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IN THE RICE PROCESSING INDUSTRY
OF SIERRA LEONE

by
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The African Rural Economy Program was established in 1976 as an activity of Michigan State's Department of Agricultural Economics. The African Rural Economy Program is a successor to the African Rural Employment Research Network which functioned over the 1971-1976 period.

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PREFACE

This paper has been developed as part of a three year study of rural employment problems in Africa financed under a U.S. Agency for International Development Contract (AID/csd 3625) with Michigan State University. The research in Sierra Leone was carried out under a Memorandum of Agreement between Michigan State University and the Department of Agricultural Economics and Extension, Njala University College, University of Sierra Leone and was financed under the terms of Contract AID/csd 3625. The Njala University College research program was also supported by grants from the Rockefeller Foundation and the Population Council. The research in Sierra Leone was under the direction of Dr. Dunstan S.C. Spencer.

1. Introduction

1.1. The Importance of Rice in Sierra Leone

Rice is one of the major crops grown in the world. In Africa the most important rice producing countries are Egypt and the Malagasy Republic which between them account for 62 percent of all the rice produced in Africa. Sierra Leone is the third most important rice producing state in Africa and the most important producing state in West Africa with about seven percent of the total African production [23].

Rice is the staple food in Sierra Leone, with over 50 percent of the total quantity of food available being rice. Rice is grown by over 80 percent of Sierra Leone farmers and accounts for at least a third of the value of agricultural trade [13].

1.2. The Policy Issues

Sierra Leone, like all West African governments recognizes that agriculture is the backbone of the national economy. Over a third of the gross national product is generated in agriculture and at least 70 percent of the population is employed in agriculture. But the growth rate in agriculture has lagged behind that of other sectors. While the national economy of Sierra Leone is estimated to have grown at an annual rate of 4.3 percent in real terms in the last decade, the agricultural sector is estimated to have grown at only 1.7 percent per annum [15], only just enough to match the population growth. The annual growth rate of the national economy itself at 4.3 percent is considered unsatisfactory, it being less than the average growth rate of five percent achieved by developing countries as a whole.

Within the agricultural sector the failure to produce enough rice for self-sufficiency has continually troubled all policy makers in West Africa. This concern led to the setting up of the West African Rice Development Association (WARDA) in 1971 as an intergovernmental agency of the West African governments, charged with helping to coordinate national policies which would help the West African states achieve their goals of regional self-sufficiency in rice production. In order to achieve the goal of self-sufficiency, the Sierra Leone as well as other West African governments are attempting to implement policies which would lead to increased domestic rice production as well as improved efficiency in the processing and marketing of rice so that rice produced can be properly utilized in satisfying regional demand. Rice production techniques and policies are the subject of a separate report [18]. This monograph concentrates on the rice processing industry.

In West Africa there is a range of technologies in use and potentially available for processing the rice crop. These range from traditional hand pounding to large mechanical mills. Because these technologies have varying factor intensities and output efficiencies the choice of technology in any country will have important effects on factor utilization and on output. Of particular interest is the potential effect on employment. In Sierra Leone the government is currently considering the need for investment in new rice processing facilities. The questions being considered relate to whether investment should be directed to rehabilitation of three old existing large mills, purchase of new large mills or encouragement of private investment in small mills and where any new mills should be located.

Recent studies in Indonesia [5, 20, 22] have shown that the choice of technique in the rice milling industry of important rice producing countries have important implications for national employment and income distribution.

In this study the rice processing industry of Sierra Leone is described and the effect of the choice of technique on efficiency, employment and incomes analyzed.

The specific objectives of this study are therefore as follows:

(1) To describe and analyze the traditional and modern techniques of processing rice in Sierra Leone.

(2) To develop a methodology which would allow explicit consideration of employment and income effects of policies designed to foster development of the rice processing industry under varying assumptions relating to factor and output prices.

(3) On the basis of the above to make recommendations on policies relating to investment in different rice processing techniques in Sierra Leone.

In the rest of this section the methodology used in analyzing the choice of technique in rice processing in Sierra Leone and the sources of data are described. In Section 2 the different rice processing techniques are described and in Section 3, the economics of their operation examined. Section 4 contains a detailed description of the Sierra Leone rice processing and transportation model while Section 5 contains the results of policy analysis using the model. The final section contains the summary and policy conclusions.

