputs for SEAVAL subprogram:

1. Maximum and minimum rice area in wet season (Ha)

2. Maximum and minimum rice area in dry season (ha)
3. Rice yield in et and dry season
4. Number of thresher in a village
5. Estimate growth rate of thresher (decimal)
6. Estimate number of laborers available in village (person)
7. Estimate growth rate of laborers (decimal)
8. Number of simulation

Outputs of the simulation were:

1. Rate of harvest on day-t (Ha)
2. Rate of production (tons)
3. Portion of rice harvested and threshed by manual method
4. Portion of rice harvested by threshed by powered threshers.
5. Total harvest losses (including threshing)
6. Labor required on day-dt
7. Number of thresher required on day-dt
8. Number of labor unused.

6.8. Model Validation

The computer simulation model has been subjected to various tests to ascertain its validity. The reason for conducting such tests is to examine how well the model simulates the interacting variables to represent the real system that it is supposed to represent. Tests of the model are intended to evaluate its logical, consistency, reasonableness and workability. The model was subjected to these tests in order to establish confidence in its ability before its applications.

Major difficulties in validation appeared when attempting to compare the results of simulation with the future output or the past behavior of the model, because of the limitation of the data and unknown future. The validation tests (verifications of the simulation model) in this study have to be based upon information that is available and related to the system model.

The methods used in this validation were primarily intuition and judgement, like the techniques applied by Haque (1977). Expertise in the study field is needed to justify that the model is reasonable and consistent (Manetsch, 1989). In this respect, the author's personal work experience gained through long association with the agricultural mechanization in West Java, and Indonesia generally, will help to justify the tests.

The second method used to validate the model was to compare the simulation output with historical information. For this purpose, published resources of secondary data were particularly helpful in tracking the time series.

The third method used statistical analysis to the extent that available data was adequate to conduct appropriate statistical test. A t-test was performed to verify significant different between the model and the farm survey.

Finally, a sensitivity analysis was conducted to test th

va

mo

is

Va

G

i

f

i

v

t

the consistency of the model. The objectives were to validate the consistency of the model and to determine the most dominant input variables for which more accurate data is needed (Haque, 1977).

Validation of Optimization Model

In this model, an optimization technique developed by Gupta and Singh (1987) was applied. Intuition and judgement is applied in this validation test since the model was not a function of time (not based on time series data) rather, it is a result of mathematical computations using several variables. To test the logical and consistency of the model, the best reference was the original results of a similar model developed by Gupta and Singh. The trend in the result produced by this model were similar to the results found by Gupta and Singh who applied the model for wheat. The application of the model to West Java indicate that the small thresher (0.5 t/hr) is the most feasible technology. The model consistently selected only thresher available in the market (0.5 -1.5 t/hr). The maximum size of thresher was 0.84 t/hr. The model selects only thresher that fall in the feasible range. The results indicated that if the cost of operation was greater than the custom rate, and the working hour exceeded the maximum annual working hour (300 hr), it will be drop from the selection.

Validation of the Model Uncertainty using Monte Carlo technique.

The uncertainty associate with the level of threshing custom work was predicted using Monte Carlo method. This method produced statistical estimates of the seasonal and yearly thresher utilization. The results were compared to the empirical results drawn from the survey. The numbers in the last two column indicates a statistical t-test. It indicates that no significant different between the survey and the simulation at $\alpha=0.05$. The summary of test is shown in Table 6.1.

Table 6.1. Statistical test of the model uncertainty.

Season	Farm Survey[a]		Model[b]		t values $\alpha=0.05$	
	Mean (t)	SD	Mean (t)	SD	observed	table
Wet Season	63.3	11.8	63.76	27.4	0.099	1.645
Dry Season	44.3	9.0	44.9	6.8	1.137	1.645

[a]: Computed for n =35 (survey sample)
[b]: Run with n =100 (simulation)

The test also proved that Monte Carlo technique worked well in this simulation, therefore can be used to predict the uncertainty of the economic performance of threshing operation.

Validation of the Seasonal Distribution Model.

The mathematical function SEAVAL, which distributed the total harvest output over the entire harvest period, was applied in this seasonal model. If SEAVAL is working properly, the cumulative output of the harvest must be equal to the product of harvest area and the corresponding yields. The results summarized in Table 6.2 indicate that the output of seasonal distribution were consistent.

Table 6.2. Seasonal Distribution of Harvest Output[a]

Season	SEAVAL	AREA * YIELD	Deviation
Wet Season (t)	66096.7	66098.5	1.8
Dry Season (t)	38541.7	38542.5	0.8

[a]: Sample was taken from Gabuswetan village with total area of 12378 Ha in the wet season and 8565 Ha in the dry season.

The above results indicate that SEAVAL worked correctly. The deviations shown in this table are small and insignificant. These results suggested that the simulated harvest pattern was similar to the actual harvest pattern in Gabuswetan village. In every year, the peak wet season harvest falls in March and the peak dry season harvest falls in July.

Population and Labor Supply Model

Population and Labor Supply models were simulated using a BOXC subroutine (Manetsch, 1989). This subroutine predicts a population pattern that will change as a function of the natural birth and death rates. The population system will be affected by its age and gender composition at the initial period. Since the historical data describing details of the age and gender composition is very limited, the 1988 data for Indramayu district was used.

The result of 20 years simulation indicates that the model consistently followed the pattern common to population model. The population growth of Indramayu district was 2.1%, and the labor force percentage ranged from 52 to 56%. Projection to 10-20 years period was likely a good range to estimate population and labor force model.

By comparison, the district statistics revealed, that total population in Indramayu (1985-1988 grew by 2.04% annually. The World Bank labor force data (1960-1985) estimated that 56% of the population (population age of 15-

64 years old) was in the labor force (World Bank, 1980, (Table. 19); and 1988 (Table 31). Figure 6.4 and 6.5 show the simulation results of the population and labor model.

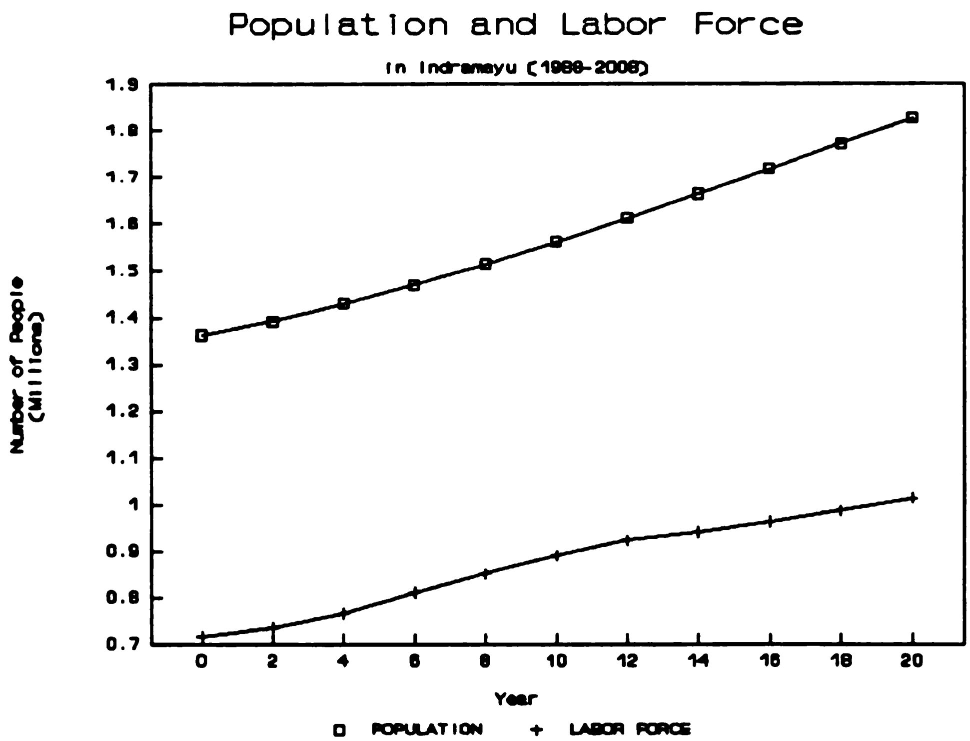


Figure 6.4 Population and Labor Force in Indramayu (1988 was used as year 0)

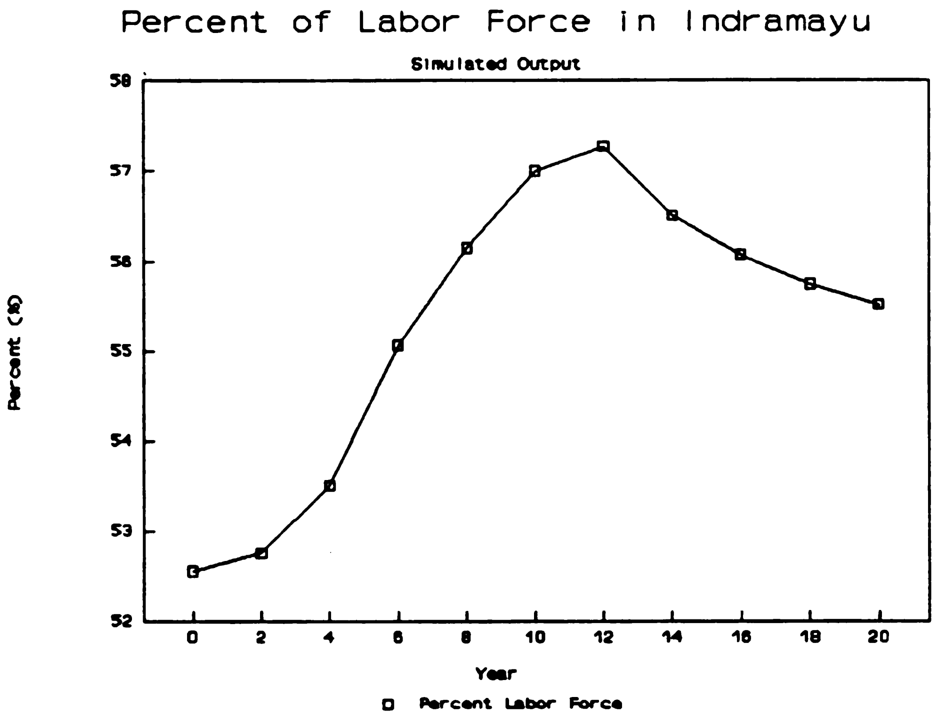


Figure 6.5 **Percent of Labor Force available for rice harvest in Indramayu. (1988 was used as year 0)**

6.9. MODEL APPLICATIONS

The economic feasibility of threshers in West Java was affected by many factors such as the price of technology, custom rates that represented the percent of throughput capacity, and thresher and engine size. Price of technology could be reduced by government policy through a subsidized credit (low cost interest rates or interest rates less than market interest rate). The farm survey revealed that custom rates of threshing varied from district to district ranging from 10% to 16.7% of the harvest share. The timeliness rate was also important to determine the contribution of this factor for the threshing cost and the optimum thresher size. Based on the farm survey, farms using threshers increased their working rate and completed the job one week faster than non-user farms. It indicated that timeliness was an important factor for reducing losses. Both larger thresher and engine size result in higher prices. The most common engine size for a thresher in West Java was the gasoline engine (4-5 Hp) and diesel engine, ranging from 4.5 Hp to 7.5 Hp. Equation 28 indicated that optimum size was sensitive to power source cost and price per unit capacity of thresher.

