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SYSTEM MODELING ON RICE MILLING
TECHNOLOGY IN INDONESIA

By

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ABSTRACT

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TECHNOLOGY IN INDONESIA

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Eriyatno

Three computer models were developed to simulate the regional rice mill operations. The first model was designed to estimate rice mill losses. Field and laboratory measurements of rice milling performances were analyzed and equations were developed for constructing the systems model. The rice mill model estimated the average mill losses in Indonesia to be 4.8 percent of rough rice production or about 3.1 percent of milled rice. The model showed that rice milling mechanization could appreciably reduce mill losses while also increasing mill yields. Improvement of pre-mill drying and grain cleaning facilities could improve the milling yeild by 2 percent and reduce the mill loss by 2.2 percent.

The second systems model was designed to forecast the regional rice mill production. Secondary data on harvested areas and yield per hectare were used in generating the dynamic model. The average annual increase of milled rice in Indonesia was projected to be 2.6 percent with the assumption that the post harvest technology was fixed. The total post harvest losses were estimated to be from

15 to 20 percent. Half of these losses were due to storage practices.

The third systems model was an optimization computer program designed to evaluate the regional mill capacity and distribution within a region, based on a financial analysis. The model was applied to the subdistricts of Ciomas and Ciawi in West Java province. Field study was conducted to compile data for model verification.

The model indicated an over capacity of mechanized mills in Ciomas and an under capacity in Ciawi. The simulation results showed that the simplest technology, the Engelberg Steel Huller and Rubber Roll Huller were generally more favorable for a mill mechanization plan. However, the milling quality consideration could shift the technology. Once the optimal condition was achieved the model forecast that the regional mill capacity in Ciomas should be increased by 3 percent and in Ciawi by 8 percent per year in consequence of the annual increase of regional rice production.

Approved by

Major Professor

Department Chairman

Dedicated to my late mother

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CHAPTER I

INTRODUCTION

Since 1950 Indonesia has been importing from 500,000 to 2,000,000 tons of rice per year. With the population growth rate at an average of 2 percent per year and more people preferring rice as their staple food, the rice consumption consequently increased from between 3.6 to 4.6 percent per year. The application of high yielding variety, fertilizer, better irrigation and expansion of new planting areas, was estimated by the Central Bureau of Statistics (BPS) of Indonesia to contribute only about 1 to 2 percent in increasing harvested paddy fields and 2 to 3 percent in increasing the yield per hectare. Considering this trend, it seems that the future situation will never be enough to reach a self supporting level for this 130 million people nation. Hence, alternative efforts must be introduced, and one of them is the improvement of a post harvest technology.

The main objectives of the post harvest technology improvements are the reduction of grain loss, better food quality and by-product utilization. The grain loss is a major issue due to the fact that substantial amounts of food may be saved. The losses occur in field harvesting, threshing, drying, milling, storage and transportation. Various studies have been done to assess post harvest losses at different stages of operation (IRRI, 1977; Ilangantileke, 1978). In Asia, the losses have been estimated from 8 to 30 percent of the rice production and potential savings through improvement of post harvest practices may be up to 10 percent (Esmay _et al_., 1977). The magnitude of losses depends upon plant variety, specific regional condition, technology practices and equipment. A reliable estimate of grain losses is required so that new technology improvement may be applied effectively.

Grain milling operations have been treated as a major part of the overall post harvest development program. Rice milling includes the process of removing the hulls and bran from the rough rice to produce edible rice. The milling operation is closely related to rough rice drying and storage facilities. The milling output determines the food quality; therefore it highly affects the sales price. The business of rice milling has an important role within the regional food marketing and distribution systems. Dependable planning and control of the milling development program is critical in order to provide better food quality at a price within the peoples' purchasing power.

The milling process equipment ranges from the simplest pestle and mortar to complex automated systems. In Indonesia more than half of the rice milling was done by hand pounding in 1947. The introduction of small mechanical milling units in 1960 reduced hand pounding to about 18 percent in 1974 (Institut Pertanian Bogor, 1975) and to about 6 percent in 1977 (Post Harvest Survey - BPS, 1978). These changes may induce an unfavorable impact on labor displacement or fuel energy utilization.

The output of large mechanized rice mills with capacities of more than 1.0 ton of rough rice per hour has been decreased by nearly 50 percent in 1947 to 12 percent of the national rice production (IPB, 1975). The Post Harvest Survey done by BPS (1978) indicated that there has been a strong tendency to increase the small milling facilities in the rural areas such as: the Engelberg Steel Huller and the Rubber Roll Huller with capacities of 0.2 to 0.6 tons of rough rice per hour. The tradeoff between operational cost and milled rice quality might be the factor in evaluating this kind of development.

The survey by BPS (1978) indicated that almost 70 percent of the mechanical mill facilities in Indonesia were operated less than half of their yearly potential capacity. This low productivity indicates improper planning distribution of technology facilities. The size and site of most milling facilities was not appropriately proportioned to the given regional rice production. This situation has produced an extremely high competitive atmosphere among the millers with the result that many are going out of business. Among the survivors, more than half operate at a very low profit margin.

Selective mechanization must be introduced to improve technology for the needs of farmers, millers and consumers. The goal is to achieve such an appropriate technology within particular regional areas. Adequate regional factors and parameters must be identified for the construction and operation of goal-seeking systems. The systems approach can help provide useful results for the planning agencies. The millers also would be assured of a viable business.

The complexity of rice milling problems made it difficult to compare experimental treatments. To compare different technology systems under field conditions all variables should be held constant except the one being observed. As this is impossible to do in the real world, a computer modeling approach was used.

1.1 Objectives

1) Evaluate existing post harvest practices and problems, and identify the regional factors that affect the development of milling technology.
2) Develop a computer model for assessment of regional rice mill losses for various post harvest technology and under different weather conditions.
3) Construct a regional rice production model based upon post harvest losses, harvesting area, yield per hectare and various technology practices.
4) Design a regional mechanization model for rice milling with respect to regional rice production,

seasonal harvesting time, machinery performance and associated costs.

1.2 Methodology

One year of in-country research was carried out in Indonesia from July 1977 to July 1978. Two national field surveys were conducted during the dry and wet harvesting seasons to compile first hand information on recent post harvest practices and problems. Each survey consisted of data collection and on-the-spot observations. The surveyors interviewed farmers as well as mill operators and managers (see Appendix A). Respondents were selected by random sampling. This survey was sponsored by the Central Bureau of Statistics (BPS) of Indonesia and was executed by a multidisciplinary team consisting of 5 agricultural engineers, 6 food technologists, 5 staticians and an agricultural economist.

The survey included 11 rice production provinces in Java, Sumatra, Kalimantan, Sulawesi and Bali. A total of 1433 farmers were interviewed and 323 milling facilities were visited. Questionnaires were completed and samples of rough rice and milled rice were collected from farm storages, millers and markets. These samples were analyzed as to physical and nutritional quality at the Food Laboratory of Bogor Agricultural University (IPB).

Several experiments were done at the Rice Processing Center at Tambun and various processing facilities in West and East Java to measure machinery performances and identify milling losses. A regional mechanization program focused on the sub-districts of Ciawi and Ciomas near Bogor. Secondary data were gathered from research and governmental institutions. Technical discussion, consultation and seminars were also held.

The data were processed partly in Indonesia. The simulation modeling and computer application was done at Michigan State University. Numerical methods for polynomial regression was extensively used in formulating inter-relationships among variables. Optimization techniques were used in the selective mechanization model. The Fibonacci search method for minimizing functions with constraints was applied.

CHAPTER II

REVIEW OF LITERATURE

The design of rice milling technology systems involves the determination of post harvest losses at mill facilities, estimation of regional rice production and selection of appropriate mill machinery.

2.1 Post Harvest Loss

An FAO survey in 1977 indicated a lack of adequate quantitative and qualitative post harvest loss data. Reports from sixteen countries showed that no information was available. Reports from eighteen other countries provided only gross estimates, frequently with considerable disparity between minimum and maximum loss estimates; thus, reflecting conflicts of opinions and unrealibility of loss levels.

Post harvest losses of rice in Indonesia have been estimated from limited case studies by several institutions. The results have been quite unreliable. Losses have been found to range from 10 to 30 percent of total production. Table 2.1 shows some of the sketchy results. No current estimation of threshing losses was available.

Table 2.1: Estimated Post Harvest Losses in Indonesia in Percent of Milled Rice

Operation	A*	B**	C ***
1. harvesting	8.0	8.0	-
2. threshing	-	-	-
3. drying	2.0	2.0	-
4. milling	4.5	4.5	-
5. farm storage	5.0	4.0	-
6. non-farm storage	-	1.0	-
7. in-field transportation	-	2.0	2.72
8. off-field transportation	5.5	1.48-3.12	2.0
9. others	-	0.26-0.62	2.0

*USAID, 1971

**National Bureau of Logistics, 1974

***Central Bureau of Statistics, 1977

Grain losses may be classified into four catagories: First is mechanical loss from the mechanical operations of threshing and milling. The losses consist of broken kernels, unhusked rice, scattered and unthreshed grain. Second is loss due to rodent, birds, insects, chickens and other animals that intervene during the post harvest period. Third is loss caused by microorganisms such as fungi. Fourth is loss due to the environmental facturs such as temperature and humidity. Fermentation and other chemical deteriorations are included here. The wide variation within each catagory makes it necessary to have many measurements to be representative of actual losses (Brooker _et al_., 1975; Tuquero _et al_., 1977).

The available data on levels of loss usually are insufficiently detailed and inconsistently representative to reliably indicate all losses at all post harvest stages. It has been established that losses in farm storage are relatively high for corn and rice and that physical and processing losses are considerable for rice (FAO, 1977).

Esmay (1978) stated that attempts to reduce post production losses have been somewhat piecemeal through the introduction of various technological changes in different areas under various conditions. Seldom have these trial introductions considered the effect of all post harvest operations, the possible social cost of labor displacement, equitable income distribution and capital requirement.

2.2 Rice Production Estimation

Generally a rice production estimation is used to support the food policy and regional development program. Several methods have been introduced to calculate present and projectory production of rice within a regional boundary. The Central Bureau of Statistics of Indonesia (BPS) used the statistical approach forecasting method through various regression analysis of past data (BPS, 1978). Basically, the BPS formula for predicting rice production at a given time is:

RPROD (t) = AVHST (t) x YPHA (t) x (CONV - LOSS)

where,

RPROD = estimation of rice production, in milled rice

AVHST = harvested area, in hectares per unit time

YPHA = yield per hectare, in kilograms of dry stalk paddy

CONV = conversion from dry stalk paddy to milled rice (0.68)

LOSS = combined losses constant, transportation (0.0472) and feed (0.0136)

The milling conversion parameter which covered from dry rough rice to milled rice varied from 0.60 to 0.74 depending upon the moisture content of rough rice, milling techniques and quality of milled rice being produced (IPB, 1975; IRRI, 1977). Research conducted by Bogor Agricultural University (IPB) together with the BPS-proposed average mill conversion was 0.6455 with respect to the technological level in 1964. Table 2.2 shows some results of rice production estimation.

Techniques of forecasting usually include data on the smoothing process and on the stochastic model. Most of the agricultural production has seasonal fluctuations which should be considered in evaluating its historical data (Hughes, 1974; Tulu *et al*., 1974). Several growth patterns used in forecasting analysis have been implemented specifically (Forrester, 1964; Pimentel *et al*., 1976;

Table 2.2: Rice Production in Indonesia, Estimated in 1000 Tons of Milled Rice

Year	1*		2**
	Low	High	
1978	14,925	15,840	--
1979	15,344	16,382	--
1980	15,729	17,058	15,290
1981	16,123	17,728	--
1982	16,522	18,508	--
1983	16,925	19,195	--
1984	17,335	19,963	15,880

*BPS, 1978

**Schmidt, 1976

Goodman, 1974).

Kormondy (1969) explained that although growth trends are difficult to come by, there are enough studies on a spectrum of different kinds of plants and animals to permit the statement that most species show a sigmoidal pattern during the initial stages of their population growth. There is, in such cases, an initial slow rate of growth, in absolute numbers, followed by an increase rate to a maximum, at which point the curve begins to be deflected downdard. It terminates in a rate that gradually lessens to zero, as the population more or less stabilizes itself with respect to its environment (Forrester, 1968; Goodman, 1974).

2.3 Rice Milling

In order to visualize the effect of the milling process on rice, a brief understanding of the physical structure of the rice grain is very essential. In spite of varietal differences, such as short, medium and long grain varieties, the structure of the grain is virtually the same. The hull (lemma and palea) which is loosely attached to the edible rice grain within, is siliceous, hard and hairy. Directly beneath, but separated from it, and firmly attached to the starch body (endosperm) of the grain, is the bran coat or layer which is arranged in enveloping seven types of layers around the endosperm in the following order from outside in: (a) epicarp, (b) mesocarp, (c) cross cells, (d) tube cells, (e) spermodern, (f) perisperm and (g) alleurone layer. The actual weight portion of rough rice is 0.65 - 0.70 kernel (endosperm), 0.17 - 0.22 for hull and 0.08 - 0.09 for bran (Wratten _et al_., 1964; Myasnikova, 1969; Pandya, 1969).

During the process of milling, most of the hull and the outer six layers of bran is removed while some portion of the aleurone layer stayed with the edible grain. Grain with hull removed is known as brown rice. It contains more protein and vitamins than milled rice but it was reported to cause digestive disturbances. Milled rice is more attractive in appearance, requires less time to cook, and maintains quality longer in storage than brown or undermilled rice, which becomes rancid easily. Nowadays, the milling business is an essential part of food production, either as a rural industry or on a greater commercial scale (Camacho et al., 1978; Yasuma, 1972).

2.3.1 Equipment and Practices

A good rice milling operation should 1) produce the maximum yield of edible rice, 2) obtain the best possible quality, 3) minimize losses and 4) minimize the processing cost. Modern rice mills will produce some 5 to 10 percent higher output of milled rice than traditional mills. Furthermore, the head yield of milled rice increases and the losses are minimized (Esmay et al., 1977).

However, there are other factors involved. These are: moisture content of the rough rice, the condition of the grain as to checks and cracks previously incurred by improper harvesting, threshing, handling and drying methods. The most neglected basic requirement for improving the output of milled rice in the tropics is to have a good condition of the input rough rice (Van Ruiten, 1975; Timmer, 1972). Percentage of seedless grain, which is approximately 2.0 to 5.5 percent, and foreign material content which is approximately 0.5 to 2 percent, also affect the mill output. Proper grain drying and cleaning may improve this condition (IPB, 1975).

The heterogenity of mill types used in the tropics causes considerable variability in the ratios of milled rice recovery and head rice yield. Table 2.3 presents some data on the efficiency of five milling operation systems.

U Thet Zin et al. (1974) suggested that the milling efficiency should more appropriately be made on the milling process rather than on huller types such as the steel huller, disc huller or rubber roll huller. Many of the rice mill systems in the tropics do not have a complete line of standard components such as rough rice cleaner and separators. Table 2.4 shows the separate milling processes on various combinations that may be found in the system. The recovery of milled rice generally increases with the addition of component parts. Column J represents a complete and complicated milling found in the modern rice milling industry, which generally has a capacity of more than 3 tons of rough rice per hour.

2.3.3 Selective Mechanization

Giles (1973) stated that only some machines when used in some farming situations and under some management expertises contribute significantly to increase yields. Giles introduced selective mechanization term as that is selective in machines, farming situations and managers.

Table 2.3: Milling Process Output in Percent of Rough Rice

Specification	Husk	Bran	Total Husk+Bran	Milled Rice Head	Milled Rice Broken	Milled Rice Total
Hand Pounding	--	--	40(1)	40(1)	20(1)	60(1),60.5-64.4(3)
Engelberg Steel Huller	--	--	36.6(1)	46.5(1)	16.9(1)	63.4(1),65.6(3)
Disc Stone Mill	--	--	32.5(2)	55.9(2)	11.6(2)	67.5(2)
Rubber Roll Huller	22(2)	8(2)	30(2)	62(2)	8(2)	70(2),65.2-66.1(3)
Rice Mill Plant	--	--	--	59.5(3)	--	61.1 - 62(3)

(1) Timmer, 1972

(2) Duff, 1972

(3) IPB and BPS, 1974

Table 2.4: Classes of Milling Facilities

Standard Process	Class									
	A	B	C	D	E	F	G	H	I	J
a. Grain Cleaner					x	x	x	x	x	x
b. Stalk paddy thresher									x	x
c. Rough Rice grader									x	x
d. Huller	x	x	x	x	x	x	x	x	x	x
e. Husk separator		x	x	x	x	x	x	x	x	x
f. Rough rice separator			x	x	x	x	x	x	x	x
g. Polisher, first stage				x	x	x	x	x	x	x
h. Polisher, second stage							x	x	x	x
i. Milled rice grading						x	x	x	x	x
j. Grain conveyor										x

Source: Esmay et al., 1977.

Pinches (1956) stressed that an agricultural engineer concerned with the integration and balancing of a system will be involved in economic relationships as well as physical and biological judgment.

There is evidence that many rice post production systems in the tropics have been improperly planned (Rawnsley, 1972; Weitz-Hettelsater, 1972). There are a total of 31,698 rice milling facilities in Indonesia in 1978, with 940 having about 12.8 milled rice tons per year capacity and 30,758 small mills having 1.2 milled rice tons per year. Recently, about 40 percent of the large mill facilities were out of business and most of the remainder were not operating in full capacity (Post Harvest Survey, BPS, 1978).

The mill location, type and size of equipment are critical for effective planning. Weitz-Hettelsater consulting engineers recommended only large capacity, capital rich, labor efficient mills for Indonesia, which has limited capital and a surplus of labor. Also, most developing countries have a very limited supply of managerial and skilled labor necessary to operate complex plants. Planning for post-production operations must be done in a systematic way to realistically consider all available human, physical and economic resources. The total transfer of complex rice mill systems from developed countries has seldom proved satisfactory (Esmay, 1977).

An effective method for evaluating development programs is required which incorporate a comprehensive analysis of all relevant factors and parameters, and which provide for iterative redesign of the development program as changes occur in its operating environment. System analysis including abstract modeling and computer simulation have a potential for meeting the requirements (Faidley and Esmay, 1974). Through such a system, bottlenecks can be more readily identified, knowledge and action gaps disclosed, interactions estimated, institutional and organizational defficiencies pinpointed and alternate pathways considered (Cox, 1975).

Koenig (1976) mentioned that the theoretical concepts in simulation, stability, control, optimization and other basic concepts of system science depends only upon the mathematical forms of the model and not the particular identification on meaning associated with the variables in the model. Manetsch (1976) stated that in developing simulation models there are three critical factors to consider: 1) the appropriateness of the problem for modeling; 2) the relevancy to the real world and whether the problem is worthy of investigation; and 3) sufficient familiarity with the subject matter of the problem to make the study feasible.

Validation is required once the modeling is completed to determine whether the model represents the real world satisfactorily. Optimization results in the specification of the best combinations of system parameters and controllable inputs which satisfy the needs given the constraints placed upon the system (Beveridge, 1970). The primary objectives of modeling an existing system is to provide a method of evaluating alternative management decisions and thus develop an optimum strategy for operating or altering the system in a rapidly changing economic and physical environment (Bowers, 1970; Hare, 1967).

2.3.3 Selection Criteria

The selection criteria used in machinery systems design is most often an economic one, i.e. least cost or maximum profit (Singh, 1978; Burrow and Siemens, 1974). To be considered are machinery, labor and timeliness. Estimating methods will vary somewhat. Different assumptions will be made regarding equipment life, repair cost and trade-in values. Cost estimates will not all agree (Hinz, 1972).

The choice of milling technique criteria employed by Timmer in Indonesia (1972) was:

$$\mathrm{MIN}_k \quad \frac{X_k^k + \sum_{t=1}^{50} \frac{W_k X_{kt}^e}{(1+i)^t}}{P^k X_{kt}^k - P^g X_{kt}^g}$$

X_k^k - capital cost of the total investment in the k-th technique, assumed to be fully incurred in year zero

W_k - wage paid in technique k

X_{kt}^e - total number of workers employed by the k-th technique in year t

X_{kt}^g - quantity of rough rice used by k-th technique in year t, assumed constant over time

X_{kt}^k - quantity of milled rice of type k produced by technique k in year t, assumed constant over time

P^k - market price of type k rice

P^g - market price of rough rice

In order to more explicitly explore the implication of social discount rate on the choice of the technique in rice processing in Indonesia, Warr (1975) used the following decision criterion:

$$\underset{k}{\mathrm{MAX}} \quad \frac{N_k}{X_k^G}$$

N - net present value of the stream of agregate consumption generated by production using technique k

X - quantity of rough rice milled by technique k

Spencer _et al_. (1976) used a continuous linear programming model to determine the optimum technique, size and location of rice processing facilities in Sierra Leone, Africa, under various conditions. Processing, as well as assembly and distribution or transportation costs, are explicitly taken into consideration in examining the effects of alternative policy choices on employment, milling output and income.