1.3. Methods of Analysis

As Timmer points out [20] economists have until recently given little attention to the employment aspects of marketing change. They have concentrated on market margin analysis emphasizing the need for modernization leading to reduced marketing margins. Within this framework labor is but one input and has received no more attention than other inputs. The need to give more explicit consideration to employment in all decisions relating to economic development policies in Africa has only recently been highlighted [2, 7].

In his study of the choice of technique in rice milling in Indonesia, Timmer developed a method of analysis that gave explicit consideration to employment. He constructed a unit isoquant in value added by each of the techniques he examined [20]. Following Warr [22] we can represent the choice of technique criterion employed by Timmer as

$$\underset{k}{\text{Min.}} \frac{X_k^k + \sum_{t=1}^{50} \frac{W_k X_{kt}^e}{(1+i)^t}}{p^k X_{kt}^k - p^G X_{kt}^G},$$

where 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}^k = quantity of milled rice of type k produced by technique k in year t

X_{kt}^G = quantity of rough rice (paddy) used by technique k in year t

p^k = market price of type k rice

p^G = market price of paddy (husk) rice.

Using the above decision criterion, Timmer shows that the small labor intensive rice mills dominate both hand pounding and more capital intensive techniques. Collier et al. [5] carried the analysis further to show that the introduction of the more efficient small rice mills in replacement of hand pounding had far reaching effects on employment and income distribution with the redistribution of income in favor of relatively large farmers and operators of small rice mills and reduced employment of women hiring out their labor for hand pounding of rice.

In order to more explicitly explore the implications of social discount rate on the choice of technique in Indonesia Warr [22] used the following decision criterion:

$$\max_{k} \frac{N_k}{X_k^G}$$

where N_k = net present value of the stream of aggregate consumption generated by production using technique k

X_k^G = quantity of rough rice (paddy) milled by technique k.

Warr concludes that if we assume that investment cost is the binding constraint the optimal technique is the small rice mill. If the supply of rough rice is considered the binding constraint then the optimal choice would be any one of the four techniques examined, depending on the other assumptions, e.g., rice prices, capital sources and cost, the social rate of discount, etc.

The studies on the Indonesian rice milling industry, referred to above only took into consideration the milling cost. In practice other considerations enter into the policy decision about the technique or combination of techniques which should be adopted. Because of the different plant sizes and level of capacity utilization each technique usually involves vastly different assembly and distribution costs of raw material (paddy) and product (clean rice), i.e., the location of the plants relative to producing and consuming centers could have an influence on the choice of technique issue.

Stollsteimer [19] originally developed a model to determine the plant size and location but it only considered assembly costs. King and Logan [10] extended the Stollsteimer model to incorporate assembly as well as distribution costs.

In a recent study in Ghana Goodwin [8] used a modification of the King and Logan technique as well as mixed integer models to examine the effect of factor price distortions on the optimum size and location of rice milling plants in northern Ghana. Goodwin found that distortions in the factor markets (the low financial cost of capital and the overvalued exchange rates) encourage larger and fewer plants than is optimal for the economy considering the social welfare costs of national resources as measured by the shadow cost of capital, the shadow foreign exchange rate and the shadow wage rate. The major limitation of Goodwin's study is that he only considered one technique of rice milling (multi-stage rice mills), various plant sizes being obtained by multiples of the basic unit at each of the thirty-three possible locations he considered.

In the study reported here a continuous linear programming model was developed and used to determine the optimum technique, size and location of rice processing facilities under various conditions.

Mixed integer programming is an efficient tool for dealing with situations in which economies of scale exist and in which it is unrealistic to expect fractions of plants to be constructed. Unfortunately there was no algorithm for solving a mixed integer model of the size needed in this study available to the authors. Since it would have taken considerably more time to obtain and operationalize a formal algorithm than was available a heuristic approach was used to partially overcome the limitations of linear programming when economies of size[1] exist as in the operation of large rice mills in Sierra Leone.

The continuous linear programming model was solved using a modification of the King and Logan technique. The model, which is described in detail later, examines five techniques of rice processing (traditional hand pounding, small steel cylinder mills, small rubber roller mills, large disc-sheller mills and large modern rubber roller mills) at each of ten possible locations in Sierra Leone. Processing, as well as assembly and distribution costs are therefore explicitly taken into consideration in examining the effects of alternative policy choices on employment, output and incomes. This situation therefore more closely approximate the real world than any of the previous studies relating to the choice of technique in rice milling.