The OPTIM Model was run using different interest rates, custom rates, timeliness factors, and farm sizes (harvested area). A wide range of alternatives was included to identify the most feasible alternatives under different environments. First, several interest rates were used to identify the impact of government intervention on farm mechanization, both through providing subsidized interest rates or lowering the price of technology. The four different interest rates included the cheapest credit given by government for common agricultural projects (12%), the medium interest rate (18%), the commercial interest rate (24%), and the most expensive interest rate (30%) available in the market. The real interest rates (24% and 30%) represented the opportunity cost of money that existed in the village.

Second, the model was run using three different custom charges, which represent the wide range (10% to 16.7% of the gross output) of typical harvest shares in Java. The custom rate was set at three different rates. These were Rp.3,500/ton, Rp.4,850/ton, and Rp.5,800 per ton.

Third, the model was run under three different timeliness costs to determine the important contribution of this factor to the optimum size of thresher, and its corresponding farm size. The three different timeliness cost factors used were 0, 0.005 and 0.01. These values can be interpreted as "no timeliness penalty", "5 kg/t-day" for each day delay in operation, and "10 kg/t-day" for each day delay in operation respectively.

Finally five alternative combinations of thresher and engine-powered source systems were considered in this model application. These combination were selected based upon the availability of power source in the Indramayu district and the possible combination that may be used by the farmers.

Common engine size used by farmers and available in the market ranged from 4.5 Hp to 7.5 Hp. These alternatives are described in Table 6.3. The model was applied for various alternative farm sizes (area under crop). This crop land area ranged from 1 to 20 hectares per year, or 0.5 to 10 hectares, assuming farmers use double cropping per year. Variation in farm size was included to evaluate the flexibility of land ownership pattern for participating in farmer mechanization, assuming the thresher can be used for custom work. This assumption allows any individual farmer or farmer groups that exist in a village to participate in managing the thresher operation.

Table 6.3. Threshing System Alternative

Threshing System	Description
System -1	Combination of threshing machine with small gasoline engine (5.5 Hp)
System -2	Combination of threshing machine with small diesel engine (4.5 Hp)
System -3	Combination of threshing machine with small 5.5 diesel engine
System -4	Combination of threshing machine with 6.5 diesel engine
System -5	Combination of threshing machine with 7.5 diesel engine

6.9.1. Threshing system under different interest rates.

A summary of the model output, subject to changes in interest rates, is shown in Table 6.4. At a 12% interest rate, the output shows that System S-2 was the most acceptable threshing systems for harvested area of 1 to 10 hectares, with the optimum size of the thresher being 0.5 t/hr. System S-5 was the most economical option for the larger area (more than 10 ha), with the optimum size ranging from 0.59 t/hr to 0.84 t/hr. When the interest rate increased to 18%, System S-1 became the least cost alternative for area under 10 hectares, while the other systems were acceptable for the larger areas. The optimum size varied from 0.5 to 0.84 t/ha. System S-1 remained the feasible system when the interest rate increase to 30%. Although larger capacity systems were available for the farmers, the model suggested that only two system remained economically feasible system. At a 24% interest rate, System S-4 and S-5 were dropped from the selection, since they are were not profitable for area less than 8 hectares.

Table 6.4. Least Cost Thresher Size (t/hr) and Threshing System at Different Interest Rates and Farm Size.

Area (Ha)	Interest Rate (%)			
	12%	18%	24%	30%
1	S-2 (0.50)	S-1 (0.50)	S-1 (0.50)	S-1 (0.50)
5	S-2 (0.50)	S-1 (0.50)	S-1 (0.50)	S-1 (0.50)
10	S-5 (0.59)	S-5 (0.59)	S-5 (0.59)	S-5 (0.59)
15	S-5 (0.72)	S-5 (0.72)	S-5 (0.72)	S-5 (0.72)
20	S-5 (0.84)	S-5 (0.84)	S-5 (0.84)	S-5 (0.84)

S-1: System with TH-6 and 5.5 HP gasoline engine
S-2: System with TH-6 and 4.5 HP diesel engine
S-5: System with TH-6 and 7.5 HP diesel engine
TH-6 is IRRI thresher model (portable size)

The results indicate that the level of the interest rate and farm size significantly affect the level of technology feasibility. The least cost size increases with increases in farm size for all interest rates. At low interest rate (12%) and farm size less than 5, System -2 was the least cost size system compare to the other four system. But at the same farm size, with an increase in the interest rate, System-1 was the least cost size system. System-5 was the least cost size thresher for farm size ranging from 10 to 20 hectares.

Table 6.4. shows that if there is no government subsidy, it would be economically feasible for a small farmer harvesting less than 5 ha per year, to only purchase

a thresher of 0.5 t/hr. Larger farmers may purchase a larger size with the potential to reduce more labor because of its larger capacity. Both S-2 and S-5 systems are favorable for larger areas. Figures 6.6a to 6.6c show the trend of optimum thresher size with the changes in farm size for different interest rates. Figure 6.4 indicates that gasoline engine (S-1) is much lower compare to the other systems at larger farm sizes. Based on Equation 28, this optimum size is sensitive to the cost of power source. Gasoline engine at 5 Hp cost about Rp 450,000 ($ 230) while the diesel engine with the same power cost about Rp 1,500,000. ($ 770).