Timeliness is a measure of ability to perform a job at a time that gives optimum quality and quantity of product. If the machine system does not have enough capacity to perform the job with desired results, the value of production loss is considered an economic penalty for poor timeliness (Singh, 1978; Tulu _et al_., 1974). Esmay (1977) proposed four steps of planning rice processing systems which are: mill site selection, equipment selection, storage facilities, and marketing and distribution.

1. <u>Mechanical Mill Production Capacity.</u> The paddy harvesting pattern is of great importance in planning a procurement program. Milling, handling, storage and transportation must all be balanced properly to provide a constant milling and market supply. Storage requirements must be planned based upon the seasonal availability of paddy. The more distributed the harvest is throughout the year, the lower are the storage requirements and vice versa (Spencer *et al.*, 1976; King *et al.*, 1964).

Excess capacity in the rice milling industry is the most marked feature. Because rice production is seasonal it is very difficult to determine the capacity of rice millers. In Indonesia, capacity utilization for medium and large mills was estimated on a basis of 200, 12 hour working days a year. In the mid 1950's, at this level, operation was about 50 percent of potential capacity (IPB, 1975).

Excess capacity affects profitability and hence new investment. The medium and large mills sometimes compete for the farmers trade by favorable credit treatment and higher prices for paddy to keep the mills in operation and retain skilled workers; but where the government administers food prices, the opportunities for such competition are limited. From time to time available paddy in each region is shared out among mills (IBRD, 1969; Collieer *et al.*, 1974).

2. <u>Distribution of Mill Technology</u>. If a specific

set of machinery is used to perform a set number of operations on a farm level of a given size, the annual use of each machine, as well as its fixed and variable costs, can be estimated. Several sizes of farm machinery sets could be simultaneously evaluated. As the size of the machinery set increases both productivity and initial price increase together with the annual machinery costs (Hughes, 1974). As a means of prediction, budgeting and control of costs, the concepts of fixed and variable costs can be helpful (Smith, 1973).

Variable costs increase proportionately with the use of machines, while fixed costs are independent of use. The costs of interest on machinery investment, taxes, housing and insurance are dependent on calendar year time and is independent of use. The cost of fuel, lubrication, daily service and maintenance are associated with use. Depreciation and cost of repairing seem to be a function of both use and time. But, most often depreciation is included in the fixed cost catagory, and repair cost in the variable cost catagory (Hinz, 1972; Burrows, 1974)

There are many levels of sophistication in calculating approximate costs. For predicting future costs of either new and used farm machinery which are intended to be used normally, the use of annual fixed cost percentage method is adequate. Total cost per year of farm machinery could be computed in several interrelated equations (Bowers, 1970):

ACOST = FCP x BUY + (REPAIR + LABOR + FUEL + OIL) x WORK

FCP = DEP + XINT + TIS

DEP = (BUY - SALV) / XLIFE

XINT = ((BUY + SALV) / 2.) x IRATE

where,

ACOST - annual cost for operating the machines

FCP - amount of annual fixed cost percentage, in decimal

BUY - initial purchase of the machine

WORK - annual use of machine, in unit time

REPAIR - repair and maintenance costs, in decimal of purchasing price per unit time

LABOR - labor wage

OIL - lubrication cost

FUEL - fuel and electricity cost

DEP - depreciation cost, straight line method

XINT - interest of investment

SALV - salvage value, usually 0.1 x BUY

XLIFE - lifetime of the machine

IRATE - interest rate

TIS - combined cost of taxes, insurance and shelter, in decimal

CHAPTER III

MILLING LOSS MODEL

A grain loss for a specific stage of the post harvest process is defined as a percent by weight of the input and is expressed as follows:

$$(\mathrm{LOSS})_n = \left(\frac{\mathrm{E(OUT)} - \mathrm{AOUT}}{\mathrm{INPUT}}\right)_n$$

where,

E(OUT) = expected weight of output or maximum conversion

AOUT = actual weight of output

n = stage of post harvest process

The milling of rice operations has an input of rough rice and an output of edible polished rice. The mill loss simplified relationship can be represented as:

$$\mathrm{E(MILOSS)} = \mathrm{E(CONVER)} - \mathrm{YREND}$$

where,

E(CONVER) = expected value of mill conversion, which relates to the condition of input material

YREND = actual mill yield, with regard to mill technology and milled rice quality

Direct measurement of mill loss is impossible as one sample of rice cannot be milled two different ways. The system modeling then is used as the estimation method. Based on the mechanics of mill and better grain handling and separator devices, the more modern the rice milling technology the less mill loss expected. Pre-milling operations such as grain drying and grain cleaning practices affect the condition of rough rice entering the mill facility and thus the mill loss.

3.1 System Constraints and Desirable Model Characteristics

1. The model should be able to represent a wide range of regional conditions with respect to geographic boundaries and the climatic factors of relative humidity and dry-bulb temperature.
2. The model should be able to take into consideration the probabilitistic nature of the weather factors that effect the mill conversion, and the distribution of input materials to the mill facilities.
3. The model should be able to handle any practical mix of mill practices and equipment.
4. The model should include the effects of pre-mill operation, which are the drying and cleaning practices.
5. The regional mill loss should consider the climatic condition differences between lowland (up to 10 meters from sea level) and upland regions.

3.2 Input Data

3.2.1 Weather Factors

The monthly averages for relative humidity and temperature were computed from several weather stations in each province from time series data between 1967 and 1977, and were compiled by the National Meterological Institute of Indonesia. Monthly variation in each province is expressed in polynomial regression equations.

Table 3.1 shows that the climatic factors differ from region to region, therefore the climatic data will be based on regional input. The system modeling assumed that the probabilistic behavior in weather simulation will be on a normal distribution pattern.

Table 3.1: Regional Climatic Factors, Yearly Average

Province	Low Region		High Region	
	Temp. (^oC)	RH (%)	Temp (^oC)	RH (%)
North Sumatra	26.85	84.15	24.79	84.35
Mid-Sumatra	26.03	85.19	25.21	83.21
South Sumatra	26.73	84.34	25.86	82.92
West Java	26.40	78.74	23.88	81.19
Middle Java	26.28	79.78	24.63	84.42
East Java/Bali	27.41	76.92	24.61	79.81
South Sulawesi	26.04	80.09	23.38	80.89
North Sulawesi	26.16	83.76	25.93	83.95
South Kalimantan	27.13	76.00	27.08	84.57

3.2.2 Moisture Content of Rough Rice

The moisture content of rough rice, when exposed to a given environment, will reach an equilibrium value with respect to the ambient temperature and humidity. The Henderson equation (1952) fixes the equilibrium moisture content relationship with environment as:

EQDB = EXP(ALOG(ALOG(1. - RH)/(-c x TEMP))/n)

where,

RH = relative humidity, in decimal

TEMP = absolute temperature, in ^{o}K

EQDB = grain moisture content, in percent dry basis

c and n = parameters, grain characteristics, dimensionless

Rough rice has c and n values of 8.82×10^{-6} and 2.22 respectively (IPB, 1976). Figure 3.1 illustrates the equilibrium moisture content curve for rough rice at $25^{o}C$ ambient temperature. The model was verified with laboratory experimental data and shows that the curve has a good fit between 45 and 95 percent relative humidity.

3.2.3 Mill Conversion Curve

Mill conversion was evaluated as percentage of head rice or whole kernel and broken rice to total input. Broken rice was defined as less than three quarters whole kernels. Fine broken rice which is less than a quarter whole kernels and known as brewer rice or "menir," was

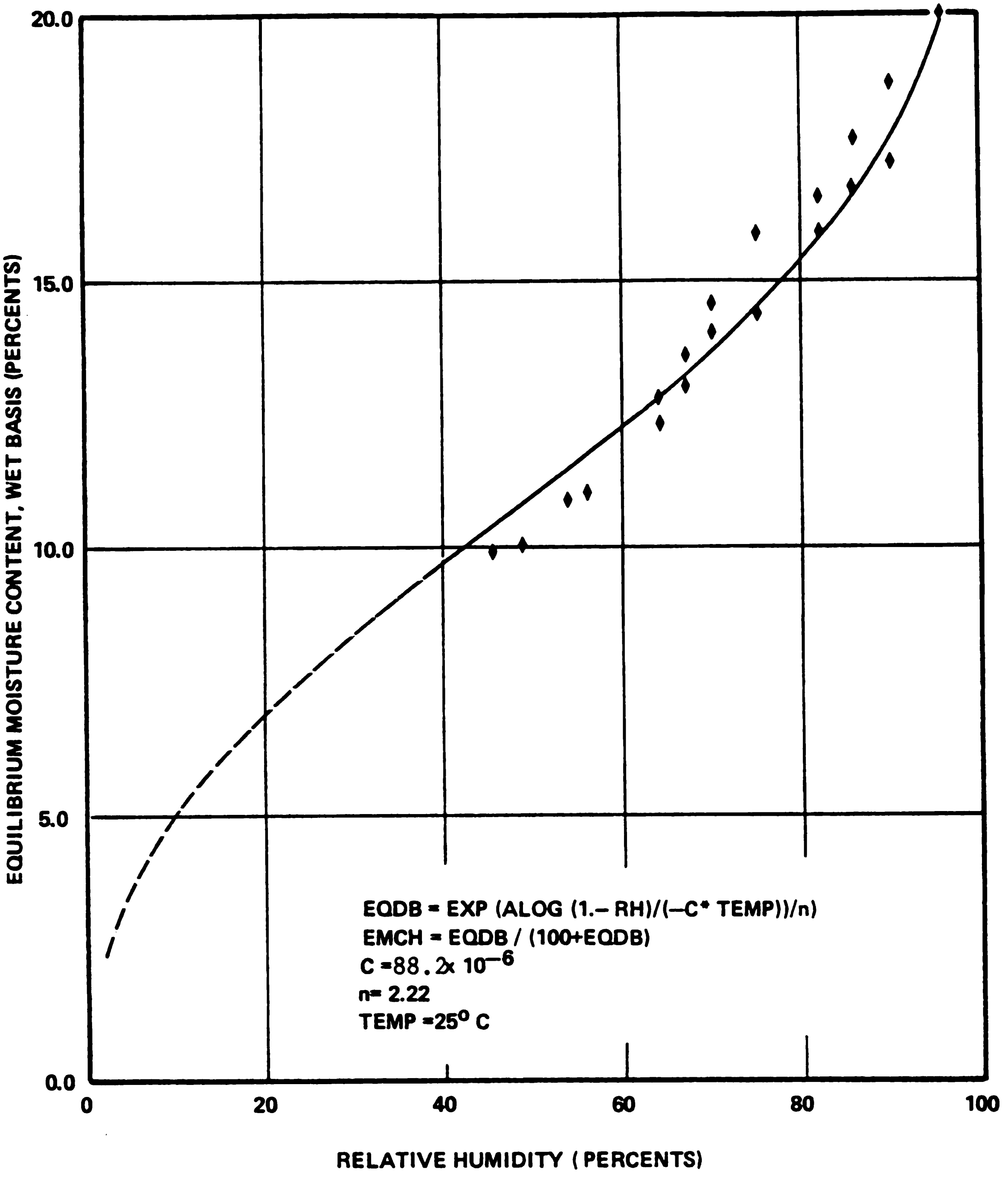

Figure 3.1: Equilibrium Moisture Content Curve Ambient Temperature = 25°C.

considered as a by-product of the mill operation. The mathematical relationship between rough rice moisture content and mill conversion was developed from laboratory experiment data. These equations were generated by non-linear numerical methods.

$$CRHEAD = -0.288790 + 18.715072 \times RRMC - 123.970912 \times RRMC^2 + 257.996278 \times RRMC^3$$

$$CRBROK = 1.297751 - 26.421624 \times RRMC + 181.129922 \times RRMC^2 - 392.976923 \times RRMC^3$$

where,

CRHEAD = percentage of head rice, in percent of rough rice

CRBROK = percentage of broken rice, in percent of rough rice

RRMC = rough rice moisture content, in percent wet basis

Figure 3.2 shows that these equations were valid between the moisture content range of 9 to 19 percent. The rough rice moisture content normally falls within this range for milling. The simulation stated CRHEAD has a standard deviation of 0.5 percent and CRBROK has 0.6 percent.

3.2.4 Milling Yield

Five levels of milling technology are considered for the evaluation of milling yield performance. They are:

1) The traditional method of Hand Pounding (HP).

2) The Engelberg Steel Huller (ETH). The hulls are

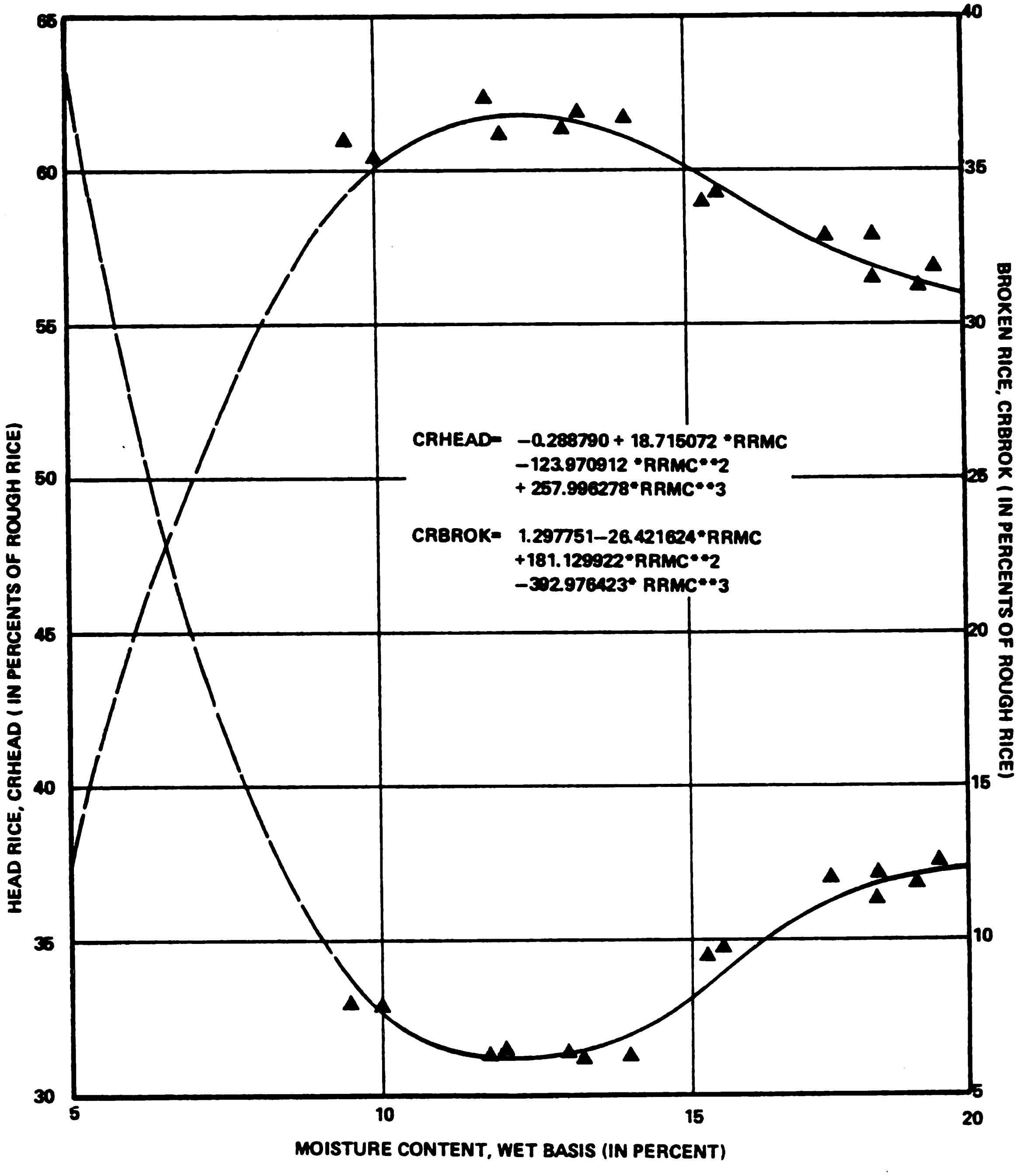

Figure 3.2: Milling Yield Curve

removed and some polishing takes place by the shearing action between the kernels and the movement of the steel roller. Axial flow movement of rough rice is accomplished with a truncated screw conveyor. A mix of milled rice, bran and hulls is delivered from the huller output.

3) The Rubber Roll Huller (RRH). The hulling element consists of two closely spaced rubber rollers which rotate in the same direction and at different speeds. The machine usually is combined with a steel polisher.

4) The Rice Mill Unit (RMU). The unit consists generally of a rubber roll husker, a steel polisher, grain separators, a husk separator and a brewer rice grader. The rice mill unit usually has grain drying and storage facilities.

5) The Rice Mill Plant (RMP). The rice mill plants generally include mechanical drying, mechanical handling equipment, and storage and modern rice milling machinery. Modern mill machinery consists of efficient grain cleaners, rubber roll hullers, various separators, cone type abrasive polishers, bran separators and grinding equipment.

Schematic illustrations of various types of mechanical mill machinery are shown in Figure 3.3 to Figure 3.6.

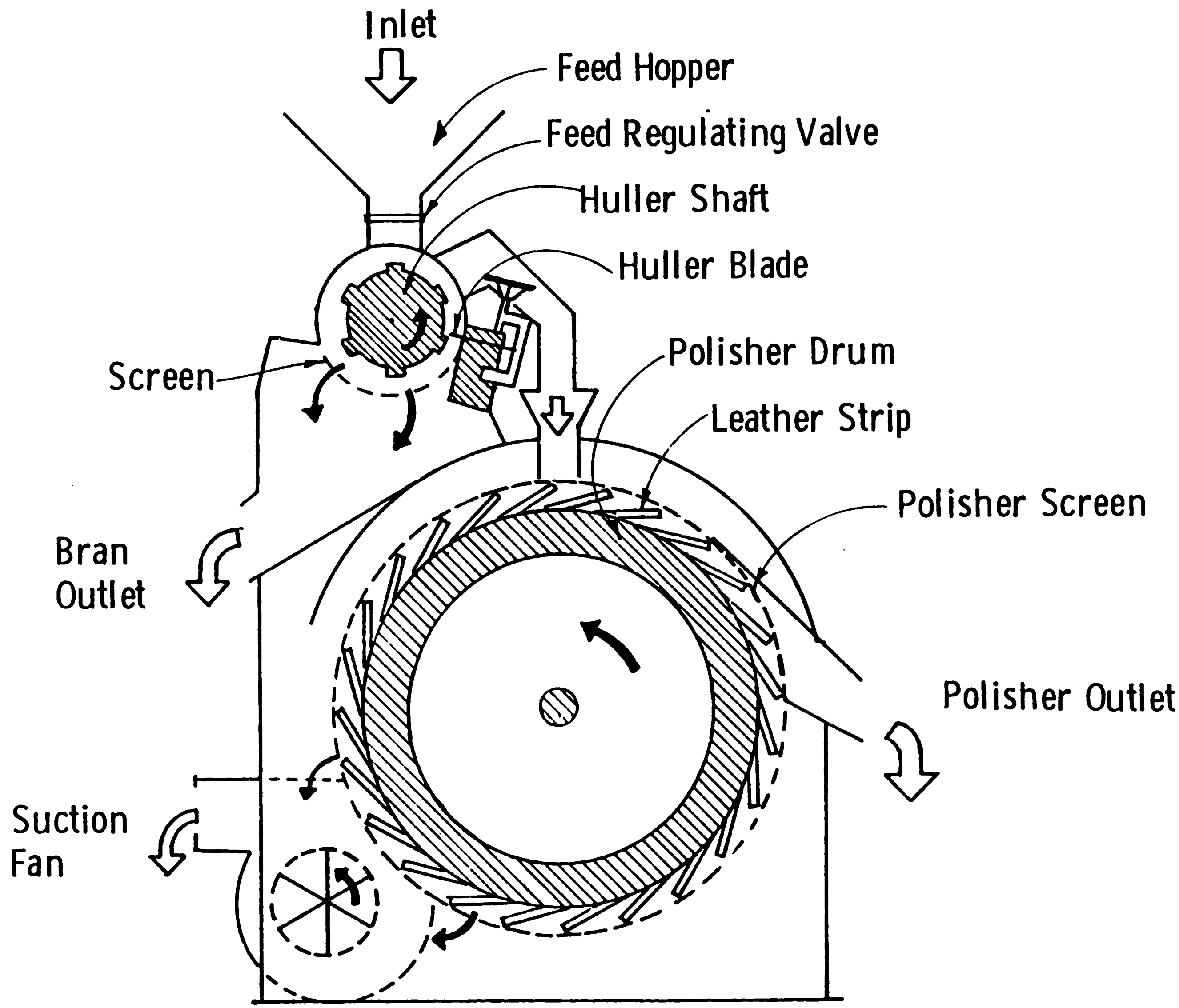

Figure 3.3: Schematic Illustration of an Engelberg-Type Huller (Above) With a Polisher (Below). (Esmay et al., 1978)