To arrive at solutions of the model which incorporate decreasing milling costs as the level of capacity utilization within a large mill increases the approach followed was to first solve a continuous linear programming model to minimize total transport and milling cost (fixed plus variable costs). In the initial run large mills were programmed at their most efficient level of operations, i.e., at 100 percent utilization of theoretical capacity. The assumption is therefore that average fixed costs and average total costs are constant and at the lowest point for all levels of capacity utilization (Figure 1, A). For all large mill sites at which a fraction of a large mill occurred in the final solution

[1]In this monograph "economies of size" is a short run phenomenon used to refer to economies of fixed capacity utilization. It should not be confused with the economist notion of "economies of scale."

of the continuous model (including zero mills), an additional milling activity was then added incorporating milling costs per ton which represent one of three levels of capacity utilization (33, 67 or 100 percent)[1] for the large mills (Figure 1, B). Also constraints on the number of mills operating at full capacity were set at the integer number lower than the fractional number in the final continuous solution. The model was solved again. If the quantities milled of each location were outside the range for the milling costs specified, the costs were adjusted and the model run again. The process was repeated until there was very little change in objective function value.

The effect of the above procedure is to reallocate rice being milled in fractional large mills in the continuous model solution to the most efficient location and technique (including hand pounding and small rice mills which are assumed to have constant average total milling costs) taking into consideration the fact that economies of size exist in large mills due to the level of capacity utilization.

1.4. Source of Data

Since adequate secondary information was only available for the large mills it was necessary to conduct a number of surveys to collect primary data for the traditional technique of hand pounding as well as for small rice mills.

Information of hand processing of rice was obtained from about five-hundred farm households located in twenty-four enumeration areas selected to represent the eight rural resource regions in the country

[1] Breaking the total cost function into three segments is believed sufficient in this case where total capacity is only 8000 tons of paddy per annum, small by United States standards.

(Figure 2).[1] As part of the study of agricultural production in Sierra Leone [18] information was obtained on the time allocated to rice processing and the quantity of rice processed during twice weekly interviews conducted between February 1974 and May 1975. The value of investment in traditional processing equipment was obtained from a stock questionnaire administered at the start of the survey period.[2]

Since hand pounding of rice is a household activity which is usually performed daily and takes around an hour each time, it was decided to supplement the information obtained in the large multiple visit survey by a smaller time and motion study. About seventy hand pounding operations were observed using a stop watch to determine the proportion of time spent pounding, winnowing and resting. The quantity of paddy pounded and the resulting clean rice output were weighed and the percentage brokens estimated.

In order to obtain information on the number, location and operation of small rice mills a special two phase study was conducted. In the first phase the total population and location of small mills was estimated. All localities in Sierra Leone with more than 2,000 people in the 1963 census were visited in 1974 and the number of small rice mills as well as small scale industrial establishments determined.[3] A questionnaire was also mailed to all Paramount Chiefs asking them for information on the number and type of small mills in their chiefdom. This mail questionnaire was supplemented by field visits to the majority of

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[1] See Appendix 1 for a list of chiefdoms in each resource region.

[2] For a detailed description of the methodology used in the farm level study see Spencer and Byerlee [18].

[3] See Chuta and Liedholm [3, 4] for a description of this survey.

Figure 2. Sierra Leone Rural Enumeration Areas and Urban Areas

chiefdoms in Sierra Leone during the almost eighteen months of field work. The second phase of the study commenced in July 1974 and ran through June 1975. In this phase, two to four mills were sampled in each of the sixteen towns selected in the small scale industry study [3, 4], depending on the size of the town. The locations of the towns are shown in Figure 2.

Selected establishments were visited at the onset to determine investment costs, source of capital, etc. Thereafter they were visited twice a week to collect information on type and quantity of paddy processed, number of customers, quantity and value of fuel and other inputs used, purchase of spare parts, hours of work, payment for labor hired as well as income from sale of by-products and custom milling fees collected. To supplement the above information sample weighings were made to estimate milling-out percentages and percent brokens.

For the large modern mills input-output information was obtained mainly from published sources [1] as well as from on-site visits to the existing mills.

2. Type and Location of Existing Rice Processing Facilities

Four techniques of rice processing are currently in use in Sierra Leone (hand pounding, small steel cylinder mills, small rubber roller mills and large disc sheller mills). In this section each of these techniques is examined. The number of establishments and their locations are described.

2.1. Hand Pounding

Hand pounding is the traditional and most widespread method of processing rice in Sierra Leone. Hand hulling of rice is performed using a mortar and pestle made of wood. Mortars are of various sizes and the pestles are usually about six feet in length. Up to three people, usually women and children, may pound paddy simultaneously in the same mortar. Pounding is continued for sometime, after which the rice is winnowed and the operation repeated several times depending on the degree of milling desired.