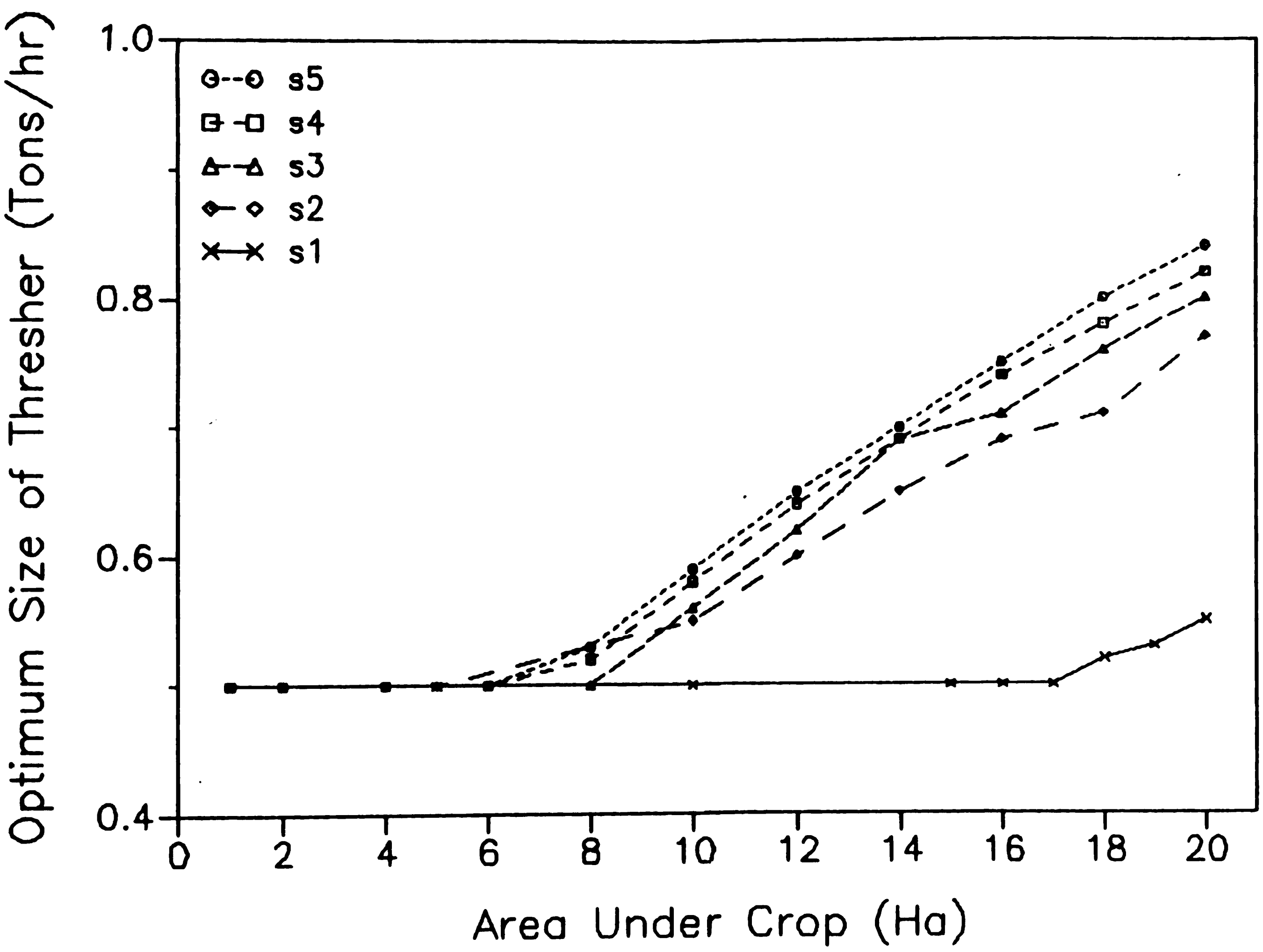


Figure 6.6a. Optimum Size of Thresher at 12% Interest Rate

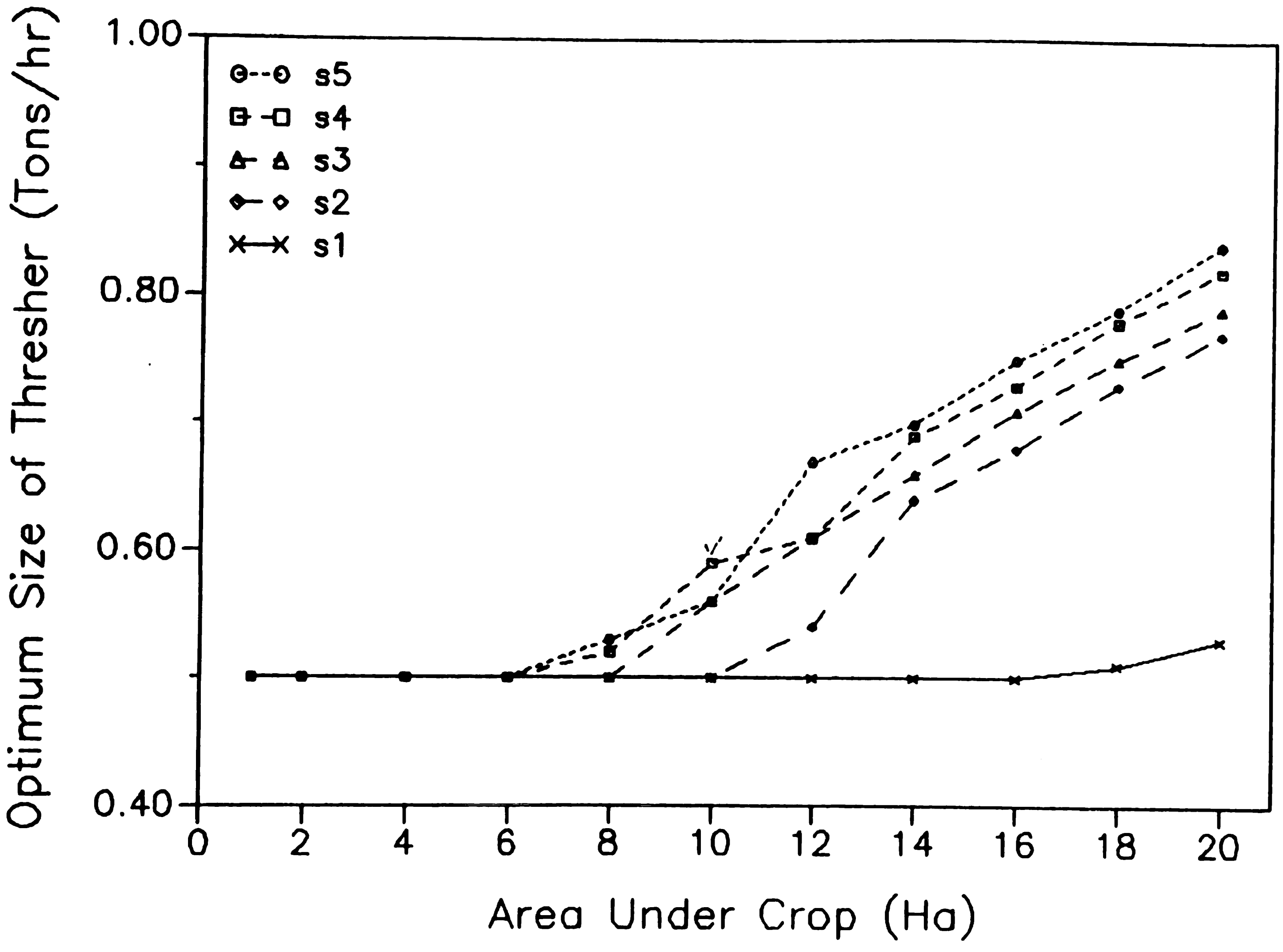


Figure 6.6.b. Optimum Size of Thresher at 18% Interest Rate

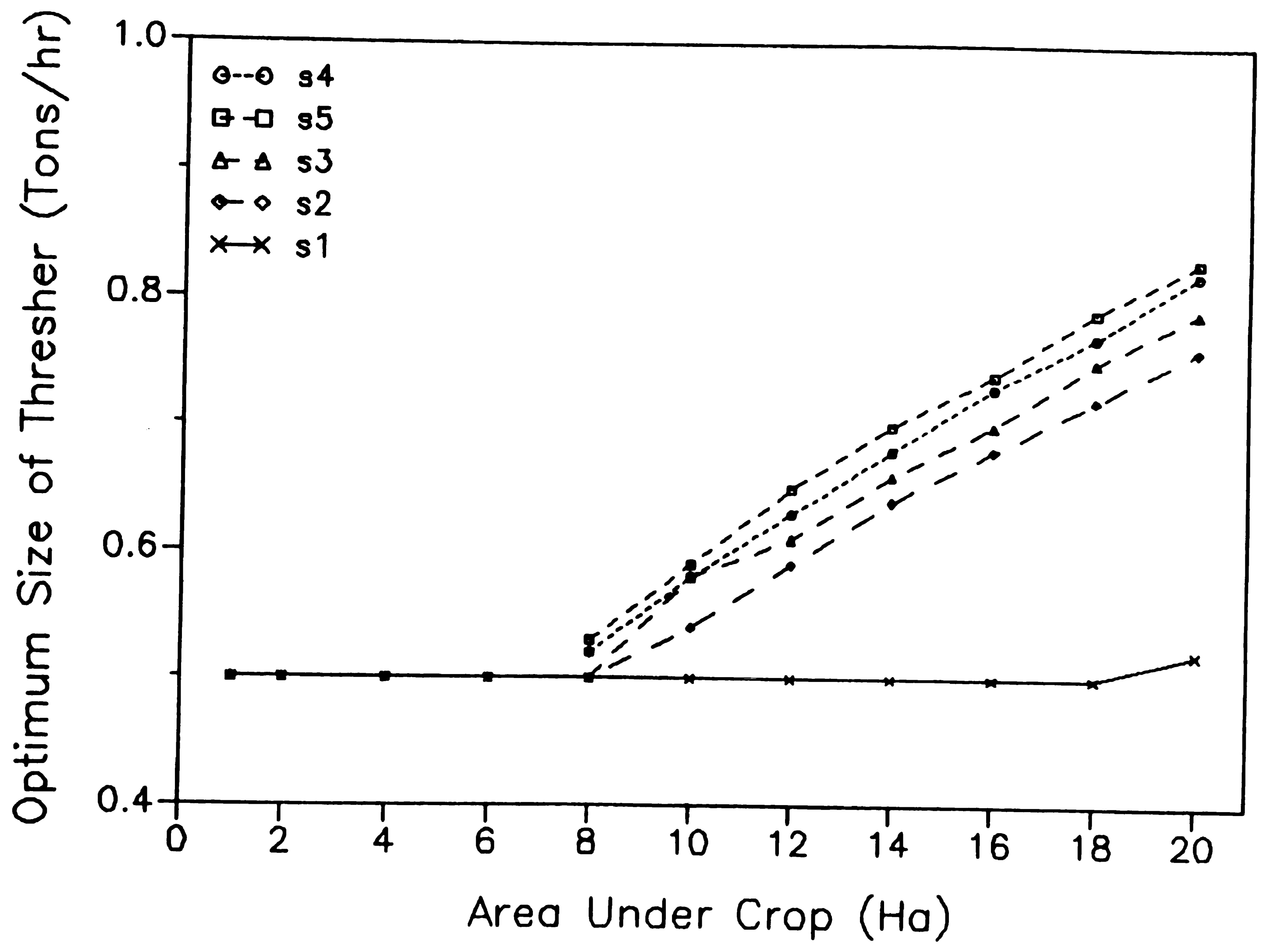


Figure 6.6c. Optimum Size of Thresher at 24% Interest Rate

6.9.2. Annual Utilization (Custom Work) versus Custom Rates

Three different custom rates (Rp 3500/t to Rp 5800/t) were used to determine the system behavior. These custom rates represented the possible threshing cost charge to the customer in Indramayu district and the neighboring districts.

With different custom rates set for the model (Table 6.5), the model output suggested that at the lowest custom rate (Rp 3500/t), system S-1 (0.5 t/hr) was the least cost system. Increasing the custom rate allows the other systems to enter as options, but system S-1 remained most favorable for the small farm size. At the highest possible custom rate, System-4 will be the feasible system for farm under 8 hectares. System-5 was the least cost system for farms with more than 8 hectares. Table 6.5 summarizes the results of the analysis of optimum size under different custom rates.

Table 6.5. Optimum Size of Thresher under Different Custom Rate and Farms Sizes.

Custom Rate (Rp/t)	<5 ha	5 ha	10 ha	15 ha	20 ha
3500[a]	0.50 (S-1)[d]	0.50 (S-1)	0.50 (S-1)	0.50 (S-1)	0.53 (S-1)
4850[b]	0.50 (S-1)	0.50 (S-1)	0.54 (S-2)	0.72 (S-5)	0.84 (S-5)
5800[c]	0.50 (S-4)	0.50 (S-4)	0.59 (S-5)	0.72 (S-5)	0.84 (S-5)

[a]the lowest custom rate (1/10 of the harvest share).
[b]the medium custom rate (1/7 of the harvest share).
[c]the highest custom rate (1/6 of the harvest share).
[d]( )indicates the least cost system

Table 6.6. shows that if the custom rate falls to Rp 3500/t, or about 1/10 of the harvest share (167 kg), the thresher must work at least 260 hours /year. At this custom rate, only S-1 will be economical. Other systems were not profitable because their required working hours were greater than the maximum available annual working hours. The maximum annual working hours were fixed at 300 hours, based on the current annual working capacity determined through the survey.

When the custom rate was increased to Rp 4850 or 23.8 kg/t of throughput, S-1 remained the most profitable threshing system for farmers with farms less than 5 hectares (10 hectare annual harvested area). The annual working hours required to make the threshing cost at least equal to the custom rate varied with the increasing harvested area.

At the highest custom rate Rp 5800 /t (1/6 of the throughput), S-4 (optimum size 0.5 t/hr) was the most economical for farms under 4 ha. System-5 is the most profitable thresher for the larger farm (greater than 5 ha) with the optimum size ranging from 0.56 to 0.84 t/hr.

Table 6.6. Custom rate and Annual Working Hours at 18% Interest Rate

Area (ha)	Custom Rates (Rp/t)					
	Rp.3500		Rp.4850		Rp.5800	
	AUTH (hours)	WHRC (hours)	AUTH (hours)	WHRC (hours)	AUTH (hours)	WHRC (hours)
1	260	250	124.8	114.8	258.9	294.0
2	260	240	124.8	104.8	258.9	238.9
3	260	230	124.8	94.8	258.9	228.9
4	260	220	124.8	84.8	258.9	218.9
5	260	210	124.8	74.8	258.9	208.9
10	260	160	283.9	191.6	183.4	98.8
15	260	110	213.1	109.6	127.8	22.1
20	238.5	50.8	167.1	47.5	119.5	0

[a]Values in a column refers to the least cost size of thresher
AUTH = Annual utilization of thresher (hrs/year)
WHRC = Working hours required at the existing custom rate (hr/year).

6.9.3. Timeliness cost and optimum size.

When a timeliness cost factor was included in the simulation, the result suggested the same trend. S-1 remained the most economical for the small farms. At timeliness cost factor equal to 0, the systems S-1, S-2 and S-5 were the most economical size for area ranging from 1-20 hectares. When timeliness factors equal 0.005 and 0.01 the results remained the same with S-1 favorable for farms less than 5 hectare (10 harvested area), S-2 for farm between 5-7.5 hectare and S-5 for farms between 7.5 to 10 hectares (Table 6.7)

Table 6.7. Optimum Thresher Size and Least Cost Threshing System at Different Timeliness Cost Rates and Different Farm Sizes.

Area (ha)	TF =0	TF=0.005	TF =0.01
1	S-1 (0.5)[a]	S-1 (0.5)	S-1 (0.5)
5	S-1 (0.5)	S-1 (0.5)	S-1 (0.5)
10	S-2 (0.54)	S-2 (0.54)	S-5 (0.54)
15	S-5 (0.77)	S-5 (0.71)	S-5 (0.72)
20	S-5 (0.84)	S-5 (0.84)	(S-5) 0.84)

[a]Number in the parentheses are the size of thresher
The results were run with 18% interest rate.