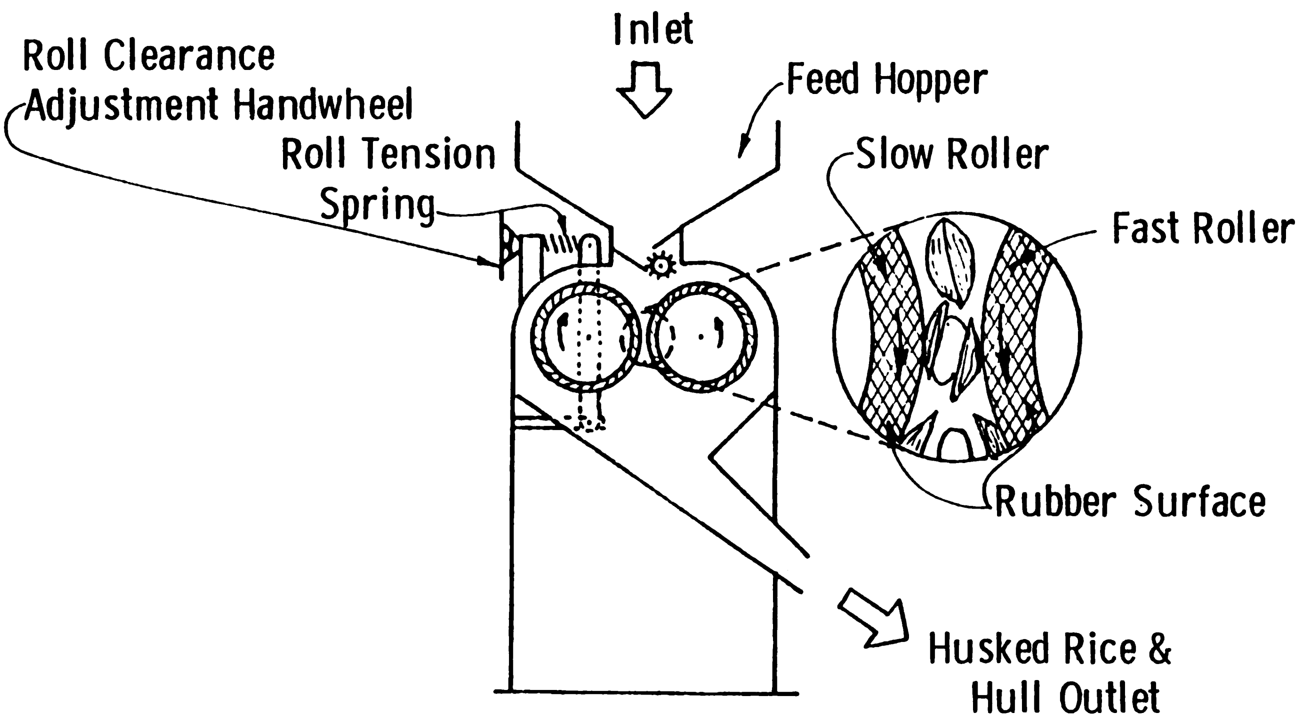

Figure 3.4: Schematic Illustration of Rubber Roller Huller. (Esmay et al., 1978)

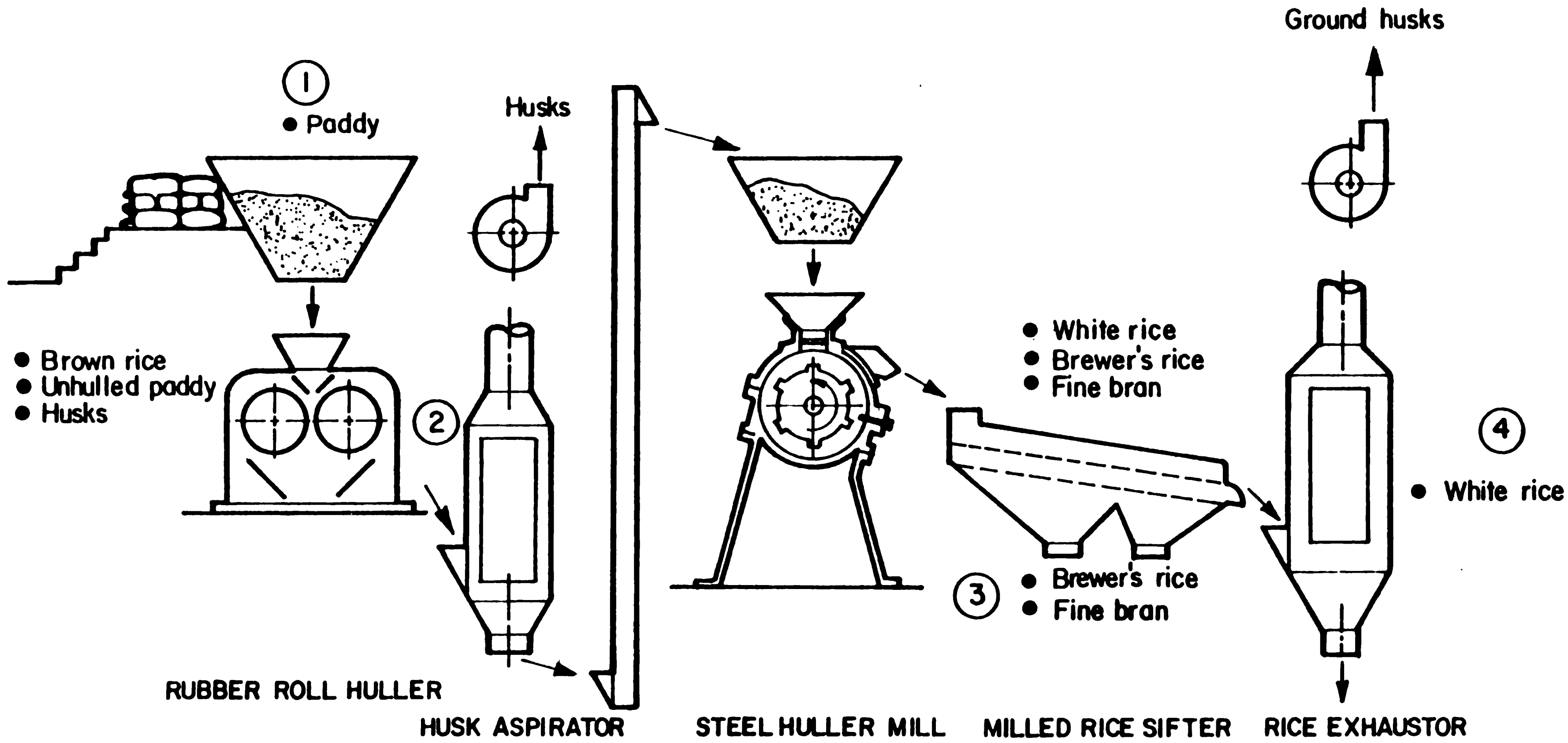

Figure 3.5: Schematic Layout of Rubber Roll-Steel Huller Mill Rice Mill Unit (IRRI, 1978).

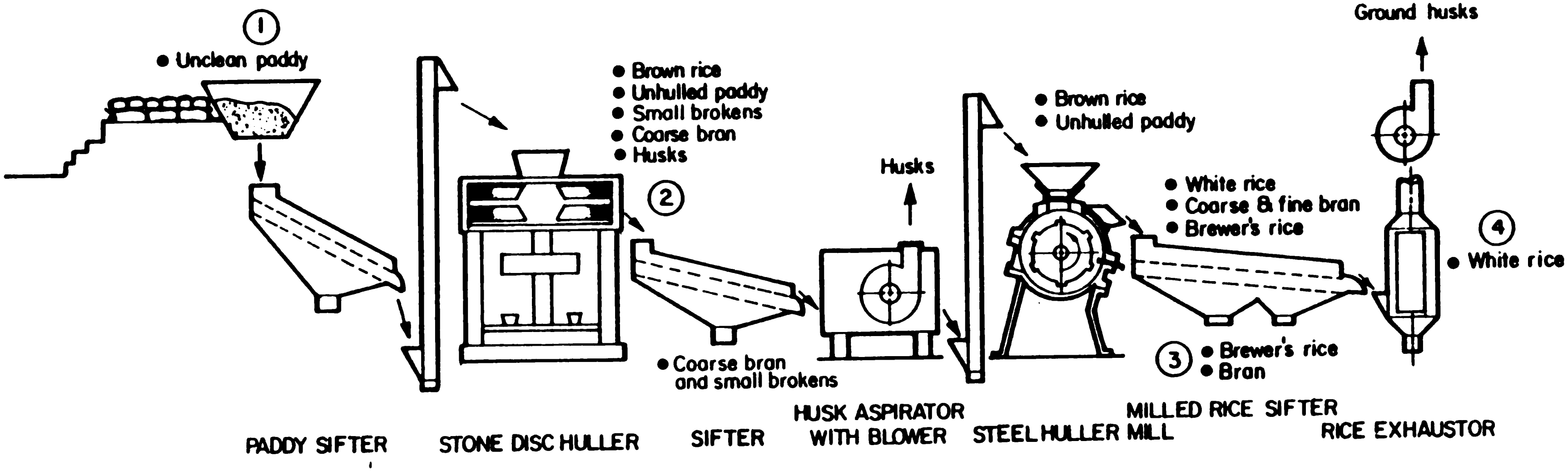

Figure 3.6: Schematic Layout of Stone Disc-Steel Huller Mill, Rice Mill Plant (IRRI, 1978).

The effect of mill technology level on the milling yields for both wet and dry seasons is given in Table 3.2. These data were generated from several experimental studies by Bogor Agricultural University and the Central Bureau of Statistics from 1974 to 1977 (IPB, 1975; BPS, 1977). The average value was computed as (Hundsberger, 1973):

$$\overline{X} = \frac{\sum_{i=1}^{k} n_i \times X_i}{\sum_{i=1}^{k} n_i}$$

where,

n = numbers of sample on experiment i

X = average value on experiment i

i = index of experiment number

The standard deviation joint estimate is:

$$S^2 = \frac{\sum_{i=1}^{k} (n_i - 1.) \times S_i^2}{N-k}$$

where,

$$N = \sum_{i=1}^{k} n_i$$

S_i = standard deviation on experiment i

k = numbers of experiment being considered

Table 3.2 shows that the milling yield is less in the wet season. This may be caused by a higher moisture content of rough rice due to humid weather. Rice losses during processing would have to be related to the method of drying and moisture levels and the precise type of

Table 3.2: Milling Yield Performance in Percent of Rough Rice

Technology	Wet Season		Dry Season		Average	
	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
HP	60.51	7.86	64.37	8.72	61.86	8.16
ETH	65.67	5.89	65.33	5.30	65.02	3.52
RRH	65.23	7.20	66.09	4.87	65.45	6.69
RMU	62.13	6.22	63.80	6.91	62.61	6.59
RMP	62.10	5.21	61.39	3.06	61.90	4.66

equipment used (FAO, 1977).

The distribution of rice mill technology in each province is presented in Table 3.3 based on the data collected fromthe Post Harvest Survey done by BPS (1977-1978). The table values represent the percentages of rough rice milled by each technology within the region. These values were used as distribution factors in the model to compute the regional milling yield.

Seedless grains (YNOSED) and foreign materials content (YDIRT) were also accounted for in the input materials. The survey data (see Appendix A) determined that the average value of seedless grains content for Sumatra was 5.1 percent, for Java 5.5 percent, and for Kalimantan and Sulawesi 6.4 percent. The average value of foreign material content for Sumatra was 0.5 percent, for Java 0.6 percent and for Kalimantan and Sulawesi 0.7 percent.

Table 3.3: Distribution of Mill Technology (in percent)

Province	HP	ETH	RRH	RMU	RMP
North Sumatra	1.7	65.0	3.3	0.5	29.5
Middle Sumatra	9.8	63.0	12.5	1.6	13.1
South Sumatra	13.8	70.1	7.7	2.1	6.3
West Java	1.5	23.8	51.0	10.0	13.7
Middle Java	2.9	12.0	63.1	13.3	8.7
East Java/Bali	3.1	27.3	41.6	12.5	15.5
South Sulawesi	0.7	43.8	50.0	0.6	4.9
North Sulawesi	0.0	82.8	17.9	0.0	0.0
South Kalimantan	0.0	79.9	10.6	1.3	8.2

3.3 System Design

The stochastic of weather inputs and milling performance were captured in the system model from the random variable generator with Normal and Gamma distribution. The averaging process of simulation results was done with the Monte Carlo technique (Manetsch, 1977). A black box concept of the mill loss model as designed is illustrated in Figure 3.7.

Computer programming consists of the main program (MILOSS) and five subroutines (CONVERT, RENDEMN, MOISTC, MILCON and GAMMA). The general flow diagram is shown in Figure 3.8. The system was operated under the assumption that normal mill operation existed, hence normal

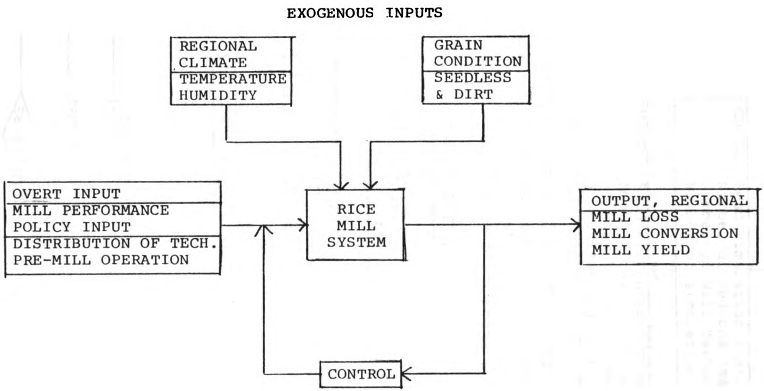

Figure 3.7: Mill Loss Model

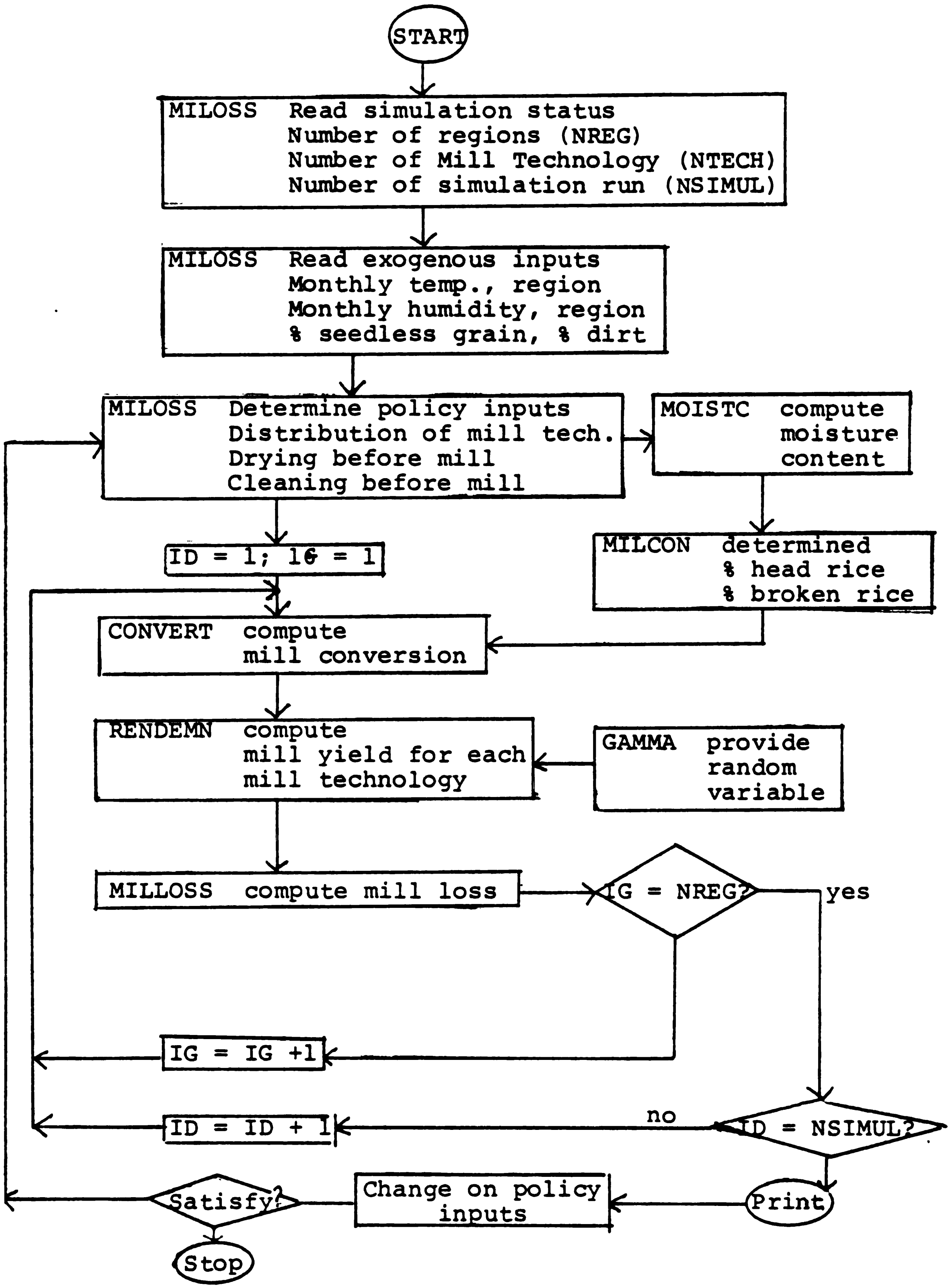

Figure 3.8: Simplified General Flow Diagram, Mill Loss Model

distribution patterns could be introduced for the mill performance.

3.4 Model Implementation

3.4.1 Rough Rice Moisture Content

The model simulated the climatic factors in each region and then computed the monthly average for rough rice moisture content. Model verification was done with actual laboratory moisture content measurements of samples taken from each province. Table 3.4 shows that the simulation data closely represents the actual condition for modeling purposes. As expected, humid regions do produce higher moisture content rough rice.

Table 3.4: Rough Rice Moisture Content, Yearly Average in Percent Wet Basis

Province	Simulation		Samples		
	Ave.	SD	Ave.	SD	n*
North Sumatra	15.36	0.12	15.56	1.24	122
Middle Sumatra	15.12	0.01	14.74	1.64	125
South Sumatra	15.17	0.07	13.41	0.88	143
West Java	14.48	0.04	14.47	0.49	137
Middle Java	14.35	0.04	14.40	1.33	118
East Java/Bali	14.26	0.04	14.25	0.89	281
South Sulawesi	14.40	0.04	14.54	0.74	105
North Sulawesi	15.24	0.03	15.99	0.97	80
South Kalimantan	15.51	0.17	14.87	1.19	136

*Number of samples collected.

3.4.2 Mill Loss Levels

The mill loss was estimated from 50 simulation runs. Table 3.5 shows the results by region. With the present distribution of mill technology, the rice production provinces in Indonesia have a yearly average mill loss estimated at about 4.8 percent of the rough rice with a standard deviation of 0.23 percent; or about 3.1 percent of milled rice with a standard deviation 0.16 percent.

Table 3.5: Estimated Mill Loss

Province	% of Rough Rice		%of Milled Rice	
	Low Land	High Land	Low Land	High Land
North Sumatra	4.47	4.56	2.82	2.87
Middle Sumatra	4.47	4.49	2.81	2.82
South Sumatra	4.94	4.99	3.07	3.10
West Java	4.59	4.72	2.95	3.06
Middle Java	4.52	4.72	2.98	3.08
East Java/Bali	4.77	4.81	3.04	3.09
South Sulawesi	4.88	4.96	3.12	3.22
North Sulawesi	5.07	5.13	3.26	3.30
South Kalimantan	5.02	5.07	3.20	3.23

The arid regions, such as Middle Java, tend to have less mill loss. High land regions had an 8 percent higher mill loss than low lands, however this difference is not significant.

The model simulated the regional mill conversion (CONVER). For all the regions the average head rice percentage was found to be 60.85 percent of rough rice with a standard deviation of 0.12 percent. The average broken rice percentage was 7.25 percent for rough rice with a standard deviation of 0.18 percent. The highest mill conversion value was found in Middle Java and the lowest in North Sumatra and North Sulawesi with both having more humid weather than Middle Java.

The annual average of actual milling yield (YREND) per region was also generated from the simulation model. For all the regions, the average mill yield was found to be 64.69 percent for rough rice with a standard deviation of 1.07 percent. The highest mill yield was found in Middle Java (65.26 percent), while the lowest one was in South Sumatra (62.13 percent). These differences were mainly due to the distribution of mill technology.

The average mill yield in Indonesia was found to be lower than other South East Asian Countries which have reported ranges from 64 to 68 percent (IRRI, 1977; IPB, 1975). Hand pounding is practiced relatively little even though most mill facilities are in poor condition and have aging machines that lack spare parts (Post Harvest Survey, BPS, 1977).

The Rice Mill Plant had low mill loss but also produced the lowest mill yield. Most of the Rice Mill Plants in Indonesia are either old or operated inefficiently, they therefore have reduced mill performance (IPB, 1975). The milling output of the Rice Mill Plant is usually more polished than others which means more bran layers are removed (Post Harvest Survey, BPS, 1977). These conditions could produce less weight of the milled rice output per kilogram of rough rice inputs.