Rice may be hulled raw, i.e., rough rice or it may be parboiled before hulling. Parboiling consists basically of saturating paddy with water and raising the temperature to that required to gelatinize the starchy endosperm. Because gelatinization fuses all the starchy molecules the rice kernel is whole and stronger when dried so that the outturn of milled rice is higher for parboiled paddy (which is also more nutritious) than raw rice [14]. The percentage brokens obtained in milling parboiled rice also tends to be lower than that obtained when raw rice is milled but the actual percentage obtained depends on the drying process [6]. Hand parboiled rice may be milled by hand or mechanically. In the most common village method of parboiling rice, a mixture of paddy and water is boiled in large iron pots or in forty-four gallon drums, or part of a drum, until the grains are slightly swollen and soft and some of them burst. The paddy is then removed and spread out to dry in the sun. Another common method of parboiling paddy involves soaking of the grain overnight and then bringing the water to boiling temperature the next morning, before sun-drying. The proportion of rice output that is parboiled varies from region to region as is discussed later.

As mentioned earlier hand processing of rice is widespread in Sierra Leone. Table 1 shows the hours and proportion of total work time

Table 1. Time Devoted to Hand Processing of Rice by Rural Households in Sierra Leone, 1974/75

(Mean Per Household Per Year)

Region	Total Hours of Processing	Percent of Total Work Hours a/
1. Scarcies	147.80	2.83
2. Southern Coast	223.95	3.60
3. Northern Plains	200.10	3.41
4. Riverain Grasslands	168.32	4.65
5. Bolilands	396.97 b/	7.60
6. Moa Basin	76.83	2.07
7. Northern Plateau	69.65	1.32
8. Southern Plains	98.55	3.61

a/ Time spent in farm and nonfarm activities. Does not include time spent in purely domestic activities such as cooking of meals and fetching water or other social activities such as litigations and parliamentary activities.

b/ Includes some rice threshing.

devoted to hand pounding of rice by households in the different regions of Sierra Leone in the 1974/75 crop year. The actual time spent pounding by each household depends importantly on household size, the total output of rice, the total proportion which is marketed as well as the proportion marketed as clean rice.

2.2. Small Rice Mills

There are two types of small mechanical rice mills in operation in Sierra Leone. The older longer established type operates on the Engelberg steel cylinder principle. The mills are powered by 10 to 15 h.p. engines. The most common make is the English made Lewis Grant mill with smaller numbers of McKinnon and German made Schule mills. One-hundred and forty-five of these mills were identified in Sierra Leone in 1967 [16].

In the last two to three years the rubber roller mill manufactured by the Japenese firm Satake has been introduced into the country. It is estimated that about thirty to fifty were sold between 1972 and 1974. Both steel cylinder and rubber roller mills are rated to process about cne-quarter ton of clean rice per hour.

Table 2 shows the regional distribution of the mills identified in two surveys in Sierra Leone, as well as the regional distribution of rice produced in 1974. The table shows that outside the Western Area, the regions which had the highest concentration of small rice mills were the Scarcies, Riverain Grasslands and Bolilands. The figures also show that between 1967 and 1974 there was an increase in the number of mills in the Bolilands reflecting the growth in commercial rice production as a result of a great increase in mechanical cultivation in the Bolilands. Acreage mechanically cultivated increased from about 10,000 in 1967 to

Table 2. Paddy Available for Consumption and Regional Distribution of Small Rice Mills in Sierra Leone, 1967 and 1974

Region	No. Rice Mills		Available Tonnage of Paddy, 1974[b/]	Tons Per Mill 1974
	1967[a/]	1974		
1. Scarcies	30	53	28,577	539
2. Southern Coast	8	6	21,647	3,608
3. Northern Plains	12	14	57,704	4,122
4. Riverain Grasslands	12	15	13,533	902
5. Bolilands	6	37	31,373	848
6. Moa Basin	5	42	80,239	1,910
7. Northern Plateau	2	18	91,366	5,076
8. Southern Plains	38	64	100,764	1,574
Western Area	32	19	1,278	67
Sierra Leone	145	268	426,481	1,591

[a/] Calculated from Spencer [16]. The figures for Region 6 are an estimate since no field work was done in the Eastern Province.