6.9.4. On-Farm and Off-farm Work Under Uncertainty

A Monte Carlo technique was used to predict the uncertainty factor that may characterize the actual off-farm and on-farm work. Table 6.8 presents the output generated from this simulation which assumed that off-farm use and on-farm use were both normally distributed. In this table, the frequency distribution of the seasonal off- and on-farm work were counted and plotted to see the distribution curve.

Table 6.8. Summary of Statistical Outcome of the Uncertainty Distribution of Seasonal Work.

Item	Wet Season (t)[a]	Dry Season (t)[a]	Annual Utili-zation (t)[b]
Number of Runs	100	100	100
Mean	63.7	45.9	109.6
Variance	152.3	107.6	260.7
Standard Deviation	12.3	10.3	16.2
Minimum	22.6	13	65.7
Maximum	97.8	73.8	153.9

aBoth Off- and On-farm used.
[b]Total Wet and Dry Season.

By using the standardized normal distribution (DeGarmo *et al., 1984)* the probability that annual capacity (custom work) will fall below the various break-even levels can be estimated. The standardized variable (Z) was estimated by using the formula:

$$Z=\frac{x_i-\mu}{\sigma} \quad (38)$$

where:

Z = standardized normal variable

σ = standard deviation of population

μ = mean of population

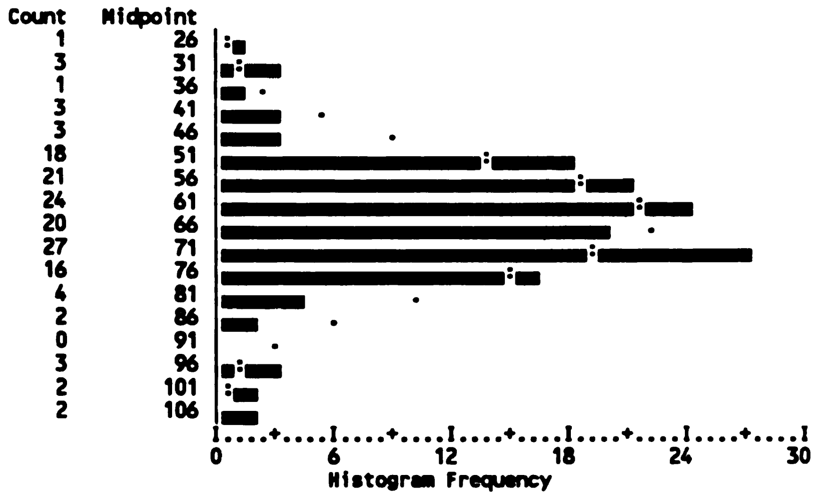
Xi = sample variable

Table 6.9 summarized these calculation. The break-even levels were assumed to be between 62.5 t/ha and 150 t/year. Figure 6.7a through Figure 6.7c shows the frequency distribution of seasonal and annual custom work.

Table 6.9. Probability of the Custom Work Utilization and Corresponding Break-even Levels.

Break-Even Level (BEP)		Probability (%) that Annual Use >BEP
hr/yr[a]	t/yr[a]	
125	62.5	99
150	75.0	98
200	100.	71
250	125	52
300	150	<1

[a]Annual working hours
at α=0.05, μ=109.6, σ=16.2

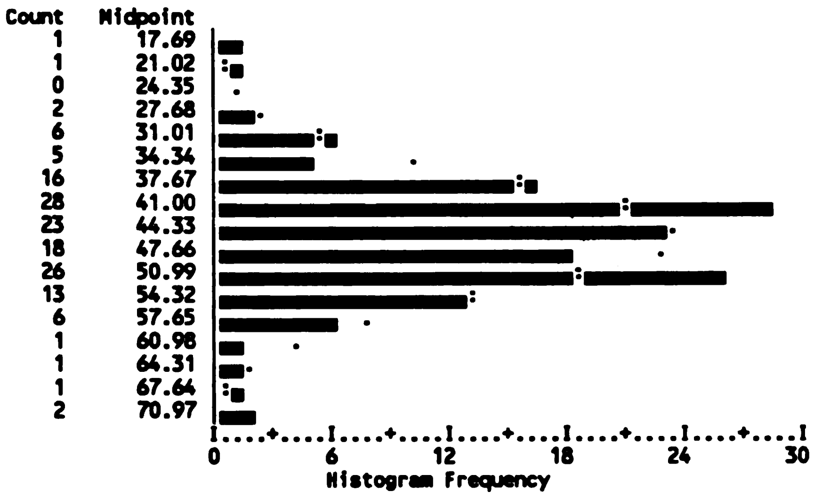


Mean	64.047	Std Err	1.095	Median	63.850
Mode	51.810	Std Dev	13.407	Variance	179.741
Kurtosis	1.421	S E Kurt	.394	Skewness	.268
S E Skew	.198	Range	77.320	Minimum	26.880
Maximum	104.200	Sum	9607.020		

Figure 6.7a. Frequency Distribution of Simulated Output of the Wet Season Off and On-Farm Work in Indramayu District (SPSS-PC Print out)[19].

---

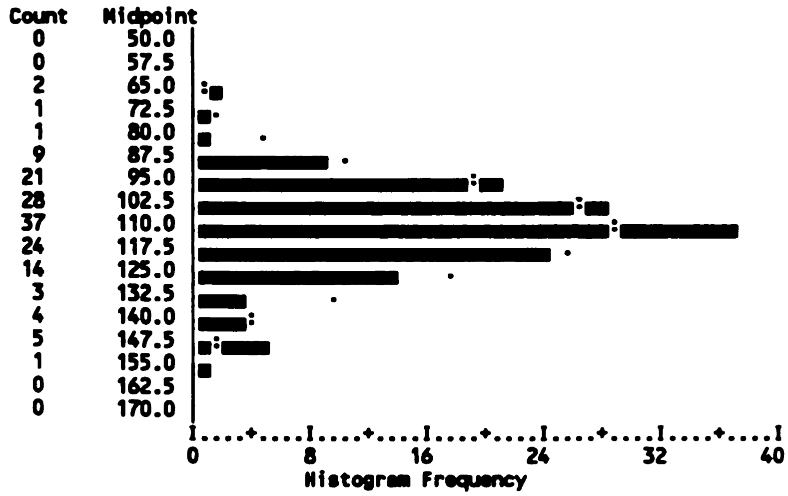
[19]Figure 6.7 a,b, and c are the SPSS-PC output. the vertical axis (Midpoint) indicates the mid-values of the seasonal or annual thresher use (total off and on-farm use)



OFFARM2

Mean	45.227	Std Err	.684	Median	44.930
Mode	44.930	Std Dev	8.380	Variance	70.226
Kurtosis	1.191	S E Kurt	.394	Skewness	-.006
S E Skew	.198	Range	53.520	Minimum	17.570
Maximum	71.090	Sum	6784.060		

Figure 6.7b. Frequency Distribution of Simulated Output of the Dry Season Off- and On-Farm Work in Indramayu District (SPSS-PC Print out).



ANNUT

Mean	109.274	Std Err	1.248	Median	108.610
Mode	113.250	Std Dev	15.279	Variance	233.445
Kurtosis	1.115	S E Kurt	.394	Skewness	.281
S E Skew	.198	Range	89.320	Minimum	62.890
Maximum	152.210	Sum	16391.070		

Figure 6.7c. Frequency Distribution of Simulated Output of the Annual Off and On-Farm Work in Indramayu District (SPSS-PC Print out).

Various Break-Even levels were set to respond to changes in prices, interest rates and custom work rates. For extremely high level BEP (150 t/year), the probability of total annual utilization greater than the BEP was very small. At the medium BEP level (100 t/year), 71% of the threshers will exceed the BEP. At the lowest level of BEP, the probability of annual utilization greater than the BEP will be 99%.

6.9.5. The Cash-Flow Analysis of Engine-Powered Threshers.

The profitability of engine-powered threshers is affected by variables such as price, interest rate, wages and annual utilization. To measure the effect of these variables on the economic performance, some variables were altered (Table 6.10). The economic performance measures currently estimated by the model are shown in Figure 6.8. The first of these is Net Annual Benefit (NAB), the yearly net revenue generated by annual thresher utilization minus annual costs of operation. The second is Net Present Value (NPV). This common measure of economic worth is the discounted net revenue over the life time of machine. The discounted net present value is subject to change in the interest rate. The NPV is the profit or loss generated by the project over the assigned lifetime of machine. The third measure of economic performance is the Internal Rate of Return (IRR). The internal Rate of Return (IRR) is the interest rate that makes the NPV equal to zero. The fourth measure is Benefit Cost Ratio, the ratio between the Benefit and Cost of the investment.

The mathematical formula of these economic performance are as follows:

Net Annual Benefit (NAB):

$$NAB = REV - COST \tag{39}$$

where,

NAB = Net Annual Benefit (Rp/year)

REV = Total Revenue (Rp/year)

COST = Total Cost of Threshing (Rp/year)

Total revenue is annual revenue (Rp/year) obtained from the custom work (t/year) multiplied by the price of paddy (Rp/t). Total operating cost is costs incurred for fuel, oil, repair and maintenance and labor costs. The Net Present Value (NPV) is the discounted net benefit as discussed in the Equation 11 (Chapter IV).

The mathematical formula of the Internal Rate of Return is described as follows:

Internal rate of Return (IRR) is mathematically described as follows (Gittinger, 1982; DeGarmo, 1984):

$$IRR = RATE_l + (RATE_l - RATE_h) * \frac{PV_l}{(PV_l - PV_h)} \qquad (40)$$

Where,

IRR = Internal Rate of Return (%)

$RATE_l$ = the lower interest rate (%)

$RATE_h$ = the higher interest rate (%)

PV_h = Net Present Value at the higher interest rate (Rp)

PV_l = Net Present Value at the lower interest rate (Rp)

The sign of the denominator in the right side of the above equation is ignored (Gittinger, 1982).

Benefit Cost Ratio is mathematically written as follows:

$$BCR = \frac{\sum_{i=1}^{N} \frac{B_t}{(1+i)^t}}{\sum_{i=1}^{N} \frac{C_t}{(1+i)^t}} \qquad (41)$$

where,

B_t = Benefits at year t

C_t = Costs at year t

t = 1,2,3,....n

n = number of years

i = interest (discount) rate

Thresher ownership is considered economically feasible if the NPV is greater than 0, the BCR is greater than 1.0 and the IRR is greater then the opportunity cost of capital.

It was shown in the optimization technique (OPTIM sub-model), that for small farms ranging from 1 to 5 hectares, the most economic size thresher was 0.5 t/hr. Although threshers available in the market ranged from 0.5 t/hr to 1.5 t/hr. In 1990, the price of a local thresher (artisan made) sold in the village was Rp 950,000, including a 5.0 hp gasoline engine. In contrast, a thresher, which domestically manufactured by some manufacturer costs about Rp 1,550,000. The local thresher was a small, portable unit manufactured by a village shop. This thresher were a modified TH-6 (IRRI type thresher), this local thresher used a small gasoline engine (4-5 Hp). The domestic thresher was a thresher manufactured by using more advance production technology, relatively more sophisticated, heavier and usually powered by a diesel engine (5-7 hp). Test reports published by Agricultural Engineering Division of the MOA (1988), revealed that these two kinds of machine were similar in terms of technical performance. However, the artisan machine was lighter (about 20-25 kg/hp) compared with the domestic machine (30-40 kg/hp).