3.4.3 Milling Technology

The interrelationships of mill technology were developed from the model with runs based on several input policies concerning mill technology distribution. System performance indicators were limited to mill losses and mill yields. The results are shown in Table 3.6.

Table 3.6: Milling Practices Performances, in Percent of Rough Rice

Specification	Mill Loss	Mill Yield
Existing Condition	4.79	64.95
All HP	6.93	62.66
Mechanized, Equal Distribution	4.74	64.15
All ETH	4.87	64.03
All RRH	2.87	68.53
All RMU	4.25	66.50
All RMP	3.49	61.17

The traditional hand pounding generated the highest mill loss of about 7 percent of rough rice with a relatively low mill yield of about 62.7 percent of rough price. Improvement milling equipment with additional pre-mill drying and grain winnower facilities could reduce the mill loss by 2.2 percent and improve the mill yield by 2 percent.

The Rubber Roll Huller had the best performance of the mechanized mill systems while the Engelberg Steel Huller had the highest mill loss. The Post Harvest Survey (BPS, 1977) indicated that most of the Engelberg Hullers have a lack of pre-mill drying and grain cleaning facility.

3.4.4 Pre-Mill Operation

Pre-Mill practices include all of the pre-milling grain treatments carried out at the milling facility. The major pre-milling operations are grain drying and cleaning. The pre-milling effects on mill losses are presented in Table 3.7.

The simulation results showed that the improvement of pre-mill facilities, specifically grain drying and cleaning practices could reduce mill loss by providing a better grain condition for the milling process.

The model predicted that an increase of about 15 percent in pre-mill facilities reduced mill loss by approximately one percent. The Post Harvest Survey (BPS,

Table 3.7: Simulated Pre-Mill Operation

Drying Practices in Percent	Cleaning Practices in Percent	Mill Loss, in Percent of Rough Rice	
		Ave.	SD
50	50	7.62	1.30
50	100	3.65	1.35
100	50	4.79	0.23
100	100	2.82	0.21

1977) indicated that the pre-mill operation is mostly inadequate in rural areas. The survey estimated that about 70 percent of rough rice was dried within the mill site, and less than 50 percent was cleaned before milling. Most of the rough rice drying is done by sun-drying and grain cleaning is still done manually.

CHAPTER IV

REGIONAL RICE PRODUCTION MODEL

The development of rice post harvest technology is dependent upon the regional rice production system. Rice mill technology improvement plans should be based on the amount and time of rough rice available in the surrounding area of mill sites. Good planning involves a future trend study of the dynamic behavior of the existing systems.

A regional rice production dynamic model has been developed to provide a quantitative analysis of the post harvest operation alternatives. Various policy alternatives may be generated for the purpose of future production planning. The model may also be used for analyzing various regional food policies and for food price forecasting.

The simplified dynamic model for regional rice production is:

$$\begin{aligned} YPROD(t) = & (((AVHST(t) \times UBIN(t)) \times (1. - FLOSS) \\ & \times (CTHRES - TLOSS)) \times (MILCON - MILOSS)) \\ & - FSTORL - TRLOSS \end{aligned}$$

where,

YPROD = regional rice production, in milled rice, tons/unit time

AVHST = harvested area of paddy rice, hectares/unit time

UBIN = yield per hectare, in tons of dry stalk paddy/hectare

FLOSS = in-field losses, in percent of rough rice

CTHRES = threshing conversion from dry stalk paddy to rough rice, in percent

TLOSS = threshing loss, in percent of rough rice

MILCON = milling conversion from rough rice to polished rice, in percent

MILOSS = milling loss, in percent rough rice

FSTORL = storage loss, in percent of milled rice

TRLOSS = transportation loss, in percent of milled rice

4.1 System Constraints and Desirable Model Characteristics

1) The model should capture the behavior mode of time dependent variables involved in the system based upon the derivation of available time series data.

2) The model should be able to represent such production constraints as land, especially that under cultivation and various post harvest practices.

3) Five year forecasts should be possible as required for regional development planning.

4) The model concentrates mainly on post production parameters up to the time the milled rice reaches the market.

4.2 Input Data

4.2.1 Harvested Area

The harvested area data should include the rice cultivation practices of irrigation. The harvested area seasonal variation should simulate not only the area planted but also the effects of plant diseases (KASS, 1972).

Java and off-Java region boundaries were considered as they have specific rice production trends. In Java, land constraint is a critical factor; whereas, off-Java there is still ample unused land. Cultural practices were divided into wet and dry rice production.

The time series data for each district in both regions were compiled monthly. The data were obtained from the Central Bureau of Statistics (CBS) in Indonesia. The model requires at least ten years of input data for reliable simulation modeling.

4.2.2 Yield per Hectare

The yield per hectare varies with the rice production cultural practices, rice variety and soil fertility. The increase of rice productivity in Java has been different from the off-Java region because of the various cultivation practices by farmers (IPB, 1974; Glassburner, 1978).

Besides the regional classification, the input data had also been classified as dry and wet land rice production and seasonal variation. Yields have been expressed in tons of stalk paddy per hectare. These data were obtained from the Central Bureau of Statistics in Indonesia.

4.2.3 Post Harvest Technology

Physical conversion data for rice during the various post production operations have been taken from tropical study sources (IPB, 1974; Badan Urusan Logistik, 1976; Tuquero *et al*., 1977; Ilangantileke, 1978; Wanders, 1978), except for the milling operation data obtained as a part of this research. Most of the parameters are assumed to have a normal frequency distribution which is significant at 0.05 probability level.

Threshing conversion from stalk paddy to rough rice was found to be 88.7 percent with standard deviation of 0.3 percent (IPB and CBS, 1975). The manual threshing method had been estimated to have a loss of 2.3 percent of rough rice with a 0.9 standard deviation. The pedal thresher has 1.2 percent with a 0.5 standard deviation and the mechanical thresher has 0.5 percent with 0.4 standard deviation. Grain damage from the threshing operation was estimated at 0.4 percent with a 0.2 standard deviation. The damaged kernels were not recovered in the milled rice output, therefore, they were considered as by-products or waste (IPB, 1975; Wanders, 1978; Ilangantileke, 1978).

In-field losses for harvest loss and in-field transportation loss were estimated to be 2.5 percent of the rough rice with 0.9 standard deviation (Ilangantileke, 1978).

It was found that the present mill conversion rate for Java was 64.8 percent with a 0.5 standard deviation, and for off-Java 63.5 percent with a 1.0 standard deviation. Average mill loss was estimated for Java at 4.6 percent of rough rice with a 0.5 standard deviation and for off-Java at 4.8 percent of rough rice with 0.3 standard deviation (see data presented in Chapter III).

Rural transportation for paddy by bullock carriage and small boat had an average loss of 0.7 percent of milled rice; whereas the mechanical transportation had an 0.3 percent of milled rice (IPB, 1974; Badan Urusan Logistik, 1976).

There are few studies on grain storage losses in Indonesia. The Post Harvest Survey by CBS (1978) indicated that farmers used to store the rough rice grain as long as 4 months (see Appendix A). Jindal (1978) predicted 0.5 percent dry matter decomposition of paddy on storage occurred within 20 days with rough rice moisture content at 17 percent wet basis.

4.3 System Design

4.3.1 Growth Model Approach

The available time series data for the harvested area and the yield per hectare had a relatively low autocorrelation coefficient of about 0.6 to 0.7. Consequently the dynamic linear regression approach with stochastic parameters (Hillier, 1967; Hundsberger, 1973) does not provide for a reliable mathematical model construction.

The simulation model used the growth trend approach

(Goodman, 1974) to capture the dynamic behavior of the rice production system. Both harvested area and yield per hectare information were used. Basically, the growth trend as a time dependent variable is described as:

$$GROWTH_{t + 1} = \frac{VAR_{t + 1} - VAR_t}{VAR_t}$$

where,

GROWTH = growth variables VAR, in percent

VAR = variables under study, in unit VAR

t = index time

Various mathematical expressions were tested during construction of the model to obtain the best fit for the available growth data. The growth might be negative and thus would equal zero. Given these inputs, the simulation model was run through time from 1978 to 1988.

4.3.2 Curve Fitting Procedure

The growth model consisted of non-linear equations as time dependent functions. Model verification was based on a curve fitting procedure using the Gauss Newton method (Marquardt, 1963). The general model is:

$$\hat{Y} = F(X_1, X_2, \ldots X_k; \hat{B}_1, \hat{B}_2, \ldots, B_m)$$

The computer programs were developed to solve for the coefficients (B) utilizing N data points for Y and X, i = 1, 2, . . . N. The procedure was generated from linearization of the proposed model with the utilization of a least squares objective function.

Starting estimates of the unknown coefficients were required in the model. The model was linearized by expanding Y in a Taylor series about current trial values for the coefficients and retaining the linear term only,

$$\hat{Y}^{i} = \hat{Y}_i{}^* + \left[\frac{\partial \hat{Y}_i}{\partial \hat{B}_i}\right]^* \Delta\hat{B}_i + \left[\frac{\partial \hat{Y}_i}{\partial \hat{B}_2}\right]^* \Delta\hat{B}_2 + \ . \ . \ . + \left[\frac{\partial \hat{Y}_i}{\partial \hat{B}_M}\right]^* \Delta\hat{B}_m$$

where,

$$\Delta\hat{B}_j = [\hat{B}_j - \hat{B}_j^*];\ j = 1,\ 2,\ .\ .\ .\ M$$

The asterisk designates quantities evaluated at the initial trial values. A least square objective function is formulated as,

$$\text{minimize LS} = \sum_{i=1}^{N} (Y_i - \hat{Y}_i)^2$$

The linearized model was substituted into the objective function and the "normal equation" formed by setting the partial derrivatives of the objective function with respect to each coefficient equal to zero;

$$\frac{\partial LS}{\partial \hat{B}_j} = 0\ ;\ j = 1,\ 2,\ .\ .\ .\ .\ M$$

The resulting normal equation was in the form of

$$(\underline{B}^T\underline{B})\ \Delta B = B^T(Y - \hat{Y}^*)$$

where,

$$\underline{B} = \begin{bmatrix} \frac{\partial \hat{Y}_1}{\partial \hat{B}_1} & \frac{\partial \hat{Y}_1}{\partial \hat{B}_2} & \cdots\cdots & \frac{\partial \hat{Y}_1}{\partial \hat{B}_M} \\ \frac{\partial \hat{Y}_2}{\partial \hat{B}_1} & \frac{\partial \hat{Y}_2}{\partial \hat{B}_2} & \cdots\cdots & \frac{\partial \hat{Y}_2}{\partial \hat{B}_M} \\ \vdots & & & \\ \frac{\partial \hat{Y}_N}{\partial \hat{B}_1} & \frac{\partial \hat{Y}_N}{\partial \hat{B}_2} & \cdots\cdots & \frac{\partial \hat{Y}_N}{\partial \hat{B}_M} \end{bmatrix}$$

$$\Delta\hat{\underline{B}} = \begin{bmatrix} (\hat{B}_1 - \hat{B}_1{*}) \\ (\hat{B}_2 - B_2{*}) \\ \vdots \\ (\hat{B}_M - B_M{*}) \end{bmatrix} \qquad (Y - \hat{Y}{*}) = \begin{bmatrix} (Y_1 - \hat{Y}_1{*}) \\ (Y_2 - \hat{Y}_2{*}) \\ \vdots \\ (Y_N - Y_N{*}) \end{bmatrix}$$

$\underline{B}^T$ is the transpose of the $\underline{B}$ matrix. The derrivatives in the B matrix may be evaluated analytically or numerically. The normal equations are a system of linear algebraic equations and may be solved by an appropriate technique for $\underline{B}$. The $\underline{B}$ vector and LS approach zero as convergence is achieved, and the final coefficients were calculated from,

$$\hat{B}_j = \hat{B}_j{*} + \hat{B}_j \; ; \; j = 1, 2, \ldots M$$

If convergence is not achieved, B may be updated by replacing the old values by the new values and the process repeated.

4.3.3 Model Construction

The simplified flow diagram of the computer programming is illustrated in Figure 4.1. This model has two main programs. Program GROWTH was designed to construct the mathematical model for simulation of harvested areas and yield per hectare growth trends. This program used non-linear numerical analysis of the Marquardt technique (Kuester, 1973; Pennington, 1965), as an extension of the Gauss Newton method.

Program FRECAST was developed to compute the regional rice production and estimate the post harvest loss that occurred in each post production stage. There were two additional sub-programs used. Program MILOSS provided the mill conversion and mill loss (refer to Chapter III). NORM provided the stochastic variables with normal frequency distribution. A ten year forecast was the output of the FRECAST program.

4.4 Model Implementation

4.4.1 Growth Model

1. Harvested Area. Several trials of the mathematical models were carried out. The most favorable moded for the yearly growth trend of the harvested area in Indonesia was found to be the Log Log Inverse function:

GROWTH = EXP(B(1) - (B(2)/TIME) - B(3) * ALOG(TIME))

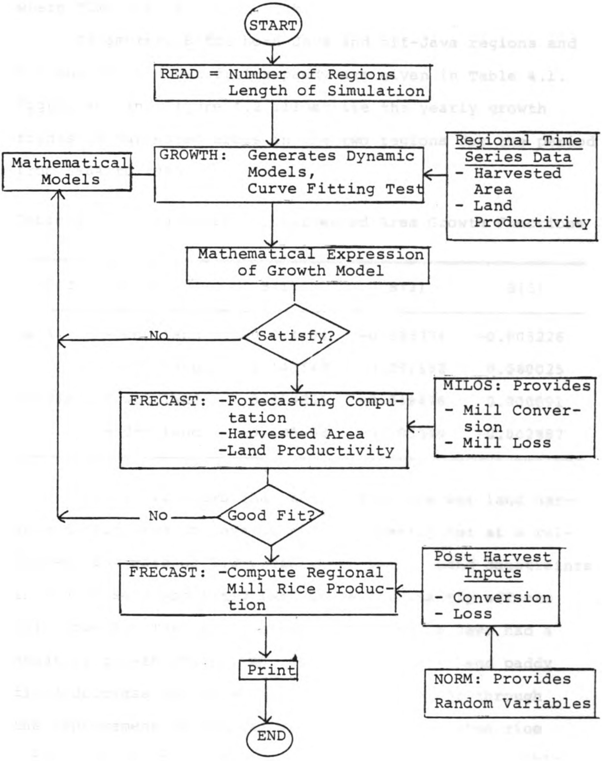

Figure 4.1. Simplified Flow Diagram of Forecasting Model for Regional Rice Production.

where TIME = 1, 2, 3, . . . k.

Parameters B for both Java and off-Java regions and for the dry and wet fields paddy are given in Table 4.1. Figure 4.2 and Figure 4.2 illustrate the yearly growth trends of harvested areas in the two regions for the period from 1964 to 1985.

Table 4.1: Parameters for Harvested Area Growth Functions

Specification		B(1)	B(2)	B(3)
Java	- wet land	-0.014704	-0.095774	-0.005226
	- dry land	0.143548	0.091592	0.080025
Off-Java	- wet land	0.018865	-0.049476	0.000091
	- dry land	-0.035668	-0.105399	-0.002887

Figure 4.2 shows that after 1976, the wet land harvested rice area in Java increased linearly but at a relatively low rate of 0.8 percent per year. Land constraints in the densely populated land of Java evidently affects this growth. The dry land harvested area in Java had a negative growth since 1968. Some of the dry land paddy field decrease may be accounted for by a shift through the improvement of irrigation systems. Also some rice land has been utilized for industrial sites and possibly for commercial crops such as sugar cane and tobacco. Urbanization may also contribute to the decrease of rice land as more and more rural people move to the cities

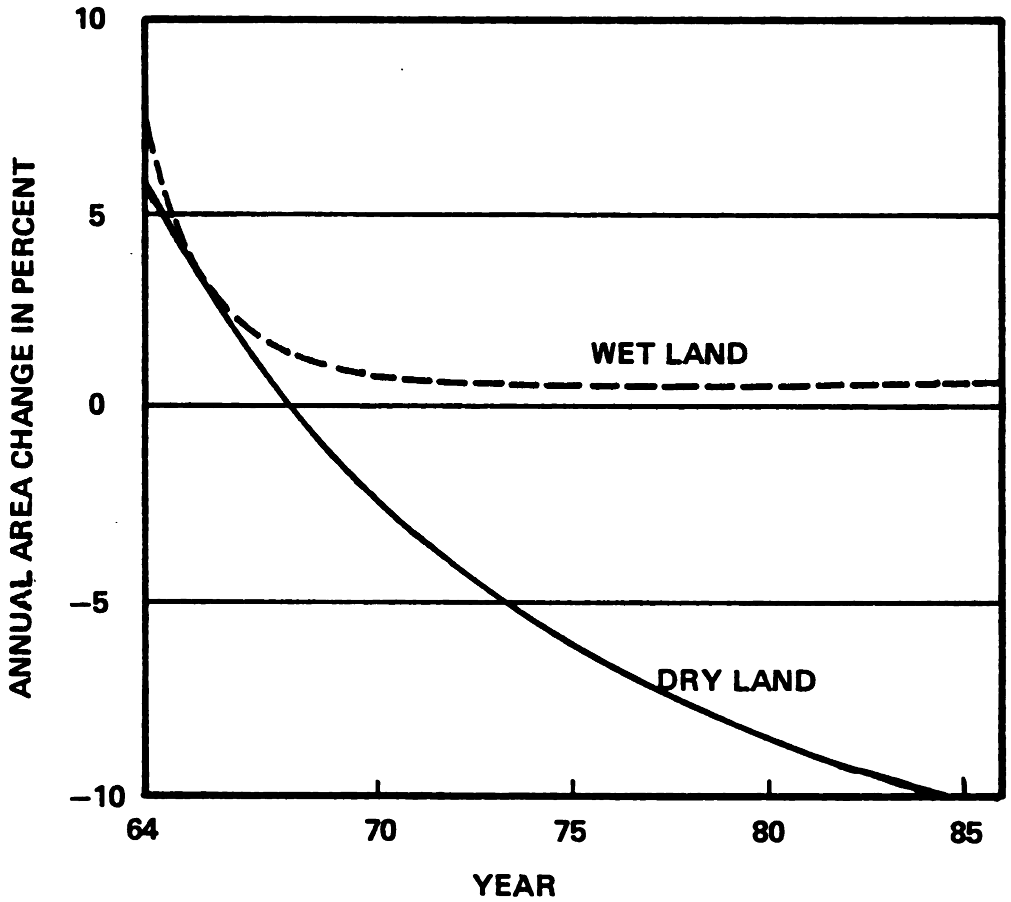

Figure 4.2: Area Change Trends for Harvested Rice in Java

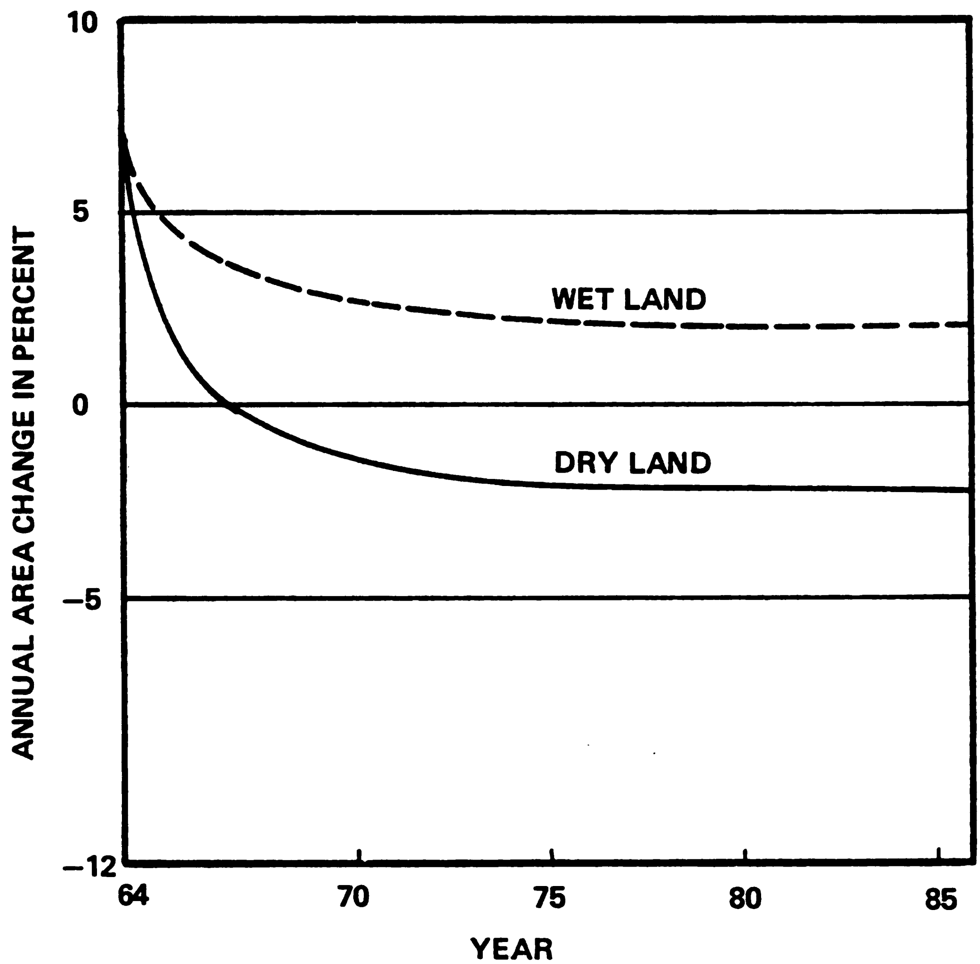

Figure 4.3: Area Change Trends for Harvested Rice in Off-Java.