The grain output from the thresher was valued at various prices, ranging from Rp 210,000 (unclean), Rp 220,000 (moderate) to Rp 225,000/kg (clean). These ranges were verified during field experiments, by asking farmers to compare one to each other. Based on this given information, the BENCOS sub-program was run under different prices, interest rates, and wages as shown in Table 6.10.

These runs were chosen based upon the assumption that thresher price, interest rates, price of rice, price of fuel and oil, custom charge and laborer wage were the most dominant factors that will affect the feasibility of thresher ownership. In these runs, total revenue and costs were generated using random numbers as described in Equation (32) and (33). RUN-1 through RUN-6 indicate the possible alternatives that currently exist or will exist in the future. These runs demonstrate the system sensitivity under different economic circumstances.

Table 6.10. Variables changed in Economic Performance of Thresher.

Variables	Run1	Run2	Run3	Run4	Run5	Run6
Price of Thresher (Rp)	950,000	950,000	950,000	950,000	1,550,000	2,050,000
Interest Rate (%)	12	18	24	24	18	12
Price of Rice (Rp/t)	210,000	225,000	225,000	225,000	225,000	225,000
Fuel Price (Rp/l)	500.	550	500	550	550	400
Oil Price (Rp/l)	2500.	2500	2500	2500	2500	2500
Custom Charge (%)	2.78	2.78	2.78	2.78	2.78	2.78
Laborer wage (Rp/mt)	900	950	900	1000	950	950

RUN-1:

Run-1 used the current price of the thresher (artisan manufactured). Subsidized credit (12%), and other price and wages represented the 1990 situation.

RUN-2:

Run-2 used same technology as Run-1, but the interest rate was increased to 18% to respond to the possibility of an adjustment in credit policy, or farmers using other credit sources. The price of paddy was increased to reflect cleaner grain output from thresher. Also, both fuel price and labor wage rate were increased by Rp 50.0/unit.

RUN-3:

Run-3 used the same technology as Run-1, but assumed a non-subsidized interest rate (24%). Price of paddy was Rp.225,000/t, and the 1990 labor wage rate and fuel price were used.

RUN-4:

Run-4 used the same scenario as Run-3, but the fuel price was increased to Rp 550/l in a village and the threshing labor wages was set at Rp 1000/t.

RUN-5:

Run-5 replaced the local thresher with a domestically manufactured machine, which was heavier, more complicated and more expensive. Thus, the price increased from Rp 950,000 to Rp 1,550,500 (with gasoline engine). The price of paddy was set at Rp 225,000./t.

RUN-6:

Run-6 used the same thresher as run-5, but used a different power source. A 4.5-5.0 HP diesel engine was used. The total cost of this unit, according to local dealer was Rp 2050,000 (1990). Price of paddy was set at the maximum price in a village (225,000/t). Credit was subsidized at 12%, and the fuel price for diesel engine was set at Rp 400.

The simulation runs are summarized in Table 6.11.

Table 6.11. Economic Performance of Rice Threshing Technology

Economic Performance Criteria	Run-1	Run-2	Run-3	Run-4	Run-5	Run-6
NAB (Rp):						
Mean	377250	393150	405973	397056	401027	435829
SD	57248	50648	59870	61897	59209	61999
NPV (Rp)						
Mean	451820	311739	189752	165272	-243232	-341049
SD	190416	158387	164368	169915	185158	223493
Prob[NPV<0][a]	0.01	0.025	0.125	0.166	0.905	0.935
BCR (%)						
Mean	1.23	1.10	1.11	1.09	0.90	0.88
SD	0.08	0.08	0.09	0.09	0.08	0.08
IRR (decimal)						
Mean	26.43	31.97	32.44	29.96	15.12	7.90
SD	0.06	0.06	0.06	0.04	0.02	0.02

a $\alpha=0.05\%$

The frequency distribution of NPV (Net present Value) of Run-1 (subsidized credit) is shown in Figure 6.8, and Run-4 (non subsidized credit) in Figure 6.9. In Run-1 (subsidized credit), the probability that NPV falls less than 0 was less than 1%. In Run-4, when the alternative investment was run under no subsidized credit, the economic performance remained quite good. The probability of NPV that may fall less than 0 was 16.7%. Or in another words, more than 83 out of 100 thresher owners will earn profit from thresher operation. Run-2 and Run-3 indicated that if the price of fuel and labor wage rate increased Rp 50/unit, the thresher remained economically feasible (BCR >1.0). In Run-5 and Run-6, the results suggested that more sophisticated design

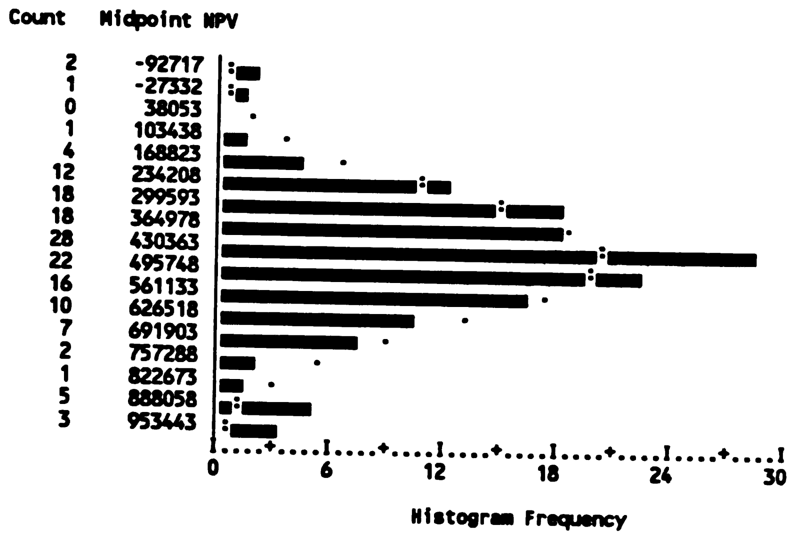


Figure 6.8. Sample Output of Net Present Value Under Run-1

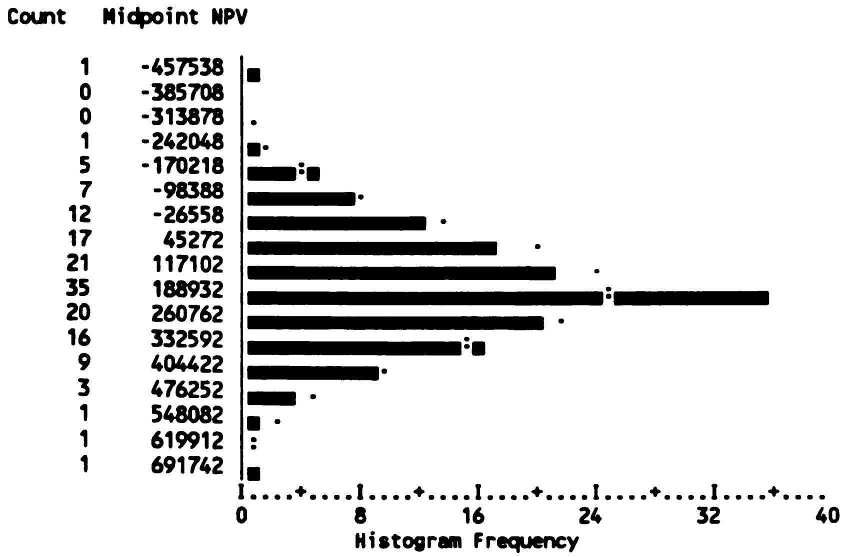


Figure 6.9. Sample output of NPV under Run-4

will not be economical, neither with subsidized credit nor without subsidized credit. In these cases, more than 90 out of 100 thresher owners will not reach the acceptable NPV (NPV > 0). The farm survey suggested that post harvest equipment provided to farmers as grants were under utilized (below capacity). This simulation results (Run-5 and Run-6) explained that this type of machine will not be economically feasible. The distribution of NPV in Run-5 and Run -6 suggested that NPV will be greater than 0, if annual utilization greater than 140 mt/hr (Figure 6.11). At the study time, the utilization capacity was only about 110 mt/ha, that was 21% below the Break-Even level.

The overall results suggested that under current utilization, a local engine-powered thresher (0.5 mt/hr) was profitable for the owner.

6.9.6. Labor and Mechanization

The demand for rice production labor can be directly estimated from the size of agricultural production (total area or total production per year). In Java, particularly West Java, it is nearly impossible to expand the irrigation land or increase the land area for rice production. The only possible way to increase the demand for labor in Java is through intensification (i.e. increasing the number of crops per year) or increasing area for producing other crops.

For developing countries (LDC's) like Indonesia, over 50% of the labor force is in agriculture. In these LDC's, the aggregate labor force is growing rapidly due to population growth. Therefore, only extremely rapid growth in the non-agricultural sector (industry, trade and service) can reduce the absolute number of workers in agriculture (World Bank, 1987). A World Bank study illustrated that if 70% of the labor force is in the agricultural sector, and the total labor force is growing at 2% per year, the non-agricultural sector would need to grow by at least 6.6% per year to keep the absolute number of workers in agriculture constant.

If there is no technological progress that increase yield, an increased number of agricultural worker will decrease the marginal productivity of labor (Stevens and Jabara, 1988, pp.187). However, the World Bank study added that the number of workers in agriculture and the wages they can earn were a reflection of a complex set of variables and not merely the results of demographic trends or merely the pace of agricultural mechanization. Developments in trade, industry and service sectors, and other favorable economic policies determine the demand for and supply of employment. In the agriculture sector, policies affecting prices, rural infrastructure and biological technology would affect the labor supply in the rural area.

In this study, a World Bank's approach was used to predict the labor situation in the rural area. The POPUL sub-program was used to estimate the trend of working-age population (15-64 years old). Then, the program projects the non-agricultural labor force based on a mathematical relationship[19] between the growth rate of non agricultural labor as the dependent variable and the growth of the working age population and share of labor in agriculture in the initial stage (World Bank, 1987). Then it assigns the remainder of the working age population to agriculture.

The results of labor estimation in Indramayu are shown in Figure 6.10. These results were based on population in the year 1988, with crude birth rate of 2.8% and crude death rate of 9 per 1000 people. The total population was estimated to grow at an annual rate of 2.3% during the 20 year simulation period. This figure also

---

[19] This mathematical relationship is taken from the World Bank Policy Study " Agricultural Mechanization . Issues and Options". where Rn = 0.0013 + 0.68164 (Rt) + 000293*Po. Rn= Rate of growth of the non agricultural labor force, R= rate of growth of population 15-64 years, and Po is the initial proportion of agricultural labor force.