(Glasburner, 1978).

Figure 4.3 shows that the change in off-Java region wet land paddy field has been almost constantly increasing at 2 percent per year. Good rural irrigation and trans-migration projects will be needed to maintain even the 2 percent annual growth. The decrease of dry land rice is greater than in Java. This decrease may be caused by shifts of crops and rice cultivation methods. Since un-cultivated land is quite available in off-Java regions there should be some positive growth trends if the exten-sification programs are improved. Presently, any increase trends tend to be off-set by declining numbers of farmers in off-Java due to migration to Java (IPB, 1976).

2. Yield Per Hectare. Several exponential functions represent the changes in yield per hectare:

$$\text{GUBJS} = \text{EXP}\ (0.115724 - (0.13885/(\text{TIME})^3)$$
$$- (0.034221) \times \text{ALOG(TIME)}$$

$$\text{GUBJG} = \text{EXP}\ (0.024405 - ((0.02496/(\text{TIME})^2)$$

$$\text{GUBOJS} = \text{EXP}\ (0.021602 - ((-0.046051)/(\text{TIME})^5)$$

$$\text{GUBOJG} = \text{EXP}\ (0.008036 - ((-0.048967)/(\text{TIME})^2)$$

where,

GUBJS = growth of yield per hectare in Java, wet land

GUBJG = growth of yield per hectare in Java, dry land

GUBOJG = growth of yield per hectare in off-Java, wet land

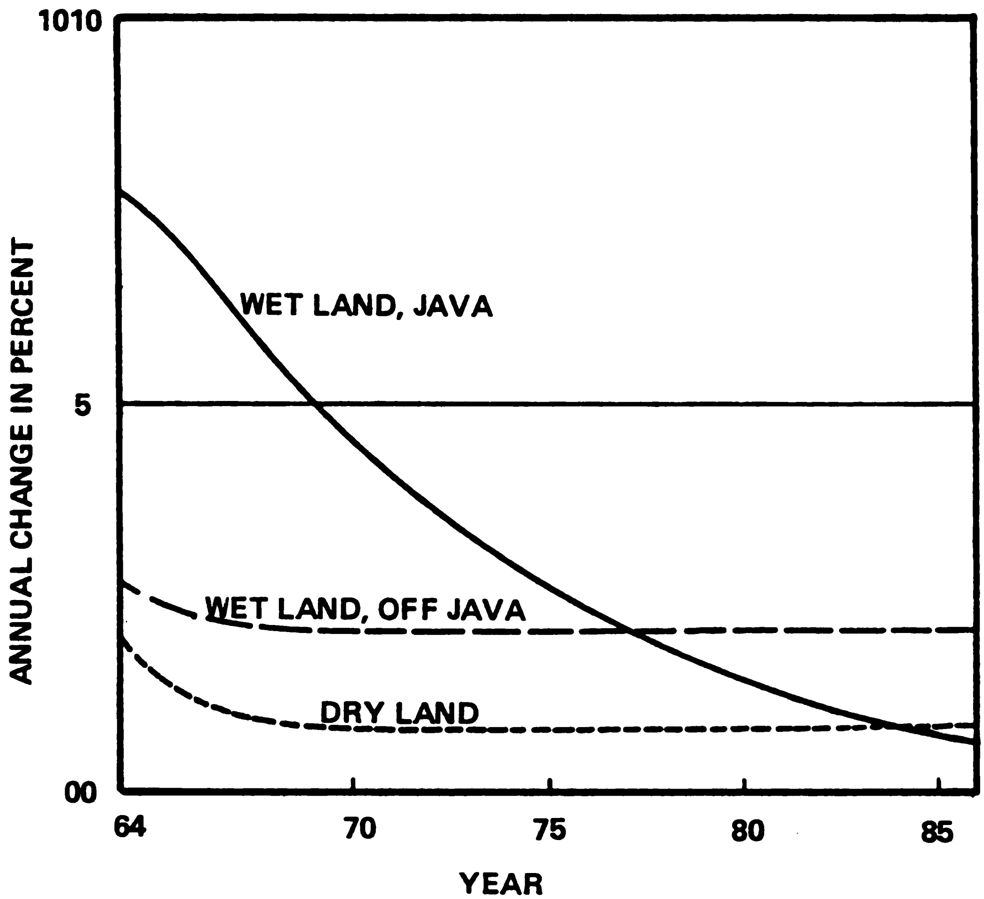

Figure 4.4: Rice Productivity Trends, Yield Per Hectare.

GUBOJG = growth of yield per hectare in off-Java, dry land

Figure 4.4 illustrates rice production trends per hectare. All classifications show a positive increase in yield. The introduction of the High Yielding Varieties of rice and better cultivation practices have no doubt contributed to these favorable trends. Wet land rice in Java shows a decreasing rate of yield growth while other classifications show a constant rate of annual increase. The dry land rice yield growth rate was about 1 percent per year while wet land in off-Java regions was about 2 percent per year.

4.2.2 Forecasting Model

1. Harvested Area. Simulation results are presented in Figure 4.5 to Figure 4.8. The simulation data curves were compared with yearly average data from the CBS (BPS, 1978). The simulated forecasting graphs show a relatively good fit with the past data and are significant at 0.05 probability level.

Java wet land paddy cultivation is increasing more slowly while off-Java regions show a higher growth rate. Dry land rice production areas reached maximum points in the period from 1965 to 1970, and has declined ever since.

2. Yield Per Hectare. Rice yield simulation curves are presented in Figure 4.9 and 4.10, together with yearly average data compiled by the CBS from 1963 to 1977 (BPS,

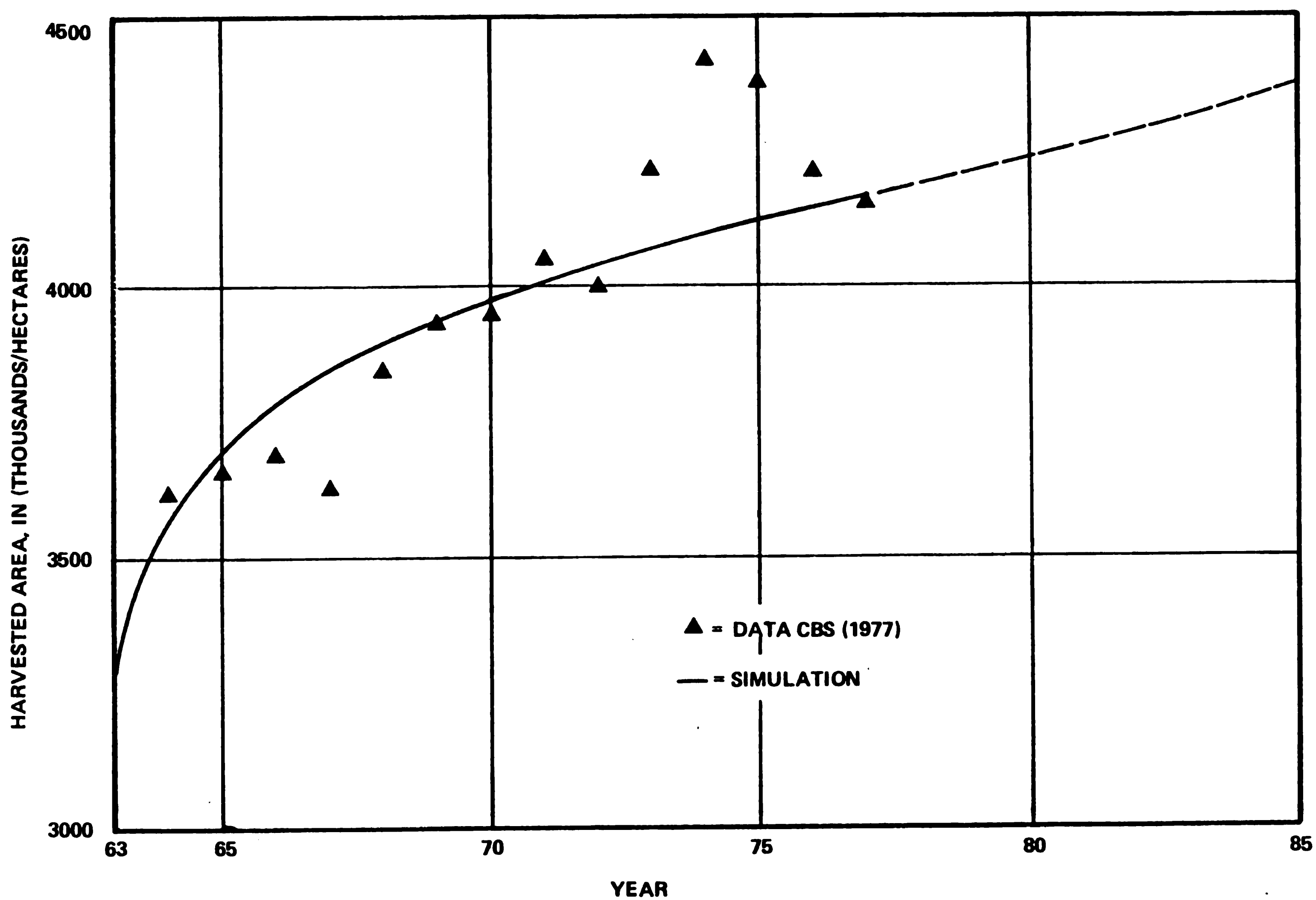

Figure 4.5: Forecasting Model Verification for Harvested Area of Wet Land Rice, in Java.

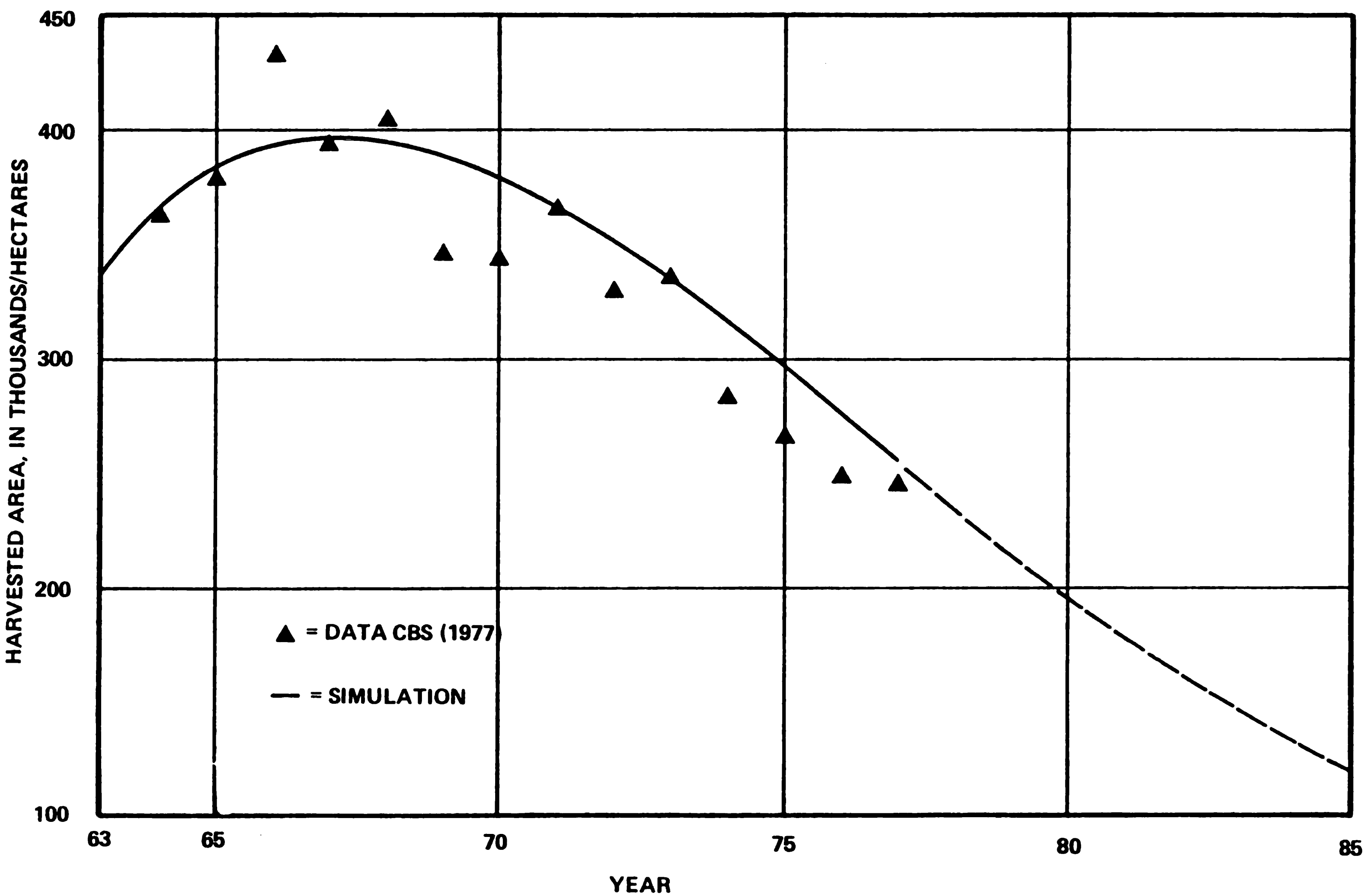

Figure 4.6: Forecasting Model Verification for Harvested Area of Dry Land Rice in Java.

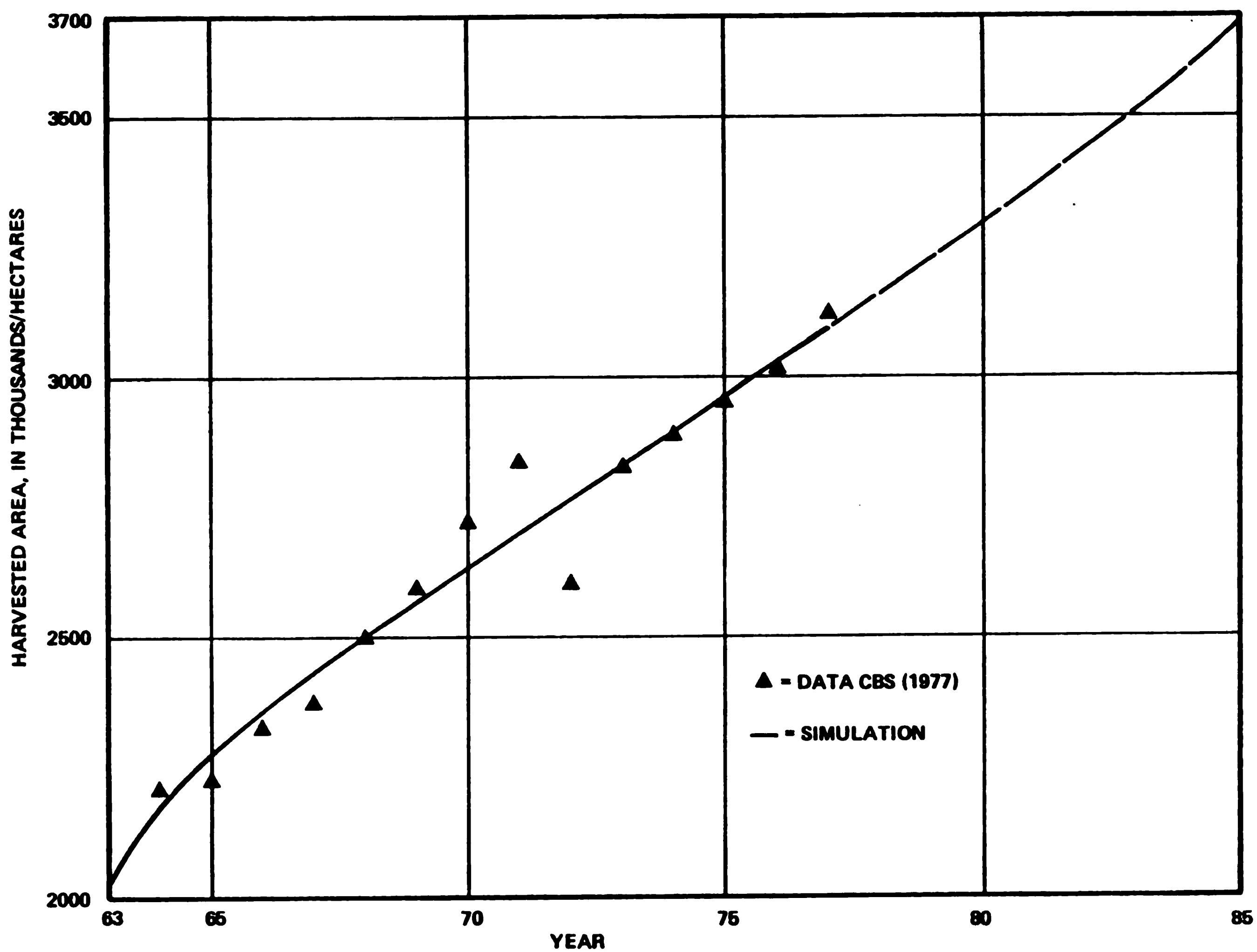

Figure 4.7: Forecasting Model Verification for Harvested Area of Wet Land Rice, in Off-Java.

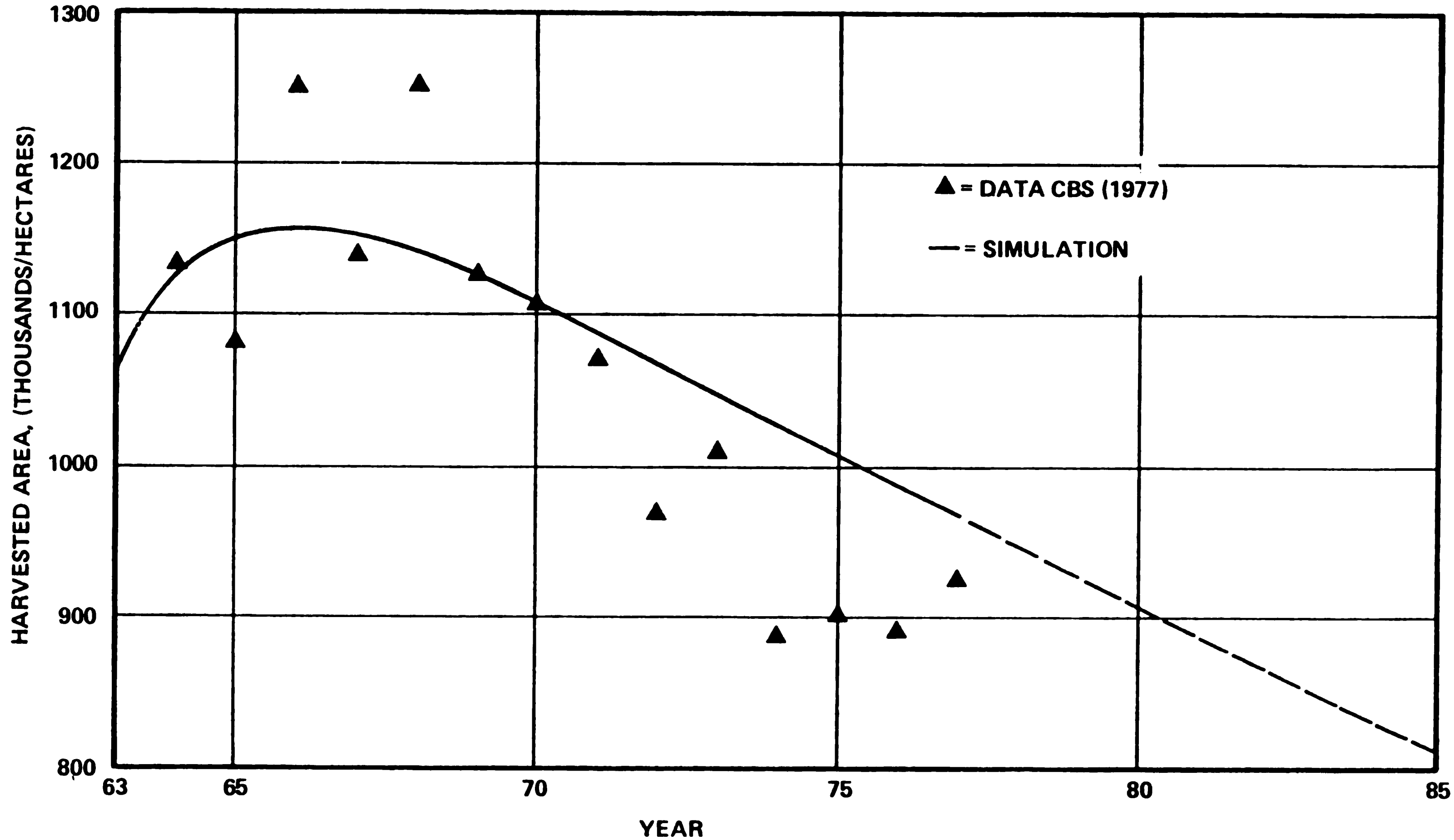

Figure 4.8: Forecasting Model Verification for Harvested Area of Dry Land Rice, in Off-Java.

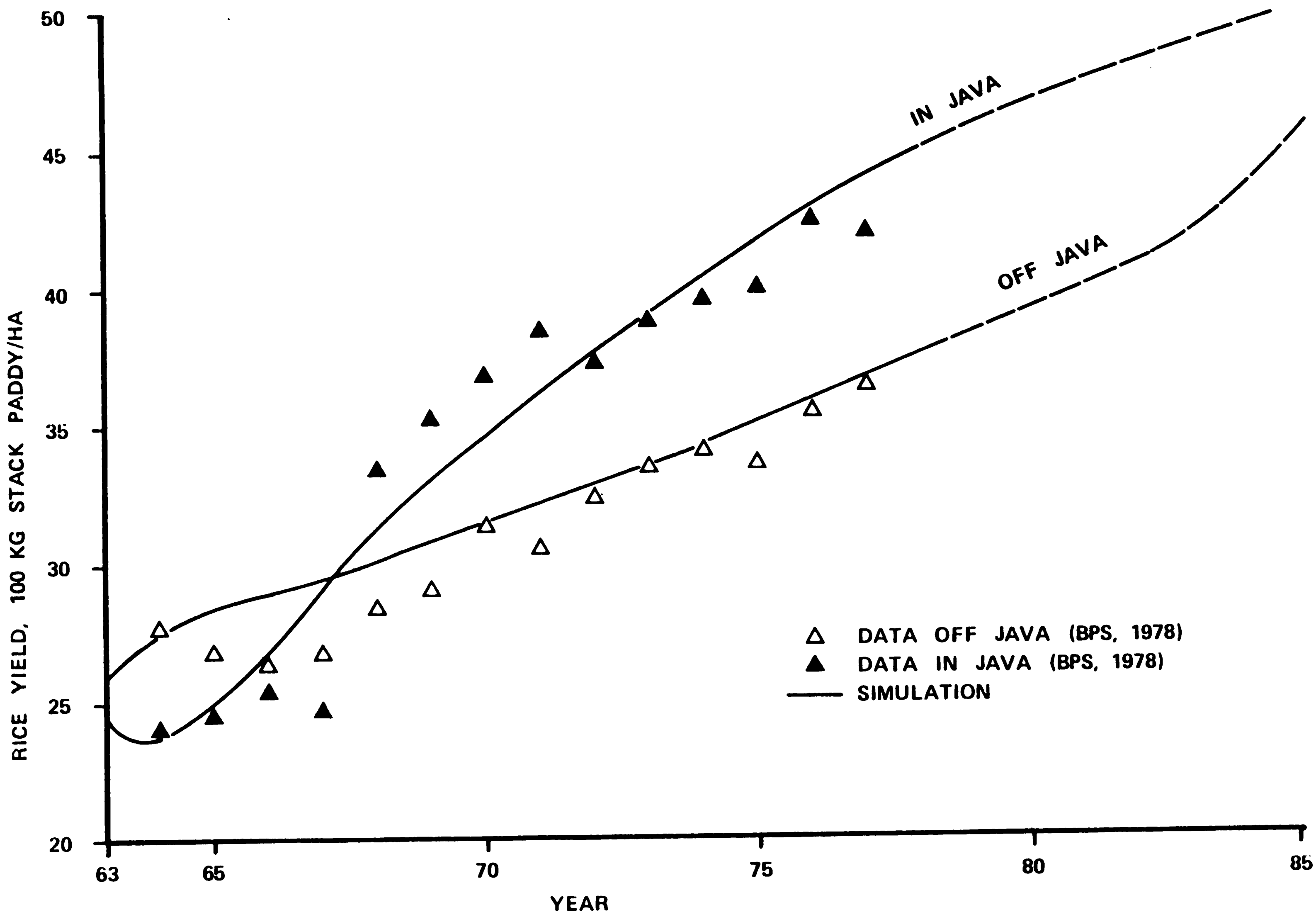

FIGURE 4.9. FORECASTING MODEL VERIFICATION FOR WET LAND RICE PRODUCTIVITY.

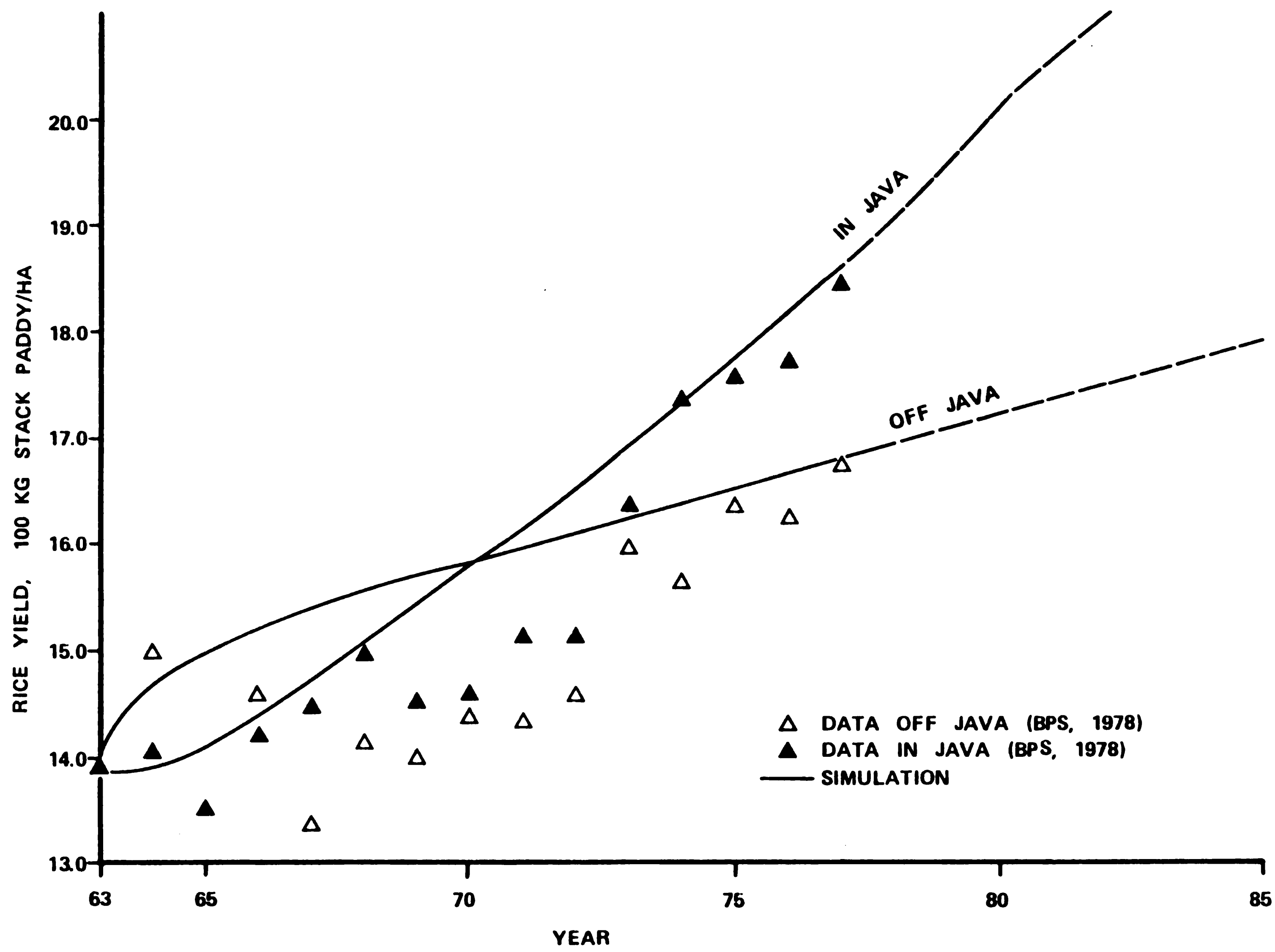

FIGURE 4.10. FORECASTING MODEL VERIFICATION FOR DRY LAND RICE PRODUCTIVITY.

1978). The simulation results have a relatively good fit with the past data and are significant at 0.05 probability level.

The simulated yields per hectare all show an increasing trend. However, on Java wet land rice a decreasing rate. In the year of 1985 the productivity of wet land rice in Java was predicted to reach 5 tons of dry stalk paddy per hectare while in off-Java region it may reach 4.5 tons. By that time, the dry field rice will reach just 1.8 tons per hectare.

3. <u>Milled Rice Production.</u> The model disaggregates the production of milled rice according to the regions and also according to the post harvest operations. Forecasted production is presented in Table 4.2 along with the estimated post harvest losses. The estimated rice consumption predicted by the CBS was also in Table 4.2 (BPS, 1978). A ten year period has been covered with the assumption that the post harvest technology was fixed. Improvement of post production practices should either increase the post harvest conversion or decrease the losses.

Simulation predicted that the annual growth rate of rice production during the period of 1978 - 1988 would be averaging 2.6 percent. Since the rice consumption rate is about 3 percent, imported rice must then also grow progressively.

The simulation model also predicted the post harvest

Table 4.2: Simulation of Rice Production in Indonesia, 1978 - 1988 in Thousand Tons of Milled Rice

Year	Rice Production	Post Harvest Losses	Rice Consumption*
1978	16,580	2,997	17,014
1979	17,210	3,468	17,731
1980	17,613	3,437	18,934
1981	17,696	3,373	19,268
1982	18,561	3,681	20,095
1983	18,774	3,199	20,959
1984	19,562	3,698	21,862
1985	19,848	3,759	--
1986	20,684	4,104	--
1987	20,564	3,704	--
1988	21,490	4,028	--

*Source: BPS (1978)

losses with technology conditions in 1978. It was estimated that the post harvest losses were about 15 to 20 percent or around 3,000,000 tons of milled rice per year. Almost half occurred in grain storage. The Post Harvest Survey (1978) indicated poor storage facilities in rural areas (see Appendix A). The simulation model predicted that a 40 percent reduction of current post harvest losses would reduce the present defficiency of rice.

CHAPTER V

REGIONAL RICE MILL MECHANIZATION MODEL

Literature contains much data on costs of operating rice milling equipment, but few publications have considered the problem of capacity and size selection (Spencer _et al_., 1976). This system model simulates a regional mechanization system for the rice milling operations based on the regional rice production constraints. The mechanization systems design procedure basically consists of a series of subsystem optimizations by an iterative search process. Each search is subject to the constraints of a specific time period upon the completion of each operation (King and Logan, 1964; Box, 1965; Singh, 1978).

The system model separates the selective mechanization into two programs: The first sub-model deals with the capacity of the mills based upon optimal solutions of the annual mill capacity. The regional mill capacity is expressed in tons of rough rice per year and related to the local rough rice production within that period. The second sub-model deals with mill size selection. Several alternative mill sizes are considered for the region. Size selection is based upon minimization of regional milling costs.

It was pointed out in Chapter I that many regions in Indonesia have an over-capacity of rice milling facilities. This over-capacity produces undesirable idle time for millers. The Post Harvest Survey (1978) carried out as a part of this study indicated that mills averaged 60 percent idle production time throughout the year. The millers' profits were cut drastically due to the unavailability of rough rice. The total time of operation is a major factor for the survival of millers. A reducing of idle time can therefore be realized through a reduction of excess capacity within the region.

On the other hand, some parts of Indonesia did not have sufficient milling facilities and labor for hand pounding was also short. Portions of rough rice were stored before it could be processed. The Post Harvest Survey found that farmers in South Sumatra and South Kalimantan stored their rough rice as long as four months. Grain storage losses are high in farm areas, and have been estimated at 2 - 5 percent of total production (FAO, 1977). The reduction of persistent under-capacity of mills should be related to the storage losses.

The first part of the model was designed to optimize the regional mill capacity through the minimization of idle time and farm storage losses. The timeliness factor (Tulu et al., 1974) was used as an indicator of both idle time cost and storage loss cost. The monthly volume fluctuation of the rice harvest was considered as the main factor affecting the timeliness factor. Production directly effects the distribution of input materials to each mill facility.

The second part of the model determines the selection of suitable mill sizes within the region. The selection criterion for optimization was based on a financial analysis of fixed and variable costs (Hinz, 1972; Hughes, 1974).

The field study was carried out to implement the regional study. Data were collected on machine performance and farmer interviews were made in two subdistricts or Kecamatan in the West Java province. Twenty mill facilities were observed and 50 farmers were interviewed in each subdistrict. The field study was conducted during two harvesting peaks and supplemented with secondary data from various government and research institutions.

The subdistrict of Ciawi had about 7,500 hectares of land and 110,000 people of which 40 percent were farmers. The subdistrict of Ciomas had about 8,500 hectares of land and a population of 172,000, of which 25 percent were farmers. Both districts appeared to be representative of rice production areas of the province. Ciomas had 8,296 hectares of wet land paddy and 596 hectares of dry land paddy, while Ciawi had 3,907 hectares of wet land only. High yielding varieties of rice and improved cultivation methods had been introduced in these areas.

5.1 System Constraints and Desirable Model Characteristics

1) The model was designed to render a quantitative analysis for a development plan of regional mill mechanization. It included the dynamics of rice production.

2) The range of sizes considered for each milling class was related to the range found in the regions under study and to the range which was sufficient to evaluate relevant financial factors.

3) The model was designed to capture an appropriate optimization technique for selecting mill technology based on the assumption that no competition for labor and machinery from other farm enterprises occurred.

5.2 Input Data

5.2.1 Harvesting Frequency

The frequency distribution of harvesting time (PROHVT) consisted of the percentage of farmers harvesting their paddy within a specific month. Data were generated from two farmer interviews in one year in each subdistrict. Samples were taken at random. Figure 5.1 presents the monthly fluctuation of harvesting time for each district.

There were two harvesting peaks; one in March and April and another in August. The August peak spread some into July and September and a secondary peak was evident in

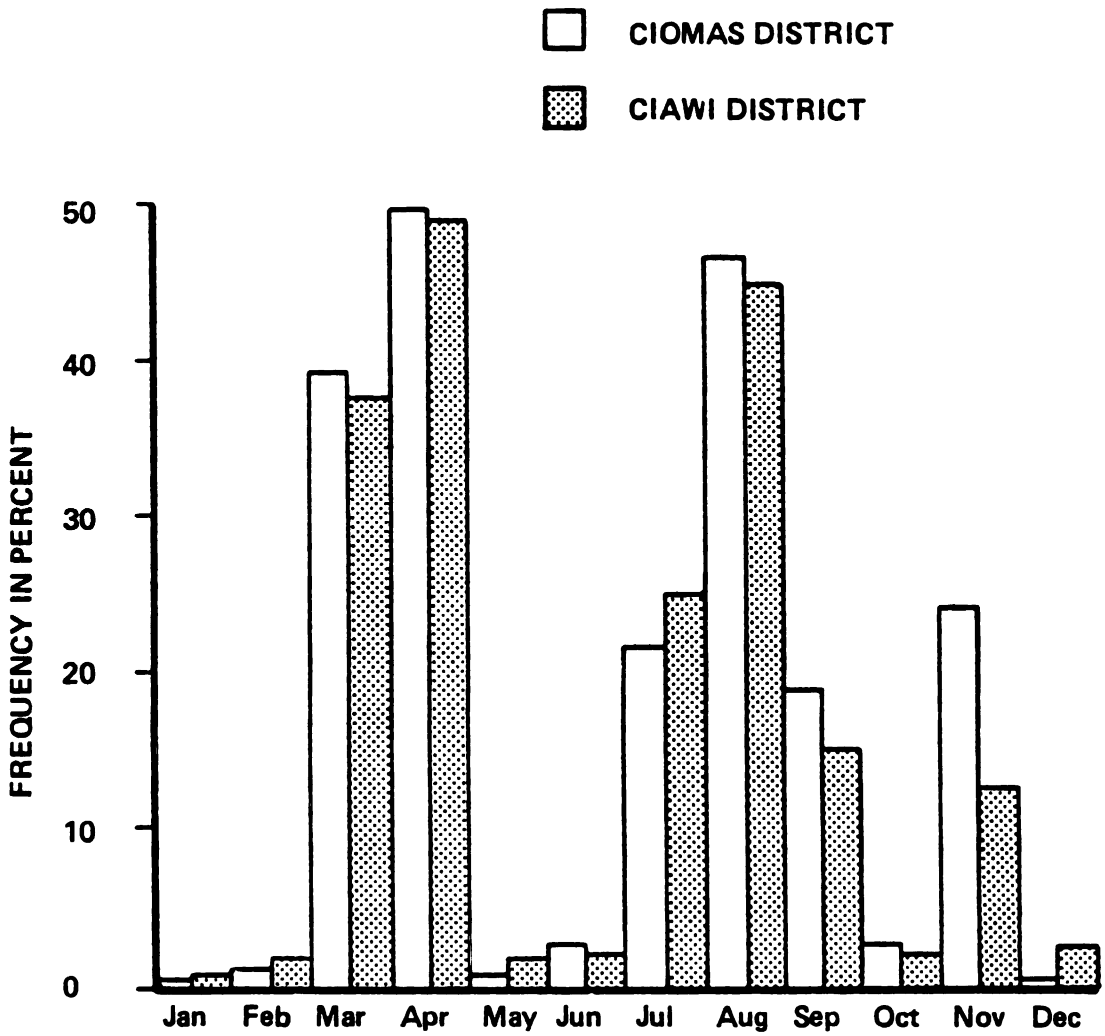

Figure 5.1: Frequency Distribution of Farmers' Harvesting Time.

November.

5.2.2 Rice Mill Classification

Mill technology was classified into four catagories. The criteria of each mechanical mill class is presented in Table 5.1. The allocation of rice production to each mill class was developed from field observation data. The rice production allocation percentages might be viewed as input targets for further regional development alternatives. The variation in the allocation percentages (XPOL) provides a basis for reevaluating mill technology distribution.

The criteria for mechanized mill classifications are: 1) power required per unit rice mill machinery (HSP) in horsepower, 2) potential mill capacity (CAP) in tons of rough rice per hour, 3) skilled operator required (OPERT) in man per unit of rice mill machinery, 4) time period required for repair and maintenance (TIRP) in hours, and 5) expected machine life (XLIFE) in years.

Table 5.1: Mechanized Rice Mill Criteria

Classification	HSP	CAP	OPERT	TIRP	XLIFE
1. Engelberg Steel Huller (EGH)	5	0.3	2	600	5
2. Rubber Roll Huller (RRH)	5	0.5	2	50	6
3. Rice Mill Unit (RMU)	15	1.0	4	100	8
4. Rice Mill Plant (RMP)	25	2.5	6	400	10

The portion of the rough rice production milled by hand pounding (HP) was also determined from the field study. Both subdistricts averaged two percent. The rest of the rice production was milled mechanically. Since transportation cost was also considered, the portion of rough rice transported (PORT) either from the paddy field to the mill or from the mill facility to the market was specified in each mill class.

Fuel consumption for stationary machines (CONSE) was estimated at 0.12 liters per HP per hour. Lubrication oil (CONSG) was estimated at 0.035 liters per HP per hour. Repair and maintenance cost (YREP) was estimated at 1.2 percent of machine price (BUY) over the time period required (TIRP) times machine life (XLIFE).

5.2.3 Regional Prices

The prices used in this study were fixed over the evaluation period. Price distortions will undoubtedly affect the model output and thus the selective mechanization (Warr, 1975; Collier et al., 1974), but these changes were not included in this model.

Table 5.3 shows the average cost and item price for each mill class operation. The currency rate in July 1978 was 450 Rupiah per US Dollar.

Diesel fuel price (SOLAR) was 25 Rupiah per liter. Lubrication oil (GREAP) averaged 350 Rupia per liter. The regional rough rice price (RRPRI) at the mill site was

77.50 Rupiah per kilogram in Ciomas and 76.30 Rupiah at Ciawi. The milling fee (XMILFE) was 4.50 Rupiah per kilogram of rough rice in Ciomas and 5.00 Rupiah in Ciawi.

Table 5.2: Mill Technology Cost Input

Mill Class	Labor Cost (Wage) in Rupiah/man-hour	Machine Price (BUY) in Rupiah	Transport Cost in Rupiah/kg Rough Rice
EGH	400.	300,000	5.
RRH	400.	825,000	5.
RMU	500.	1,625,000	10.
RNP	500.	3,000,000	10.

5.3 System Design

5.3.1 Model Structure

1. Regional Mechanized Mill Capacity. The deterministic model was designed to compute the regional mechanized mill capacity (XP) through minimization of the objective function which consisted of the timeliness cost of storage losses and idle time. A simplified mathematical expression of the model objective function was

minimize Y = f (DISCO1, DISCO2)

subject to XP $\geq$ 0

DISCO1 is timeliness cost due under capacity,

DISCO1 = DAMAGE x RRPRI

where DAMAGE was storage loss in tons of rough rice at 2 percent per month. In the model, DAMAGE was accumulated yearly using the DELAY subroutine with the EULER integration technique (Manetsch, 1976). DAMAGE was a function of the regional rice production per unit time (XRRY) and the mill capacity (XP). The average delay was one week.