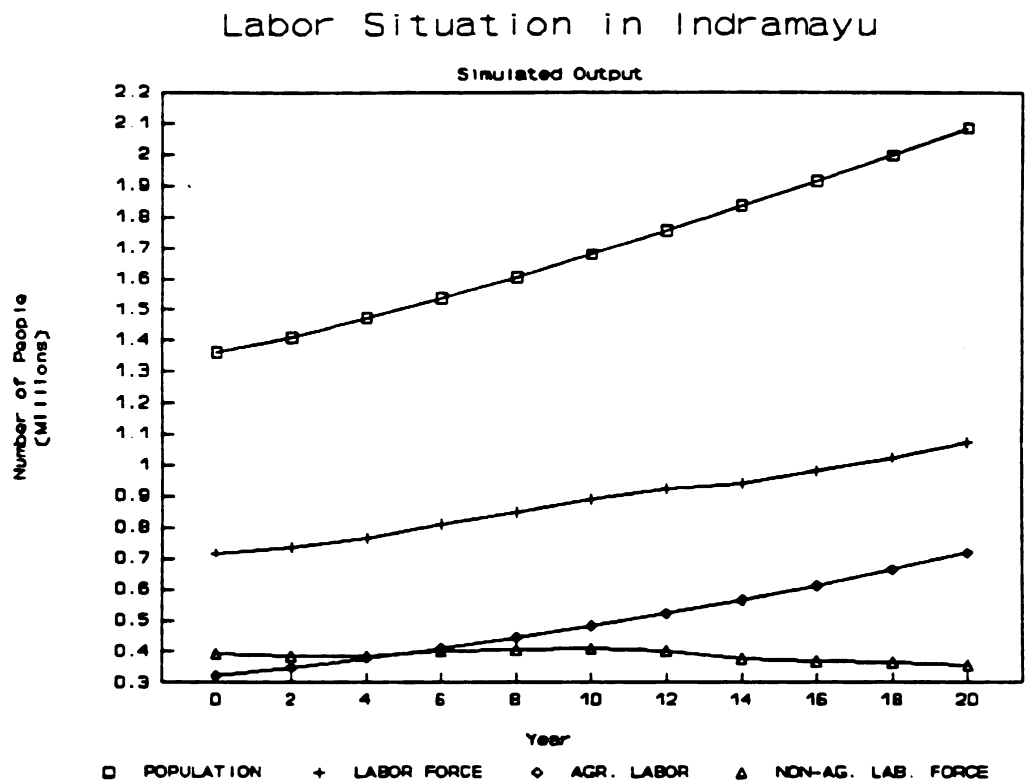


Figure 6.10. Labor Situation in Indramayu (0 was used as year 1988)

shows that population working age (15-64 years) increased at 2.6% per year, while the non-agricultural labor force increased at a rate of 6.1% annually, However, the agricultural labor force increased at a rate of 0.4% in the first ten years and then decreased at a rate 1.3% for the years 11 to 20. By using the World Bank approach, this study estimated that the agricultural share of the labor force will decrease from 55% (West Java average) to 45.9% or at a rate of 0.9% annually from 1988 to 1998. In the second period (1998-2008), the share will decrease at a rate of 1.3% annually. However, this model was only reasonable for 1 to 20 years period. Longer than these period was likely not reasonable and need more justification.

This simulation provided a crude estimate of the labor situation for the next 20 years. However, the results suggest a trend in the labor market for the next 20 year period and provide an estimate of the labor situation for consideration in planning further mechanization development. In the case of labor wages, the trend implied that the real labor wages will likely stagnate or decline in the first 10 year period, but increase in the second 10 year period.

Seemingly, mechanization of rice production will be an increasingly important policy issue in the future. In the first ten year period (1988-1998), it is important that rice mechanization development be focused on the introduction of new cost-reducing technology that is not highly labor displacing and on increasing the rate which research, development, extension, and machinery supply systems are able to provide farmers with cost-reducing machines (Stevens and Jabara, 1988, pp244). In the second 10 years period (1998-2008), the focus may shift to a larger mechanization capacity in respond to decreasing agricultural labor. With current industrial development, it is expected that from 1988-1998 (two 5-years development phases) Indonesia will already be able to produce agricultural machines, which are necessary for the Indonesian rice production.

Experience suggests that linkages between universities, agricultural research agencies and international development have served to strengthen agricultural mechanization technology development in Indonesia (Esmay, 1989). Since research in agricultural engineering and mechanization are very limited in Indonesia, the government needs to place greater priority in this field to increase the rate of development of the cost-reducing mechanization technology.

6.10. Implication of Farm Survey and Simulation Results

The subprogram OPTIM was altered with different prices, interest rates, custom rates, and timeliness factors. The results suggested that the optimum size of threshers was sensitive to price of technology, interest rate and custom working rate. First, simulation results (Table 6.1 to 6.8) based on the wide range of alternative evaluated (reflecting different size of harvested crop area, price of technology, interest rate, and timeliness factor) suggested that only the 0.5 t/hr size engine-powered thresher, was economically acceptable for use on small farms (less than 2.5 hectare under double crops annually). Second, the results suggested that if the custom rate falls to Rp.3,500/t, the 0.5 t/hr thresher was the optimum size that was economically acceptable for all farm sizes (1-20 ha). Third, the results indicated that in Indramayu, West Java, if current price, wages and average annual working hours held constant, a local thresher with a minimum 0.5 t/hr, powered with 5.0 gasoline engine was optimum. A domestic thresher with more sophisticated design and heavier than the artisan product (modified TH-6 IRRI portable thresher) would be less appropriate for farms less than 5 hectares, but more appropriate for farms larger than 5 hectares.

The second subprogram (BENCOS) was applied to evaluate the economic performance of this optimum thresher size under uncertainty, represented by a random variability of annual thresher utilization. The results suggested that in both a very pessimistic situation (high interest rate, high cost of fuel and labor) and in a very optimistic situation (subsidized credit, low wage and fuel price), the current thresher size (0.5 t/hr) gave good economic performance. Furthermore, the Monte Carlo simulation suggested, that in the pessimistic situation, the probability of Net Present Value (NPV) will fall below 0 was 16.7%. In the optimistic situation, the probability of NPV falling below 0 was less than 1%. On the other hand, the simulation results suggested that more sophisticated design was not economically feasible if its price was higher than Rp 1,550,000. The probability of the NPV falling below 0 was higher than 90% with price higher than Rp 1,550,000. This suggested that for more than 90 out of 100 thresher owners, ownership will be unprofitable. Although ownership might be profitable if the annual utilization at least 140 t/year, current survey result suggested that annual utilization capacity are 110 t/year or 21% under the break-even level.

The farm survey and the simulation model suggest that there were four major constraints to the adoption of rice threshing mechanization in Indramayu, West Java.

1. Size of Land Holding

Studies of the adoption of rice mechanization technology (Consequences Workshops, 1981) and technology-based rural development (Schutjer, 1977) inevitably stressed that adoption rates among farmers vary with different farm sizes. Generally, farm machines, unlike seed, fertilizer, and pesticide are less divisible; and large farmers typically have greater access to credit which is often subsidized. Thus, a major concern is that any program of rice mechanization should not only benefit to larger farmers but also the smaller farmers.

In the simulation, a wide range of farm sizes were assigned to the model to examine the divisibility and acceptability of rice threshing machines. The results suggested that the smallest size (0.5 t/hr) thresher was optimal, assuming the thresher can be used for custom work. Larger size units were not optimal for small farm sizes, because they require higher investment (and therefore have higher operation cost) and higher utilization rate to break-even. On the other hand, small machines are more divisible than larger machines and are likely more accessible to small holders. One way to make a small machine more divisible is by diffusing it through a cooperative, so it is available to all members. Furthermore, Schutjer (1977) argued that the problem of divisibility can be solved by the introduction of custom work. The first, custom work service arrangement enables the small landholders to purchase machines and sell the excess capacity to other farmers. The second, custom arrangement would make the thresher service available to smallholder who could not purchase machines. The farm survey suggested that small farmers in Indramayu did sell their excess capacity to other farmers. Their on-farm utilization was only about 11% (13 t/year) of the annual utilization, while the rest, 89% (94 t/year) was off-farm utilization. Currently, since farmer interest in cooperatives is weak, extension work is still needed to use this strategy for increasing utilization rate among the small farms and thereby solve the divisibility problem.

2. Custom rate

The custom rate in Indramayu was negotiated between thresher owner and landless laborers/thresher-hiring farmers. The rates ranged from 14.0% to 16.7% of the harvest laborers share, or equivalent to about Rp 4850 to Rp 5800/t, depending on the price of paddy. These rates were higher than the rates available in Central Java (Rp 3,500 to Rp 4,500/t). The simulation suggested that size of thresher was sensitive to custom rate and that the most acceptable size when custom rates ranged from Rp 3500 to 4800, was 0.5 t/hr size. The custom rate adjustment and its related thresher size, support the proposition that small farm holders need more divisible machines.

Consequently, if the custom rate fall to Rp 3500/t (16.7 kg/t), harvest laborer will only be paying about 10% of their share to the machine owner, or 1.67% of the gross product. Table 6.6 suggests that reducing this cost will force the owner to increase machine utilization to more than 250 hr/year to make the thresher economically feasible.

3. Demand for using mechanical thresher

Demand for the engine-powered thresher is closely related to the benefits of using this technology. Government has sought to increase the demand for engine-powered threshers through demonstrations, village-based extension work, and farmer-to-farmer learning. Experimental results have been used to convince farmers that the engine-powered thresher was a cost-reducing technology, which would increase farmer's return by decreasing losses and would maintain product quality. Evidence from analyzing the diffusion of engine-powered threshers in Indramayu, West Java, suggested two conclusions that represent general constraints to technology adoption in developing countries (Schuther and Veen, 1977). First, post-harvest technology policies and development programs have tended to focus on adoption rate, in contrast to effective utilization. This was indicated by the sharp growth rate of engine-powered threshers in the early period (1986-1988) and the large post-harvest equipment grant provided to the farmers in the late 1989. This great number, however, lacks proof of performing effective utilization. Second, post-harvest technology programs often fail to assure technical congruence between farmers' conditions and recommended practices. Although technically efficient, many post-harvest machines such as an engine-powered reaper, winower and mechanical dryer are economically rejected by farmers, because they do not fit the farmer conditions and overall rural economics, particularly in Java.

4. Price of technology

The high price of technology is one of the economic constraints to accelerating farm mechanization. An engine-powered thresher (0.5 t/hr) costs at least Rp 950,000. This is equivalent 4.5 t of paddy or the output from a 1 hectare farm. Since the average farm size in Indramayu is less than 1 hectare, it is difficult for a small farm to purchase this machine individually by cash without any financial assistance.

Subsidies are usually harmful (World Bank,1987) since they encourages large farmers to adopt more sophisticated technology and often more labor-saving technology. This accelerates the pace of mechanization faster than it would otherwise proceed. However, in some circumstance, a subsidy is required to allow farmers to learn about new technology that may benefit them. The sensitivity analysis suggested that local engine-powered threshers are more profitable, acceptable, and moveable than foreign design that are assembled locally. Engineering research has contributed a lot to reducing the size and power requirements for threshers. In the future, research in this field is still needed to reduce fuel consumption in anticipation of the increasing price of fuel. If Indonesia becomes a net oil importer in the next 10 years, increases in fuel prices will substantially affect the economic feasibility of mechanization.

The Economic Effect of Mechanization of Rice Threshing

Agricultural mechanization can broadly affect the economy of individual farms, and entire countries and regions (World Bank, 1987). In developing countries when most agriculture is labor intensive, mechanization reduces drudgery associated with manual work, and if the land owner is the worker it will free up time for other activities. On the other hand, mechanization may adversely affect other groups in the community. Two aspects are important to discuss regarding thresher mechanization in West Java; first the effect on the operation efficiency and second, the effect on employment.

Effect on Efficiency of Operations.

A major benefit of mechanization is its ability to reduce the cost of operation by reducing the amount of human labor or animal power needed to complete a task. Another gain of using mechanization is the ability to reduce the timeliness penalty due to delay in operation. Costs incurred by the producer are wages for the laborers. Decreasing the number of harvest laborers to reduce cost of labor, and replacing them by new mechanization means the laborers lose a source of income. This argument, is true if the new machine, like the engine-powered thresher does not create new job opportunities for the displaced laborers.

This study showed that the impact of thresher adoption on returns to owner was not so impressive, but the accompanying reduction of threshing losses will be worth a billion of rupiahs annually for the country. Adoption of engine-powered threshers in Indramayu demonstrated the efficiency of operation for the thresher owners. Table 5.17 suggests that engine-power thresher increased return to the thresher owner due to gain from use of the thresher in their own land. The custom work also proved that the thresher provided additional gain for them.

This additional return was actually a transfer of income from the harvest laborers to the owner of the machine. For the owner, the thresher had reduced cost of total harvesting (including threshing) operation from 16.7% to 13.9% of the gross output. This was due to the change from manual harvesting-threshing to manual harvesting-mechanical threshing. The cost of threshing (2.8% of the gross output) that went to the thresher owner include fixed cost (55%), and operating cost (45%). However, for the harvest laborers it was an income loss. Assuming 1% adjustment made for threshing loss, the adjusted yield was 5.39 t/ha[20]. The cost for threshing that went to thresher owner would be 149.7 kg instead of 148.5 kg, and total return for the owner would be 4.62 t/ha instead of 4.57 t/ha. The harvest labor income was adjusted to 748.5 kg/ha instead of 742.5 kg/ha, an increased 6 kg/ha for every 1% adjustment, but it remained 141 kg lower or Rp 29.610, when compared to traditional practices (891 kg/ha). In traditional practice, the number of harvest laborers required for every hectare was 35, thus each harvest laborer lost about 4 kg of paddy or Rp.840/ha. The amount was about

[20] The aggregate yield was 5.34 mt/ha. A 1% adjustment would make yield at 5.39 mt/ha or 50 kg increase every 1% adjustment.

a half day work in West Java.

Although thresher technology reduced losses, it did not compensate for the lost in laborers' income. On the other hand, at the national level, reducing threshing field loss by 1% contributed to increasing total national food supply. It also increased the food security of the nation, reduced the dependency from food import, and contributed toward maintaining domestic price stability.

Timeliness is one possible benefit of using a rice threshing machine. This study, however, did not emphasize the effect of the rice threshing operation on timeliness. The information gained indicated that threshers were mainly utilized in the wet season (60%). The most likely reason was that in the wet season, wet field condition did not allow farmers to practice manual-threshing in the field so that most paddy was threshed at the farmer's house.

The thresher was able to maintain the quality of rice by reducing rice checking. However, this study did not intend to observe this factor.

Use of a thresher enables the farmers to finish threshing 1 week faster than when using the traditional threshing method. Theoretically, this could reduce turn-around time between the wet and dry season, and possibly increase the opportunity to plant a third crop. However, this study found that thresher-user farmers did not increased their cropping index from 2 to 3 due to thresher use. In Indramayu, West Java, a few farmers plant a secondary crop after rice. For a very long period, farmers in Indramayu planted only a single crop each year. Increasing the number of crops from 2 to 3 required a major effort and many technical and social problems must still be solved. These include availability of seed, and chemical inputs, and price and marketing incentives, that encourage farmers to plant crops such as soybeans and other beans. Also, experience gained from recent secondary crop development efforts in West Java suggested that planting a third crop after the second rice crop, was not free of risk (Rural Extension Center, 1990).

Effect on Employment

As noted earlier, this study found that the engine-powered threshers decreased the harvest labor requirement from 280 persons/ha to 216 persons/ha. This reduction was mainly the result of replacing human labor used in threshing operations. This impact was similar to the consequence of tractors adoption about 15 years ago when farmers, especially large land owners, adopted tractors to reduce cost of land preparation. Although tractors substantially reduced human labor, about 90% of the rice farms in Indramayu were plowed with a tractor. This high rate of tractor utilization suggested that tractors operation was profitable and highly demanded, even after the subsidy was removed.

Threshing mechanization followed a pattern similar to tractor mechanization. Beginning in 1985, farmers started to adopt the engine-powered thresher to reduce the cost of threshing. The private profitability and high wages (16.7% of the gross output) were the main reason why threshers were adopted in Indramayu. If the average utilization rate was 110 t/yr (20 harvested ha per year), total rice farms covered by engine-powered thresher in 1990 were only 5920 ha or 3.2% of total Indramayu harvested area. The total laborers used per year were about 166,000 persons, and total estimated laborers replaced were equivalent to 41,000 persons (24% decreased)[21]. This would be a social problem if other economic sectors were not ready yet to accept laborers released from agricultural work.

However, there are still possibilities for farm mechanization to create new jobs in a village such as Gabuswetan and Anjatan in Indramayu. Examples that might emerge are selling, repairing, operating, and other businesses related to mechanization. Rural industry is also a possibility for creating new jobs, although it needs more skill and specialization.

This study summarizes that rice mechanization such as an engine-powered thresher in Indonesia, and particularly West Java, is accelerated by factor price (increasing wage rates). Decreasing laborers' income would not occur if the

---

[21] One hectare rice harvested crop required 35 persons to harvested and threshed manually, and required 28 persons if harvested manually and threshed by engine-powered thresher.

laborers that are displaced by the mechanization can find non-farm employment with equal or higher earning than remaining farm workers. Therefore, it would be dangerous if in a low wage environment, "premature mechanization" were encouraged by distortion such as subsidies to credit and thresher purchase. To avoid a significant loss in both efficiency and equity due to such premature mechanization, an optimal timing (rate of introduction) of thresher mechanization with respect to labor supply and demand is critically demanded. This optimal timing is needed to decide the optimal period to introduce farm mechanization, the magnitude and level of mechanization, and the rate in which mechanization should be introduced in order to avoid unnecessary losses in economy. A comprehensive policy action involving agricultural engineering research, extension, education, and training are therefore required to enhance mechanization development.

VII. CONCLUSION AND RECOMMENDATION

The following conclusions are based on farm survey, field experimentation, system modeling and analysis:

1. The rapid growth of rice production in Indramayu, West Java was the result of government efforts to create a favorable rice production environment and farmers' dynamic response to new opportunities to their productivity by using newly available technologies. These favorable conditions, including subsidies (at first phase) and price policies (increasing price of rice every year), lead the farmers to seek an alternative mechanization to reduce cost, drudgery, grain losses, and risk from late planting.
2. The rapid growth of mechanization of rice production in the beginning of 1970s (small tractors and rice milling machines) and in 1985 (engine-powered thresher) were the results of changes in relative prices, laborer wages, cropping pattern, and farm power available and subsidies.
3. A farm survey, conducted in the dry season in Indramayu West Java suggested that in the wet season 1989 thresher-hired farmers and pedal-thresher owners produced highest yield (5.5 t/ha), followed by the thresher-owners (5.3 t/ha) and the lowest yields was

the manual-farmers (5.2 t/ha). These average yield, however, was not significantly different at α=0.05. In contrast, in the dry season 1990, the yields across all the strata decreased. Pedal-thresher owner averaged 5.3 t/ha, followed by thresher-owner and thresher-hired farmers (4.9 t/ha), and the lowest yields was the manual-farmers (4.6 t/ha). These averages was statistically different at α=0.05. These yield differences were likely due to difference among the strata in the level of input used, and management practiced followed.

4. In the dry season 1990, field measurement of harvest and threshing losses indicated that sickle-harvesting (handcut) losses ranged from 5.0% to 7.4% of the pre-harvest yield and averaged 6.2%. The threshing rate of the hand-threshed method ranged from 39.2 kg/hr to 49.2 kg/hr and averaged 43.4 kg/hr. Threshing efficiency of the hand-threshed method ranged from 94.3% to 95.7%, and averaged 94.9% of the pre-harvest yield. The hand-threshed method produced an average grain purity of 87.8%, grain losses ranged from 2.2% to 5.4% of the pre-harvest yield and averaged 4.5%. Total grain losses of the sickle-harvesting/hand-threshed system averaged 10.8% of the pre-harvest yields.

5. The threshing rate of an engine-powered thresher (5 Hp) ranged from 251 kg/hr to 507 kg/hr, and averaged 377 kg/hr. Grain losses produced by the engine-powered thresher ranged from 1.7% to 3.8% of the pre-harvest yield. The grain purity of the engine-powered thresher ranged from 87.5% to 95.8%, and averaged 92.8%. The efficiency of the engine-powered thresher averaged 96.7% of the pre-harvest yield. Total grain losses of sickle-harvesting/engine-powered thresher system averaged 9.1%.

6. Based on the aggregate yield of 5.34 t/ha, and assuming losses were not included in the analysis, the sickle-harvesting/hand-threshed system provided net return to the harvest laborers (891 kg/ha) or 16.9% of the gross output, but achieve lower labor productivity (3.16 kg/person) and lower return to the land operators (4.45 t/ha). This system required 35.2 person/ha of harvest laborers. In contrast, the engine-powered thresher reduced the cost of threshing by 2.7%. This represented income that was transferred from the harvest laborers to the thresher owner. Harvest laborers on engine-powered threshed farms earned lower return (742.5 kg/ha) or 13.9% of the gross output, but achieved higher labor productivity on thresher owner farms (3.93 kg/person) and on thresher-hired farms (4.19 kg/person).

7. Assuming a 1% reduction made for system grain loss, the adjusted yields were 5.39 t/ha[22]. The cost for threshing that went to thresher owners was 149.7 kg instead of 148.5 kg, and total return for the owners was 4.62 t/ha instead of 4.57 t/ha. Similarly the harvest labor income was reduced to 748.5 kg/ha instead of 742.5 kg/ha, an increased 6 kg/ha for every 1% adjustment, but it remained 141 kg lower (Rp 29,610) when compare to traditional practice (891 kg/ha).