DISCO2 was the penalty cost caused by over capacity which lead to a loss of benefit as

$$DISCO2 = (XP - XRRY) \times CIDLE$$

$$CIDLE = XMILFE \times (EBC/(1. + EBC)) \times CF$$

where,

XP = designated level of regional mechanized mill capacity, in tons of rough rice per year

XRRY = regional rough rice production, in tons per year

CIDLE = penalty cost due to idle time, in Rupiah

XMILFE = expected milling fee, in Rupiah per ton rough rice

EBC = intended benefit cost ratio of mill business, dimensionless

CF is correction factor and defined as

$$CF = 1 + \frac{XP - XRRY}{XRRY}$$

If there was no mechanization (XP = 0), the model showed that CIDLE would equal zero. If the regional mill capacity equaled rice production the CIDLE would also equal zero which means there was no idle operation. If the XP was less than the XRRY, the DISCO2 becomes negative but on the other hand increased the value of DISCO1. This tradeoff situation should be optimized.

Weekly simulation was done to compute yearly regional mill capacity. Comparison with existing conditions was carried out, where the present mill capacity in the region (ACCAP) was computed as

$$ACCAP = \left(\sum_{i=1}^{4} A_i \times C_i \right) \times WORK$$

where,

C = average capacity of the mechanical mill, in tons of rough rice/hour

A = amount of specific mill types in the region

WORK = machine operating time per year, in hours

2. Mill Technology Selection. The deterministic model was designed to provide information on the feasibility of each mill class for the region. Two factors were included in the system modeling. First was the output from the regional mill capacity program (XP) which acted as a physical constraint. Second was minimization of the regional mill costs based upon the operational cost of each mill class as compared to the distribution of rough rice regional production for each mill class.

Basically the model consisted of a series of equations for each mill technology fixed and variable costs. The objective function was:

minimize $Y = ACCOST_i/XPM_i$

subject to $XPM \geq 0$ and $ACCOST \geq 0$

where,

i = mill class index

ACCOST = regional mill cost per year, in Rupiah

XPM = portion of regional production distributed into mill class i, in tons of rough rice per year

Several equations supported the regional mill cost function. Some notations have been described earlier in this chapter. The X_i is the designated amount of each mill class within the region.

$WORKH_i = XPM_i/(CAP_i \times X_i \times EFF)$

where,

WORKH = operation time per year, in hours

EFF = production efficiency, dimensionless

$ENERGY_i = HSP_i \times WORKH_i \times CONSE \times SOLAR$

where,

ENERGY = cost of fuel per year, in Rupiah

$GREASE_i = HSP_i \times WORKH_i \times CONSG \times GREAP$

where,

GREASE = cost of lubrication per year, in Rupiah

$LABOR_i = OPERT_i \times WAGE_i \times WORKH_i$

where,

LABOR = cost of labor per year, in Rupiah

$REPAIR_i = YREP \times BUY_i \times (WORKH_i/TIRP_i)$

where,

REPAIR = cost of repair and maintenance per year, in Rupiah

$RRANS_i = TRC_i \times XPM_i \times PORT_i / X_i$

where,

TRANS = cost of rough rice transportation per year, in Rupiah

$VARCO_i = ENERGY_i + GREASE_i + REPAIR_i + LABOR_i + TRANS_i$

where,

VARCO = regional variable cost per year for mill class i, in Rupiah

$DISC_i = 0.9/XLIFE_i + 0.076$

where,

DISC = annual discount percentage, with Salvage value = 0.10

0.076 = coefficient which represented a straight line depreciation cost, taxes, insurance and shelter

$FCOST_i = DISC_i \times BUY_i \times X_i$

where,

FCOST = regional fixed cost for specific mill technology, in Rupiah per year

$ACCOST_i = VARCO_i + FCOST_i$

where,

ACCOST = regional mill cost for specific mill class, in Rupiah per year

The comparison method used in this analysis was similar to the Bayer decision procedure (Hillier, 1967), which selects an alternative such that

$$\text{minimize } E(l(a,\theta)) = \sum_{k=1}^{4} l(a,k)W_{\theta}(k)$$

where,

$l(a,\theta)$ = comparison level, in Rupiah

a = mill class alternatives

θ = indicators

W = weighing policy for indicator, in percent

The indicator (θ) in this evaluation was the milling cost, operation time, fuel consumption and labor requirement. The comparison level was converted to Rupiah.

5.3.2 Variable Search Method

This system modeling determined the minimum of a single variable non-linear function subject to constraints. The search technique used was the Fibonacci method which was an interval elimination procedure. The region in which the optimum lies was sequentially reduced by the search procedure (Rosenbock, 1960; Beveridge, 1970; Kuester, 1973).

Starting with the original boundaries of the independent variable, the interval in which the optimum value of the function occurred was reduced to some final value, the magnitude of which depended on the desired accuracy. In this model, the accuracy was set at 10 percent of the value of the independent variable. The location of points for function evaluations was based on the use of positive integers known as the Fibonacci numbers (F_n). No derivatives were required. A specification of the desired accuracy determined the number of function evaluations.

The variable search procedure started with a determination of the original search interval as L_1 with boundaries a_1 and b_1. The required Fibonacci number was computed as:

$$\alpha = \frac{1}{F_N}$$

$$F_0 = F_1 = 1$$

$$F_n = F_{n-1} + F_{n-2} \; ; \; n \geq 2$$

where α was the desired accuracy.

The algorithm proceeds as follows:

1) Place the first two points, X_1 and X_2 ($X_1 < X_2$) within L_1 at a distance d_1 from each boundary,

$$d_1 = \frac{F_{N-2}}{F_N} \times L_1$$

$$x_1 = a_1 + d_1$$

$$x_2 = b_1 - d_1$$

2) Evaluate the objective function at X_1 and X_2. Designate the functions as $F(X_1)$ and $F(X_2)$. Narrow the search interval as follows:

$$a_1 \leq X^* \leq X_2 \quad \text{for} \quad F(X_1) < F(X_2)$$

$$X_1 \leq X^* \leq b_1 \quad \text{for} \quad F(X_1) > F(X_2)$$

where X* was the location of the optimum. The new search interval was given by

$$L_2 = \frac{F_{N-1}}{F_N} \times L_1 = L_1 - d_1$$

with boundaries a_2 and b_2.

3) Place the third point in the new L subinterval, symmetric about the remaining point,

$$d_2 = \frac{F_{N-3}}{F_{N-1}} \times L_2$$

$$X_3 = a_2 + d_2 \text{ or } X_3 = b_2 - d_2$$

4) Evaluate the objective function $f(X_3)$, compared with the function for the point remaining in the interval and reduce the interval to

$$L_3 = \frac{F_{N-2}}{F_N} \times L_1 = L_2 - d_2$$

5) The process was continued with the preceeding rules for N evaluations. The general equations were:

$$d_k = \frac{F_{N-(k+1)}}{F_{N-(k-1)}} \times L_k$$

$X_{k+1} = a_k + d_k$, or $X_{k+1} = b_k - d_k$ (symmetric about mid-point).

$$L_k = \frac{F_{N-(k-1)}}{F_N} \times L_1 = L_{k-1} - d_{k-1}$$

After N-1 evaluations and discarding the appropriate interval at each step, the remaining point was precisely in the center fo the remaining interval. The objective function was then evaluated and the final interval where the optimum was located was determined. A simplified diagram illustrates the procedure in Figure 5.2.

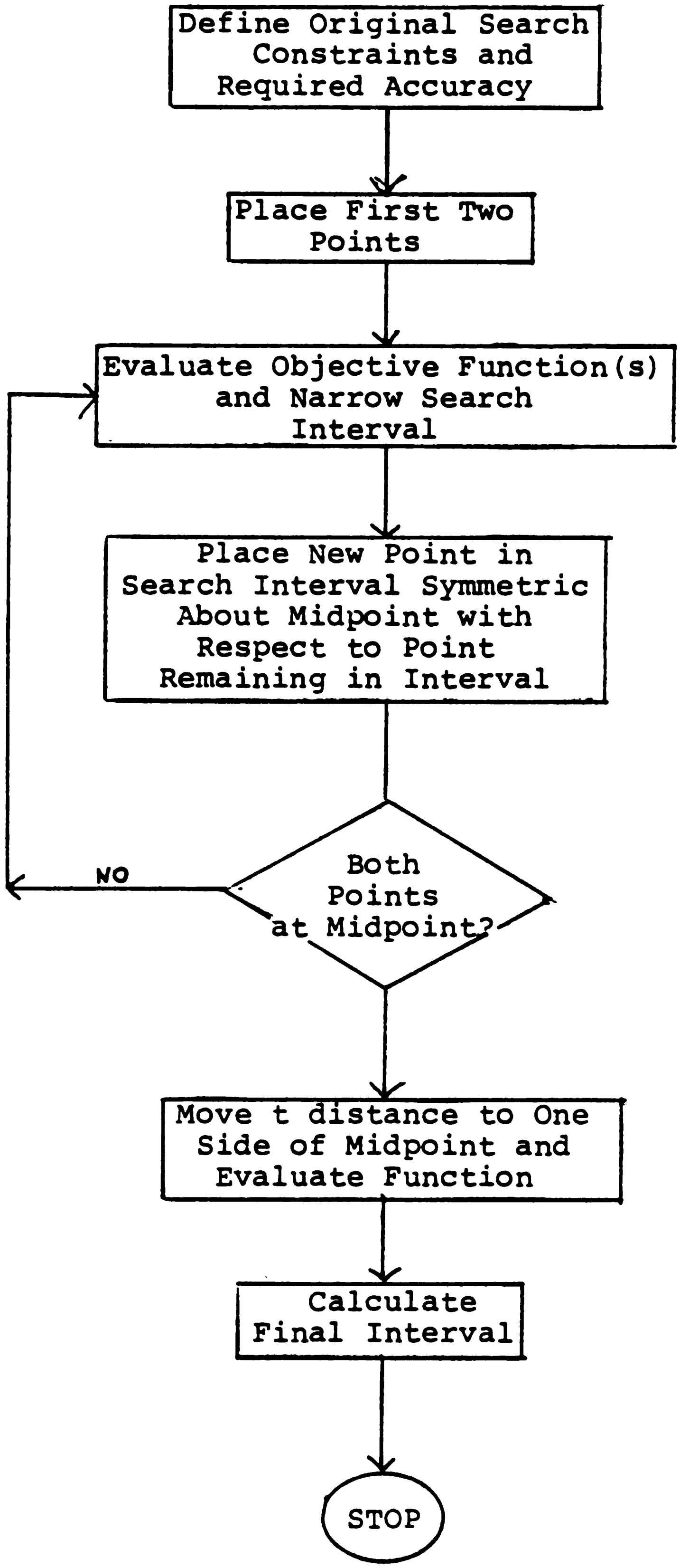

Figure 5.2: Fibonacci Logic Diagram

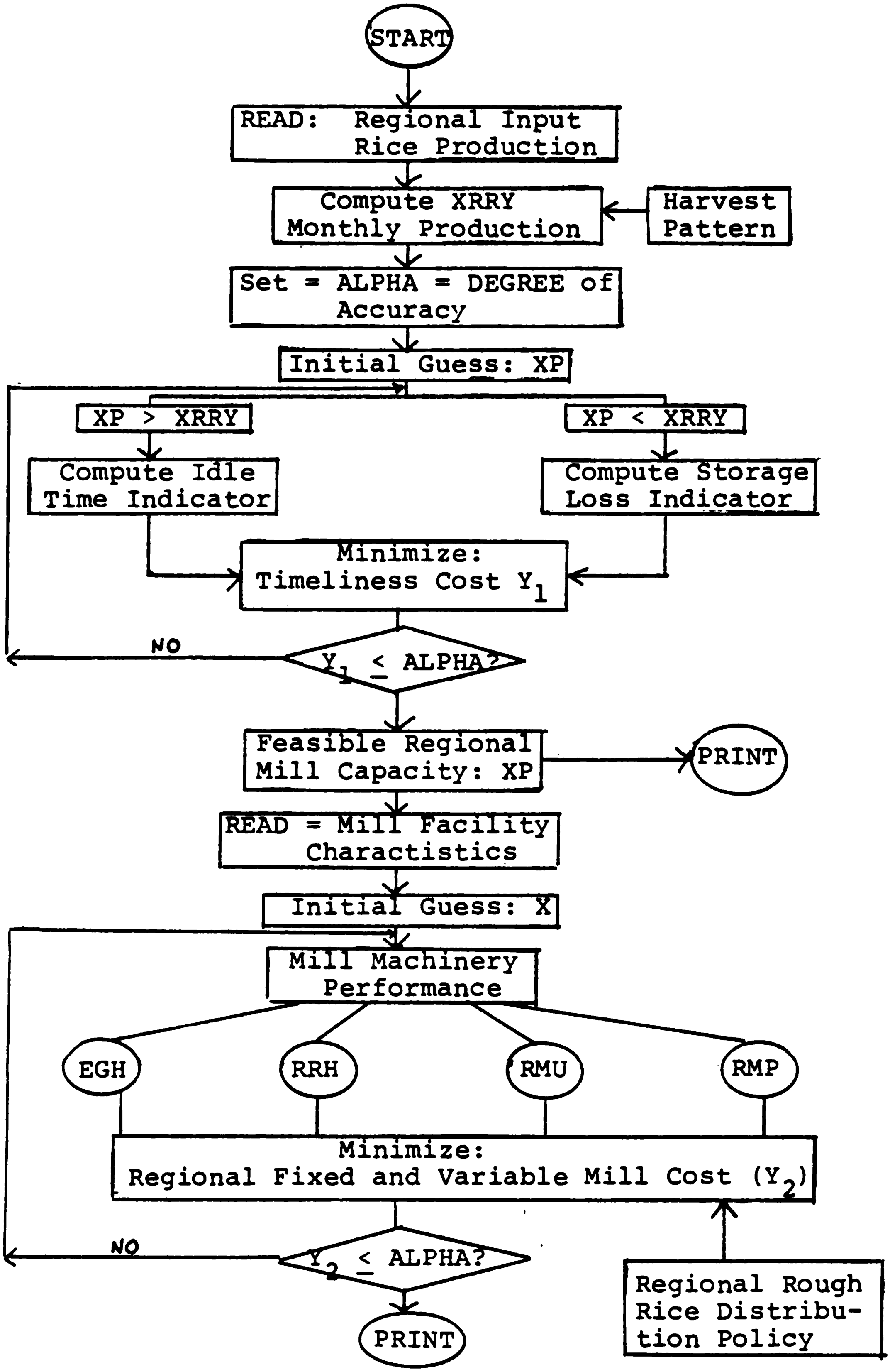

Figure 5.3: Simplified Flow Diagram for Regional Rice Mill Mechanization Model.

5.3.3 Model Construction

The model consisted of the two main parts as described previously; the MECMIL for regional mill capacity and the SEEFAC for size selection. Figure 5.4 gives the simplified flow diagram for the computer programming.

5.4 Model Implementation

5.4.1 Mechanized Mill Regional Capacity

The yearly production in subdistrict Ciawi was 22,304 tons of rough rice and in Ciomas 27,843 tons of rough rice. Ciomas had 16 Engelberg Steel Huller (EGH); 45 Rubber Roll Huller (RRH) and 2 Rice Mill Unit. Ciawi had 13 Engelberg Steel Huller and 5 Rubber Roll Huller, and part of its rough rice production was transported outside of the district for milling. Ciomas however had to close some mill facilities due to lack of input materials. Small mill facilities tended to go out of business first, but some medium Rice Milling Units were also found closed.

The system model simulated the optimal mechanized mill capacity in each subdistrict based on input data and simultaneously compared that with conditions at the year 1977 - 1978. The results are given in Table 5.5.

The field study carried out in 1978 indicated that Ciomas had an over-capacity of rice milling mechanized operations. Most of the mills operated less than 500 hours per year. The simulation projected that for optimum conditions the regional mill capacity should be decreased

Table 5.3: Results of Regional Mill Capacity Simulation

Specification	Subdistrict	
	Ciomas	Ciawi
1. Regional mill capacity, in tons of rough rice/year		
a. 1977-1978	41,580	8,960
b. Simulated, optimal	12,594	10,133
2. Idle time indicator, in percent		
a. 1977-1978 (Standard)	100	100
b. simulated	23	116
3. Storage loss indicator, in tons of rough rice/month		
a. 1977-1978	3.4	7.1
b. simulated	6.9	6.8

by 60 percent. This would reduce the idle operation by 77 percent. It would however produce more storage losses due to under-capacity during the harvesting peak month. The storage losses would be increased by 3.5 tons of rough rice per month during the harvesting peak. Storage losses might be offset some by increasing hand pounding practices and by increasing the man-hours per day at the mill facility during the harvest month. Regular man-hour per day was 5 to 6 hours in Ciomas.

The model simulation showed the subdistrict Ciawi had an under-capacity in mechanized rice mills. The simulation results suggested at least a 15 percent increase in mill capacity in order to improve the millers profit while also reducing the farm storage loss chance. The 15 percent increase indicated a storage loss reduction of about 4 percent. Idle operation time would increase 17 percent due to over capacity during non harvesting. Nevertheless, the idle time in Ciawi would still be relatively low compared to Ciomas. The optimum condition in Ciawi was for a 20 percent less idle time than in Ciomas.

The simulation model indicated a trade-off between the idle operation time and storage losses. Since that was not a simple linear interrelationship between these indicators, complex results occurred. In general, the idle time indicator dominated the system. Storage loss was less effective in the optimization process.

Further analysis was done in parameter sensitivity. The percentage of hand pounding practices (HP) was found to have a linear relation with the model output. The optimum regional mill capacity did not change with alternative price inputs since the model did not include the effect of price distortion on mill technology performance. The variation of several parameters do however affect the final value of the objective function (Y). Ten percent step increase in each parameter was generated to evaluate the effects on objective function.

Most parameters did not have a linear relationship with the timeliness cost. Ten percent increases in rough rice price (RRPRI) reduced Y value by 0.4 percent, while ten percent reduction of the milling fee (XMILFE) reduced the Y value by 9.5 percent. The milling fee showed a greater influence particularly in the penalty cost structure due to idle time. There was reduction of the Y value of about 4 percent for every ten percent increased of the Benefit-Cost ratio (EBC). The model therefore indicated a benefit to the rice mill business as affected by the system and vica versa. The EBC was viewed as other inputs to the system modeling.

5.4.2 Mill Size Selection

1. Regional Mill Distribution

Distribution of mill facilities in each subdistrict was simulated through optimization of the objective function, the regional mill cost. The computation was based on the output of the regional mill capacity program as discussed previously in this chapter. The optimum mill capacity was computed in Ciomas as 13,643 tons of rough rice per year and in Ciawi as 10,133 tons of rough rice per year.

Two system alternatives of rough rice distribution of each mill class were considered in the model. First Alternative (ALT 1) was to follow the 1977-1978 situation in both subdistricts which was EGH at 60 percent, RRH at 30 percent, RMU at 10 percent and none for RMP facility. The second alternative (ALT 2) considered was for equal distribution among mill facilities, which was 25 percent for each mill class. The average operation time for milling activities per year is 1000 hours. The simulation results along with 1977-1978 mill facilities in the subdistrict is given in Table 5.4.

Table 5.4: Regional Mill Distribution

Mill Class	Ciomas			Ciawi		
	1977-1978	Alt 1	Alt 2	1977-1978	Alt 1	Alt 2
EGH	16	27	11	13	20	9
RRH	45	8	6	5	6	5
RMU	2	1	3	0	1	2
RMP	0	0	1	0	0	1

Alternative I indicated that 80 percent of RRH should be reduced in Ciomas subdistrict. This reduction was mainly due to the lower level of regional mill capacity in 1978. The shift to more EGH might be favorable since it is the simplest technology and required less cost and spare parts than others. Alternative 1 in Ciawi indicated an increase of all mill facilities, as higher levels of regional mill capacity was predicted.

The output in Alternative 2 showed the difference between mill class due to the mill cost variation and mill performance of each technology. The result showed more of the EGH facility. However, the simulation model did not include the quality of milling output as a system variable. Generally, the EGH milling output has more broken and less polishing of rice (IPB, 1975; IRRI, 1977). As discussed in Chapter III, the EGH has a higher mill loss than others. Milling quality consideration might shift the technology.

2. <u>Mill Class Comparison</u>. To compare the mill technology the model was run for subdistrict Ciomas with different inputs on rough rice distribution. Each trial placed the whole rice production into each mill class. A relative comparison scoring method was then formulated. The lowest comparison indicator was set as a 100 score.

Table 5.5: Mill Class Comparison Score

Indicator (θ)	Mill Class (a)			
	EGH	RRH	RMU	RMP
Milling cost	100	124	196	222
Operation time	286	334	176	100
Fuel	100	117	185	175
Skilled Operator	195	100	189	200

The mill cost indicator favored the EGH and RRH. The operating time was most favorable for the RMP and RMU. An energy conservation program would favor the simplest technology. The smallest labor cost was for the RRH facility.