8. The optimization technique, developed by Gupta and Singh and applied in this simulation worked well. Result obtained using this optimization model suggested that the optimum size thresher for farms ranging from 1 to 10 hectares of harvested area was 0.5 t/hr. This suggested that the threshers used by farmers in Indramayu were an appropriate size. For larger size farms size (10 hectare to 20 hectares of harvested area), the optimal size thresher varied from 0.54 to 0.84 t/hr.

9. The Monte Carlo simulation suggested that at current working capacity, price, market interest rate and laborers wages, a thresher size of 0.5 t/hr with gasoline engine was profitable with an NPV Rp 451,000.,

[22] The aggregate yield was 5.34 t/ha. A 1% adjustment would make yield at 5.39 t/ha or 50 kg increase every 1% adjustment.

BCR 1.23, and IRR 26.4. The Net Annual Benefit (NAB) here was Rp 377,000. In this case, the probability that the NPV fell below 0 was less than 1%. However, the profitability of the thresher decreased if the gasoline power source of thresher was replaced by a diesel engine. This was due to the higher purchasing price of the diesel engine. For a diesel engine-powered thresher, the NPV decreased to minus Rp.-341,000.0, with a BCR of 0.88, and a IRR of 7.9%. The probability that the NPV was greater than 0 was only 6.5%, and it could only be reached were at least 140 t/year or 280 hour/year.

10. This analysis and the simulation results, shows that the change in threshing method from hand-threshed to engine-powered thresher was influenced by the high private profitability of the thresher ownership. In this case, the engine-powered thresher increased net return by decreasing threshing cost. This cost reduction resulted from a decreased in the amount of laborers required (20%), and lower threshing costs (2.7%), decreased grain losses (1.7%), and additional returns due to off-farm use (Rp 377,000 per year).

11. The simulation of the labor force in Indramayu (1988-1998) suggested that the size of the non-agricultural force increased 6.1% annually, while the size of agricultural force increased only 0.4% annually. In the period of 1998 to 2008 the agricultural labor force

will decrease by 1.3% annually. The absolute number of agricultural labor force will decrease after the year 1998, and by that time the agriculture share of the labor force will be only 46%.

12. The trend in the agricultural labor force in Indramayu suggested that the rice mechanization program in the period of 1988 to 1998 must give priority to enhancing the capacity to design mechanization technology that will be required in the period after 1998, when the agricultural labor force will decline. Research and development in agricultural engineering must focus on developing cost-reducing machines and other mechanization technology to anticipate the high-cost of labor that may occur in the future. In contrast, the extension programs for rice mechanization, prior to the 1998 must focus on providing farmers with a better understanding of machinery management practices for the farmers, and encouraging the improvement of village cooperatives for better machinery utilization.

The following recommendation are made for further study and actions regarding agricultural mechanization management:

1. Further study on harvesting/threshing system loss is needed in Indonesia to estimate the timeliness cost penalty due to delay in harvesting and threshing operation, and incorporate it into the optimization technique.

2. Additional analysis is needed to integrate the effect of subsidized and non subsidized credit, cost of extension and promotion, and level of profitability to the rate of adoption of the new mechanization technology for rice production. This proposed analysis will help to increase the understanding of social-economic aspects of mechanization diffusion and thereby strengthen the agricultural extension program in the country.
3. Credit for purchasing new thresher technology should be given only to the harvest laborers team in order to avoid harvest income loss but maintain benefit both to laborers and land owner through decreasing grain losses.
4. Government should encourage an effective repair and parts supply system. This will help to create an alternative job opportunity for farm workers displaced by mechanization and provide better support system for a continuous mechanization operation.
5. In areas where social and private gain from mechanization is high but serious loss of employment for labor follows, government actions are necessary to slow the impact on labor by increasing tariff and taxes on large size machines.

BIBLIOGRAPHY

BIBLIOGRAPHY

Abkin, M.H. and Manetsch, T.J. " Simulation Model of Southern Nigeria". IEEE Transaction on System, Man and Cybernetics, September 1972, pp. 474 - 485

Amjad, N., David Gee-Clough. 1983. Field Performance Evaluation of Rice Reaper. Agricultural Mechanization in Asia, Africa, and Latin America. Vol.14 No 4. pp 35-40.

Anonimous, 1989. Rice Post Harvest Losses Assesment in Yogyakarta, Indonesia. Department of Agricultural Engineering. Gadjahmada University. Indonesia.

Barker, R; Herdt, R.; and Rose, B.1965. The Asian Rice Economy. Baltimore. John Hopkins University Press

Binswanger, H.P. 1984. Agricultural Mechanization : A comparative Historical Perspective. Agricultural and Rural Development Working Paper 673. Washington D.c. World Bank.

-----------------.1980. The Economic of Tractor in South Asia. ADC, New York.

Buck, James R. , 1982. Risk Analyis Method Can Help Make Firms' Investments Less of Gamble. Industrial Engineering, Vol.14, No 11, pp35-41.

CBS (Central Bureau of Statistic). Annual Statistical Yea Book. Various Series. Indonesia.

DeGarmo E.Paul, William G. Sullivan, and John R. Canada. 1984. Engineering Economy. Seventh Edition. Macmillan Publishing Company. New York. Collier Macmillan Publisher. London.

Djojomartono, M. 1979. Simulation to Evaluate Alternatives Post Rice Production . Unpublish PhD. Thesis, Michigan State University.

Eriyatno. 1979. System Modelling on Rice Milling Technology in Indonesia. Unpublish PhD. Thesis, Michigan State University.

Esmay , M.L., and Hall, C.W. eds. 1973. Agricultural Mechanization in Developing Countries. Tokyo. Shin-Norinsha.

Esmay, M.L. 1988. Agricultural Engineering Techologi Development and Utilization with Emphasize on Post Harvest Mechanization in Indonesia. UNDP/INS/85/004. Directorate of Food Crops. Ministry of Agriculture. Indonesia.

Esmay, M.L., Soemangat, Eriyatno, and Allan Phillips. 1979. Rice Post Production Technology in the Tropics. An East-West Center Book from the East-West Food Institute. Published for the East-West Center by The University Press of Hawaii Honolulu.

Evenson, R.E. " Benefits and Obstacles in Developing Appropriate Agricultural Technology". In Agricultural Development in the Third World. Edited by C.K. Eicher and J.M. Staatz. Baltimore: John Hopkins University Press. 1984

Gaiser, David. 1981. Traditionla Rice Harvest Losses and Labor Value in Indonesia. Unpublish PhD Thesis Michigan State University.

Gupta, M.L. Gajendra Singh, and P.K. Gupta. 1986. "Mathematical Model for Selecting Wheat Threshing System for Farms in North India". Agricultual Mechanization in Asia, Africa and Latin America. Vol.17. No.2, 1986. pp 61-67.

Gittinger, J. Price. 1982. Economic Analysis of Agricultural Project. Second Edition, Completely Revised and Expanded. Published by the Economic Development Institute of The World Bank. The Johns Hopkins University Press. Baltimore and London.

Hayami, Yujiro, and Vernon W. Rutaan. 1985. " Agricultural Development in International Perspective". In Agricultural Development in the Third World. Edited by C.K. Eicher and J.M. Staatz. Baltimore: John Hopkins University Press.

Hayami, Yuyiro, and Kawagoe, Thoshihiko. Farm Mechanization , Scale Economies and Polarization. Journal of Development Economics. Vol.31, 1989, pp.221-237

Hunt, Donnell R. 1986. Engineering Model for Agricultural Production. The Avi Publishing Co. Inc. Westport, Connecticut

Ilangantileke, S.G. 1978. Post Rice Production System Analysis. Unpublish PhD Thesis Michigan State University.

JICA (Japan International Agency). 1982. Rice Post Harvest Survey in Indonesia.

Juarez, F, and Pathnopas R, 1981. " A comparative Analysis of Threshing Adoption and Use in Thailand and the Philippines. Working paper No. 28. The Consequences of Small Rice Mechanization Project. International Rice Research Institute, Los Banos, Manila. The Philippines.

Llewllyin, Robert W., 1965. FORDYN, An Industrial Dynamics Simulator. Raleigh, North Carolina, Privately Printed.

Liedholm, C. and Donald Mead. 1987. Small Scale Industries in Developing Countries: Empirical Evidence and Policy Implication. MSU International Development Paper No.9. Michigan State University.

Manetsch, T.J. and Gerald L. Park, 1976. Syatem Analysis and Simulation with Application to Economic and Social System. Part I and II. Department of Electrical Engineering. Michigan State Univesrity.

Nichols, F.E., 1974." Factor in Establishing Test Procedure Under Local Condition for Harvesting and Threshing Machinery". In the Report of the Expert Consulation Meeting on the Mechanization of Rice Production. International Institute of Tropical Agriculture, Ibadan, Nigeria, June 10-14.

Pingali, P.L.; Bigot, Y; Binswanger, H. 1986. Agricultural Mechanization and the Evolution of Farming System in Sub-Saharan Africa. Baltimore: John Hopkins University Press.

Ruttan, V.W. 1989. "Institutional Innovation and Agricultutral Development". World Development. Vol.17 No.9, September (pp.1375-1386). New York. Pergamon Pers.

Sarwar, J.G. and A.U. Khan, 1987. " Comparative Performance of Rasp-Bar and Wire-Loop Cylinders for Threshing Rice Crop". Agricultural Mechanization in Asia, Africa and Latin America. Vol.18 No.2. pp 37-42.

Schultjer, W.A. and M.G. van der Veen. 1977. Economic Constraint on Agricultural Technology Adoption in Developing Nations. The Pennsylvania State University. USAID Contract Number AID/CM/TA-147-442.

Singhal, O.P, and Thierstein. 1987. " Development of an Axial Flow Thresher with Multi-Crop Potential ". Agricultural

Mechanization in Asia, Africa and Latin America. Vol. 18. No.3. pp 57-42.

Soedjatmiko. 1983. " Learning from The History of Agricultural Mechanization in Indonesia" (In Indonesian). In Proceeding of the Seminar on the Consequences of Small Scale Farm Mechanization In Indonesia. Agency of Agricultural Research and Development. Indonesia.

Stevens D. Robert and Cathy L. Jabara. 1988. Agricultural Development Principles. Economic Theory and Empirical Evidence. Baltimore and London. The John Hopkins University Press.

Sullivvan, William G and R.Gordon, 1982. Monte Carlo Simulation Analysis Alternatives in Uncertain Economy. Industrial Engineering, Vol.14, No 11. pp35-41.

Timmer, C.P. 1984." Choice of Techniques in Rice Milling on Java." and Reply. In Agricultural Development in the Third Worls, edited by C.K. Eicher and J.M. Staatz. Baltimore. John Hopkins University Press.

Timmer, C.P.; Falcon, W.P.; and Pearson, S.R. 1983. Food Policy Analysis. Baltimore: John Hopkins University Press.

World Bank. World Development Report. New York, Oxford Univeristy Press. Various Series.

World Bank. Agricultural Mechanization. Issues and Options. World Bank Policy Issue, 1989.