3. Plan Projection. A future plan for milling technology development must consider the predicted input of regional rough rice production. Simulation forecasting based on data from two subdistricts was carried out using the Regional Rice Production Model. It was assumed that the trend of harvest area change and yield per hectare, for both wet and dry land rice followed the general pattern in Java (see Chapter IV). The model was run with the assumed 1977-1978 post harvest technology condition.

The simulation results as illustrated in Figure 5.4 combine past data (1972-1976) collected by the district office of Ciawi and Ciomas. The simulation predicted an increase of rough rice production in Ciomas of 400 tons per year in Ciawi, 800 tons per year for the period of 1975 to 1985. Consequently the regional mill capacity should be adjusted to changes. Computations showed that after the optimal condition was achieved the regional mill capacity in Ciomas should be increased 3 percent and in Ciawi 8 percent per year after the optimal condition was achieved. These figures may be altered as different post harvest technology are introduced to the simulation model.

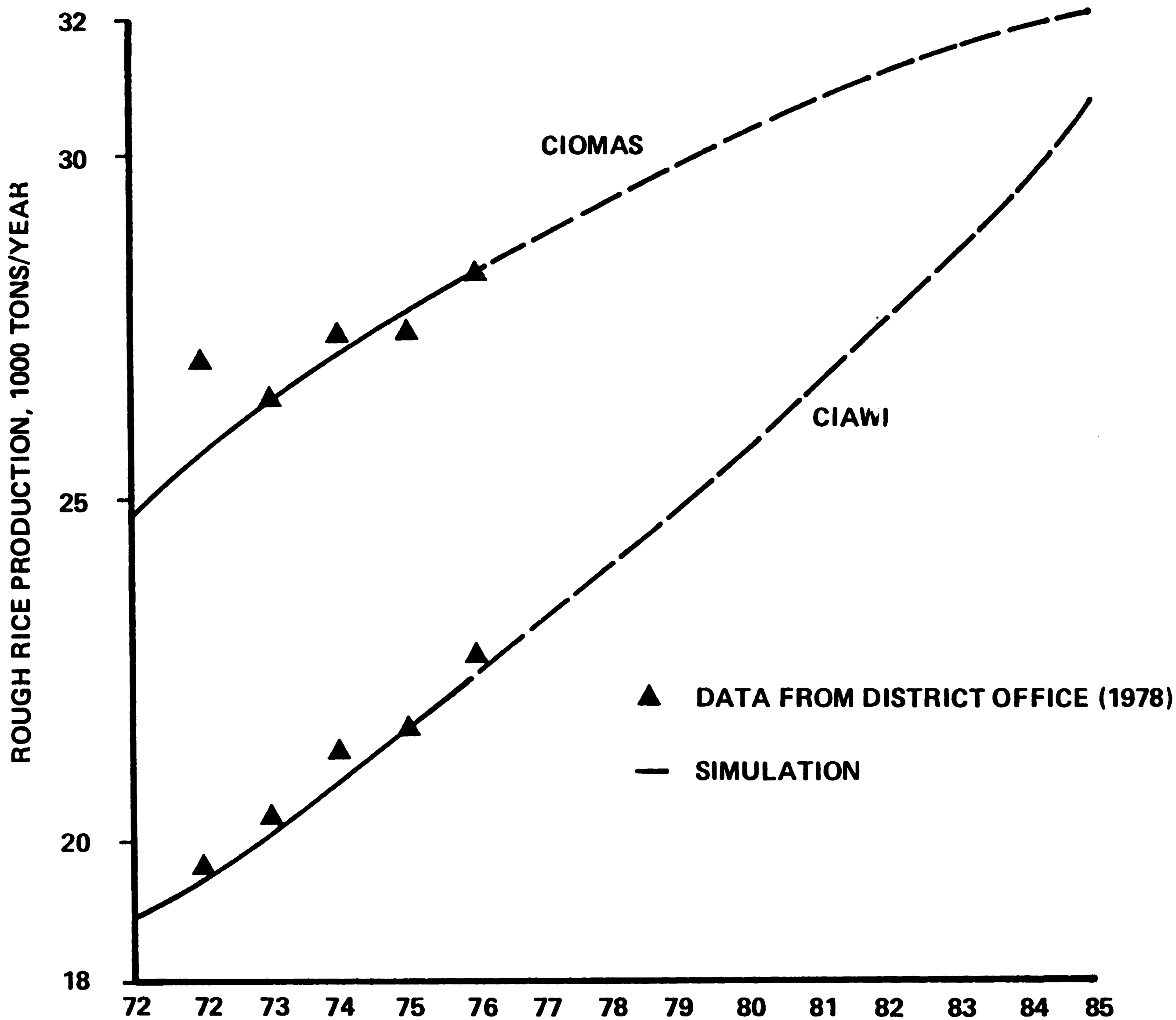

Figure 5.4: Forecasting Simulation of Rough Rice Production in Ciomas and Ciawi.

CHAPTER VI

CONCLUSIONS

The conclusions from this research are:

1. Given reasonably accurate input data, the Milling Loss Model will estimate mill loss levels by region for selected technologies.

    a. The simulation model estimated the average mill loss in Indonesia at 4.8 percent of the rough rice production or about 3.1 percent of milled rice with a standard deviation of 0.2 percent. These relatively high loss magnitudes indicate a need for improvement in grain processing methods and technology.

    b. Traditional hand pounding showed the highest mill loss of about 7 percent of the rough rice with a relatively low mill yield of 62.7 percent of rough rice. The Rubber Roll Huller (RRH) had the best performance of the mechanized mill systems with 3 percent mill loss and 68.5 percent mill yield. The model showed that mechanization of rice milling did reduce mill losses and increased mill yields.

c. Better pre-mill drying and grain cleaning could reduce mill losses by 2.2 percent and improve the mill yield by 2 percent. A semi-mechanical grain cleaner, for instance the pedal drive winnower might prove to be an appropriate intermediate technology.

2. The regional rice production computer simulation model was developed and used to forecast the regional rice production for a ten year period. Based upon the input data and assumptions made the following results were generated:

a. Wet land paddy cultivation in Java will increase linearly at a relatively slow rate of 0.8 percent per year, while in off-Java regions there will be a higher growth rate of 2 percent per year. A decrease of dry land rice acerage is predicted.

b. The yield per hectare of paddy will be changing. The dry land yield will increase about 1 percent per year, and wet land paddy in off-Java about 2 percent per year. Wet land paddy in Java will have a decreasing rate of yield growth.

c. With the assumption that the post harvest technology will be fixed for the period of 1978-1988, the average annual growth of milled rice in Indonesia is projected as about 2.6 percent. The total post harvest losses are estimated at about 15 to 20 percent. About half of these losses will continue to occur from storage practices.

3. The regional mechanization computer model was developed and used to evaluate the rice milling situation in the subdistricts of Ciomas and Ciawi based on 1977-1978 conditions. The following conclusions were drawn from the simulation:

a. Subdistrict Ciomas had an over-capacity of mechanized mills. The simulation projected that the regional mill capacity should be decreased by 60 percent in order to reduce the idle operation time by 77 percent. However, storage loss would be increased by 3.5 tons of rough rice per month in harvest peaks. Storage losses might be offset some by increasing hand pounding practices and by increasing the milling hours per day during the harvest peaks.

b. Subdistrict Ciawi had an under-capacity of mechanized rice mill capacity. This effort indicated reduction of storage losses by about 4 percent. Idle operation time would increase 17 percent during non-harvesting months but would still be relatively low compared to the total operation time per year.

c. Two simulation alternatives evaluated the distribution of mill facilities in each subdistrict.

The output showed the differences between mill class due to the mill cost variation and mill performance of each technology. The results showed that the simplest technology, Engelberg Steel Huller (EGH) and Rubber Roll Huller (RRH), were in general, most favorable. However, the milling quality consideration could shift the technology.

d. The simulation forecast an annual increase of rough rice production in Ciomas of 400 tons per year and in Ciawi 800 tons per year for the period of 1975-1985. Consequently the regional mill capacity in Ciomas should be increased by 3 percent and in Ciawi by 8 percent per year. The simulation model may be used annually to evaluate the different post harvest technology.

CHAPTER VII

SUGGESTIONS FOR FURTHER STUDY

1. Mill Loss Model
   a. Include the effects of grain threshing, storage, pre-mill drying and transportation on the broken rice and kernel damage percentages, to get a more complete picture of the mill conversion.
   b. Include mill by-products percentages for various mill technology in the model, to make a complete analysis of mill losses.
2. Regional Rice Production Model
   a. Better data are required in field harvesting, threshing, transportation and storage losses for various post harvest technologies, to increase the reliability results.
   b. Include factors affecting the production as system variables. The main rice production factors will be rice variety, irrigation practices, pest control, fertilizer application and cultivation methods.
   c. Include explicit exogenous variables in the system such as rainfall distribution, soil

fertility and price effects on planted area changes.

3. Regional Rice Mill Model

    a. Enlarge the model by including the price distortion effect on the system, especially the interrelationships between the milling fee, rice price and the mill performance.

    b. A better optimization technique on the multi-variable constrained search method is suggested to allow a multiple trade-off analysis between the various mill technologies.

    c. Expand the model to include labor availability inputs and a population sub-program to allow for labor displacement evaluation as affected by mill mechanization.

    d. More detailed data on fuel consumption and distribution on each mill technology are needed to evaluate energy utilization changes due to mechanization.

    e. Include mill output evaluation in rice quality for each technology to make better comprehensive analysis on the choice of technique.

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APPENDIX A

RICE POST HARVEST SURVEY IN INDONESIA, 1977/1978

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The Rice Post Harvest Survey was carried out by the interdisciplinary team from the Central Bureau of Statistics of Indonesia (BPS) in Cooperation with the Bogor Agricultural University (IPB) College of Agricultural Engineering and Product Technology. The survey was done during two harvesting periods, in September 1977 for wet season and in March 1978 for dry season. Two weeks of field observation was conducted by 15 enumerators who interviewed farmers and rice millers. The survey covered 11 provinces in Indonesia which are rice production regions. Two districts were chosen from each province. The respondents were selected randomly within the district. Numbers of respondents is given in Table A.1.

The general objective of the survey is to collect first hand information on post harvest practices and problems in Indonesia. Detailed data was emphasized on technical and economical subject of rice milling industry. Those informations will be used for supporting such of development policy on post harvest technology of rice.

Table A.1 Respondent

No.	Province	Farmer		Rice Mill Facility	
		Survey I (SI)	Survey II (SII)	Survey I (SI)	Survey II (SII)
I	North Sumatra	81	38	19	10
II	West Sumatra	118	40	20	20
III	South Sumatra and Lampung	204	40	47	11
IV	West Java	111	100	22	21
V	Middle Java	106	40	24	20
VI	East Java and Bali	189	40	44	15
VII	South Sulawesi	106	39	21	23
VIII	North Sulawesi	-	40	-	18
IX	South Kalimantan	104	38	35	17

To gather information on post harvest operation outputs, samples of rough rice and milled rice were collected from the survey area. Each sample weighed about 25 grams, was examined for its physical and chemical characteristics in the Food Laboratory of Bogor Agricultural University. Rough rice samples were collected from farmers and mill sites where milled rice samples were collected from mill sites and several markets. Amounts of samples collected is given in Table A.2.

In order to gain a general view on post harvest of rice in Indonesia several results from the survey are presented in Table A.3 to Table A.8. Some of the results have been related to the System Modeling under study. The Survey Report will be published by the Central Bureau of Statistics of Indonesia.

Table A.2 Grain Samples

No. Province	Rough Rice				Milled Rice			
	Farmers		Rice Mill		Rice Mill		Markets	
	SI	SII	SI	SII	SI	SII	SI	SII
I	29	40	18	35	18	28	46	58
II	32	40	25	20	16	40	49	40
III	58	40	33	12	40	12	75	46
IV	24	100	5	8	11	9	29	120
V	20	40	18	40	24	40	47	60
VI	80	40	52	29	37	28	83	60
VII	16	40	9	40	40	40	84	60
VIII	-	40	-	38	40	40	-	40
IX	31	40	27	38	40	34	48	60

Table A.3 Harvesting Practices (Frequency Distribution in Percents)

Specification	Province								
	I	II	III	IV	V	VI	VII	VIII	IX
1. Harvesting Month									
a. Jan - Feb	42	14	0	2	2	13	5	62	0
b. Mar - Apr	1	14	1	43	38	29	31	2	15
c. May - Jun	1	21	2	4	11	7	2	11	0
d. Jul - Aug	38	21	26	44	14	45	46	0	57
e. Sep - Oct	13	13	38	7	34	6	16	15	28
f. Nov - Dec	5	17	33	0	1	0	0	0	0
2. Harvesting Time									
a. earlier	5	1	0	9	25	12	3	38	0
b. in optimum time*	9	70	2	0	32	0	6	0	85
c. delayed	86	29	88	81	38	88	91	52	15
3. Harvest Equipment									
a. Ani - Ani	7	0	97	60	100	48	5	0	100
b. Sickle	93	100	3	40	0	52	95	100	0
4. Labor									
a. 1-5 man/ha	4	42	51	2	0	0	1	82	29
b. 6-10 man/ha	12	47	37	2	0	15	2	18	44
c. 11-25 man/ha	12	8	6	4	3	10	3	0	16
d. 25- man/ha	72	3	6	92	97	75	94	0	11
5. Harvest Duration									
a. 1 day/ha	12	24	0	35	9	32	94	0	2
b. 2-3 day/ha	23	39	7	23	39	47	5	15	7
c. 4-5 day/ha	16	6	3	20	14	17	1	35	4
d. 5 day/ha	49	31	90	22	38	4	0	50	87

*Based on farmers experience.

Table A.4 Drying and Threshing Practices (Frequency Distributions in Percents)

Specification	Province								
	I	II	III	IV	V	VI	VII	VIII	IX
1. Stalk Paddy Drying									
a. none	98	96	90	90	95	80	100	100	27
b. in-field	1	3	8	0	0	0	0	0	23
c. in drying-floor	1	1	2	10	5	20	0	0	50
2. Days Lag before Threshing									
a. -1 day	80	86	64	95	83	90	100	100	14
b. 2-3 day	17	13	25	5	17	10	0	0	35
c. 4-5 day	2	1	8	0	0	0	0	0	11
d. 6- day	1	0	3	0	0	0	0	0	40
3. Threshing Equipment									
a. by flail	70	2	27	12	20	6	0	0	0
b. smashing	30	34	5	3	2	46	100	100	0
c. manual treading	0	64	68	83	73	22	0	0	100
d. pedal thresher	0	0	0	2	5	20	6	6	0
4. Rough Rice Drying									
a. over bamboo or wood layer	97	84	88	65	85	42	90	20	100
b. concrete drying floor	3	16	12	35	15	58	10	80	0
5. Drying Labor									
a. none	100	60	100	12	92	67	95	96	100
b. hired labor	0	40	0	88	8	23	5	4	0

Table A.5 Farm Milling and Storage Practices (Frequency Distribution in Percents)

Specification	Province								
	I	II	III	IV	V	VI	VII	VIII	IX
1. Milling Techniques									
a. Hand Pounding	2	12	7	3	2	4	0	0	0
b. Mechanical Mill	98	88	93	97	98	96	100	100	100
2. Mill Frequency									
a. 1-2 times/month	92	77	97	60	33	48	58	32	68
b. 3-5 times/month	8	23	3	40	57	21	41	46	32
c. 6-10 times/month	0	0	0	0	10	19	1	20	0
d. 10- times/month	0	0	0	0	0	12	0	2	6
3. Milling Month									
a. Jan - Feb	17	16	17	16	15	9	14	16	14
b. Mar - Apr	16	16	15	16	17	19	16	16	17
c. May - Jun	16	17	13	16	16	22	18	16	17
d. Jul - Aug	16	16	15	16	16	19	16	16	16
e. Sep - Oct	16	16	18	16	17	27	18	17	18
f. Nov - Dec	16	16	22	17	16	4	18	16	18
4. Farm Storage									
Average length, in months	5.6	3.0	6.0	3.5	2.6	1.3	2.5	1.4	7.1
5. Storage Equipment									
a. Bag	31	46	58	34	22	66	39	15	46
b. wood-box	42	2	3	28	40	0	57	10	34
c. bamboo-box	1	0	0	17	36	19	0	0	0
d. Bulk	36	52	39	21	2	15	4	75	20

Table A.6 Marketing and Post Harvest Cost

Specification	Province								
	I	II	III	IV	V	VI	VII	VIII	IX
1. Rough Rice Marketable Surplus in Percents	31.4	40.4	28.6	40.8	49.5	62.1	52.8	47.4	40.1
2. Harvesting Cost Frequency Distribution in Percents									
a. -10,000 Rupiah/ha	68	45	87	48	92	66	97	100	18
b. 10,000-20,000 Rupiah/ha	24	10	10	49	3	26	3	0	59
c. 20,000-30,000 Rupiah/ha	8	35	3	2	0	0	0	0	18
d. 30,000- Rupiah/ha	0	10	0	1	5	8	0	0	5
3. Threshing Cost in Rupiah/kg paddy	4.4	3.4	2.9	2.0	3.0	2.7	2.1	2.0	3.6
4. Drying Cost in Rupiah/kg paddy	*	1.0	*	0.6	0.8	0.9	2.5	2.1	*
5. Milling Fee									
a. in Rupiah/kg rough rice	*	10.0	9.0	6.4	6.6	*	3.2	6.4	*
b. in percents of milled rice	5.0	5.7	6.0	9.8	*	4.0	4.9	*	9.9
6. Transport Cost in Rupiah/kg rice	*	6.3	1.2	2.0	1.0	1.6	0.8	3.5	2.0
7. Farm Rough Rice Price in Rupiah/kg	61.89	*	65.0	65.0	52.9	56.8	48.1	79.1	*
8. Rural Market Milled Rice Price in Rupiah/kg	130.0	113.0	137.7	109.1	98.9	115.0	100.3	*	177.0

*Inadequate data

Table A.7 Rough Rice Condition

Specification	Province								
	I	II	III	IV	V	VI	VII	VIII	IX
1. Moisture Content in Percents Wet Basis									
a. in farm: - Survey I	14.72	14.95	13.53	14.41	14.76	15.73	13.24	*	14.52
- Survey II	17.10	14.58	15.08	16.42	16.46	14.65	14.96	15.99	15.78
b. in mill site: - Survey I	14.75	14.74	12.43	14.47	14.40	14.01	13.70	*	14.23
- Survey II	16.36	13.57	13.41	16.47	15.89	14.54	13.07	14.54	15.51
2. Seedless Grain in Percents									
a. in farm	5.03	5.24	5.38	3.59	6.54	10.29	5.13	*	7.71
b. in mill site	4.87	5.21	4.26	3.88	6.72	12.22	5.59	*	6.24
3. Foreign Materials Content in Percents									
a. in farm	0.22	0.32	0.85	0.37	0.81	0.60	0.61	*	0.72
b. in mill site	0.24	0.28	0.84	0.20	0.45	0.76	0.60	*	0.63
4. Grain Size in mm									
a. length	8.89	8.98	8.67	8.51	8.62	8.49	8.72	*	8.03
b. width	2.76	2.80	2.93	2.93	2.94	2.98	2.92	*	2.88
c. thickness	1.94	2.03	2.00	2.02	1.94	2.01	1.95	*	1.98

*Inadequate Data

Table A.8 Milled Rice Condition

Specification	Province								
	I	II	III	IV	V	VI	VII	VIII	IX
1. Moisture Content in percents wet basis									
a. in Rural Market	12.46	*	11.37	13.23	13.07	12.37	12.32	12.53	*
b. in Subdistrict Market	12.54	12.45	11.48	13.18	12.88	12.11	13.62	12.22	13.88
c. in District Market	12.09	12.51	11.38	13.62	12.92	12.27	12.10	12.06	13.56
d. in Mill Site	12.34	11.82	10.83	13.18	12.27	12.32	12.16	11.85	13.53
2. Protein Content in percents dry basis	5.50	6.91	7.19	8.82	10.13	9.71	9.85	8.26	6.52
3. Carbohydrate Content in percents dry basis	*	71.03	73.09	72.01	72.24	72.51	*	72.74	71.30
4. Anylose Content in percents dry basis	25.23	23.60	23.16	23.96	22.94	23.36	23.25	*	22.75
5. Head Rice in percents of milled rice									
a. in Rural Market	66.96	*	62.64	70.60	70.47	68.66	74.51	69.39	*
b. in Subdistrict Market	67.30	65.48	62.57	71.14	66.54	69.31	70.73	62.97	61.34
c. in District Market	68.72	64.34	65.41	65.31	74.75	69.81	76.45	62.74	68.62
d. in Mill Site	61.67	63.82	71.73	72.55	78.62	65.21	69.17	73.41	57.89
6. Brewer Rice in percents of milled rice									
a. in Rural Market	1.15	*	4.55	2.05	1.32	1.69	0.99	*	*
b. in Subdistrict Market	0.50	3.04	3.04	0.49	2.03	0.83	*	*	3.59
c. in District Market	1.79	3.11	1.62	2.01	2.45	1.38	1.46	*	1.42
d. in Mill Site	1.62	2.95	1.86	0.42	1.73	4.33	2.92	*	7.13

*Inadequate Data