[b/] Derived from [1, 23] by reallocating district total production by the proportion of the district in the resource region and by defining available tonnage as equal to total production less allowance for seed (60 pounds per acre) and losses (10 percent).

32,000 in 1974 [17]. Large increases in mill numbers have also occurred in regions 1, 6, 7 and 8. At the same time the number of mills in Freetown (Western Area) have dropped drastically as worn out mills have not been replaced. This reflects the fact that more rice is now being milled in producing areas than was the case in the past when the rice was usually partially milled by hand and shipped to Freetown to be further milled in the small mills before sale to consumers. This trend is verified later in the rice processing model.

2.3. Large Rice Mills

There are at present three large rice mills in Sierra Leone, owned and operated by the Rice Corporation, a government owned institution with monopoly powers for importing and exporting rice. One of the three large mills is situated at Kissy in Freetown, the other at Mambolo in the Scarcies Region and the third at Torma Bum in the Riverain Grasslands (see Figure 2). These mills are of the disc-sheller type and are each equipped with large mechanical parboiling plants, with mechanical drying at the Kissy plant. The mill at Mambolo has a capacity of about 1,600 pounds per hour and was installed in 1950. Those at Torma Bum (about 1,600 pounds per hour) and Kissy (about 4,480 pounds per hour) were installed around 1960. Each mill has large storage facilities (8,000 tons at Kissy, 4,000 tons at Mambolo and 3,000 tons at Torma Bum) so that rice can be purchased at harvest and milled throughout the year [13]. About twelve to fifteen men are required per shift to operate the mills. These large mills have not operated in the past two years.[1] To get them fully operational again would need some capital investment for

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[1] Personal communication from Mr. Arthur Davies, Mechanical Superintendent, Rice Corporation.

rehabilitation. The Rice Corporation is presently considering whether to rehabilitate and put the mills back into service.[1]

3. Operation of Existing Rice Processing Facilities

In this section the operation of hand pounding and mechanical milling facilities is described. The information on hand pounding was derived solely from the primary surveys conducted during the period of field work for this study, that for the small mills was derived mainly from the primary surveys supplemented with some existing secondary information. The information in the large rice mills was derived mainly from secondary sources.

3.1. The Hand Pounding Operation

3.11. Capital Cost

The capital requirement of the traditional hand pounding system like that of most traditional systems is very low. In the farm survey of about five-hundred rural households, all of whom had mortars and pestles, the mean replacement costs of mortars and pestles was Le 1.30 (S = 1.32)[2] with an average age of 3.28 years (S = 2.68).

Parboiling drums and pots cost Le 2 to 4, and can be expected to last up to six years of regular use.

3.12. Labor Utilization

Hand pounding is the most labor intensive of all the techniques of rice processing and it is female dominated. The farm production study and the time and motion study of hand pounding showed that 80

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[1] Arthur Davies, Ibid.

[2] Le 1.00 = $1.10 U.S. at the time of the survey. S = standard deviation.

percent of the people involved in hand pounding are female. Males taking part in hand pounding were usually boys under the age of twenty-one (Table 3). One to three people (mean = 1.61, S = 0.75) take part in each operation.

3.13. Output

Table 4 shows that about four pounds of paddy were pounded on each occasion in the north, nine pounds in the south with a national mean of about seven pounds per pounding.[1] The mean quantity of paddy pounded per person per minute (adult equivalent including rest time) was about 0.17 pounds in the north as well as in the south. This is equivalent to about 10.2 pounds (4.6 kgs.) per hour, a figure similar to the 11 pounds (5.0 kgs.) per hour reported by Collier et al. [4] for Indonesia, but vastly different from the 100-140 pounds per hour assumed by Agrar Und Hydrotechnic in their study of rice marketing in Sierra Leone.

There is also alot of difference between the form of rice pounded in the south and north. About 79 percent of the rice pounded and consumed[2] in the south was raw rice compared to about 44 percent in the north. These figures indicate that a much lower proportion of parboiled rice is consumed in rural areas of Sierra Leone than had been generally assumed and that the consumption of parboiled rice is more common in the rural areas in the north than in the south. As is shown later more parboiled rice is consumed in urban than rural areas.

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[1]The larger quantity pounded on each occasion is partly a reflection of larger household sizes in the north and partly a reflection of the desire to pound rice less frequently but in larger amounts.

[2]All the observations in the time and motion study were of rice being pounded for home consumption. Rice for sale is sometimes hand pounded also.

Table 3. Frequency Distribution of Family Labour by Type in Hand Pounding of Rice in Sierra Leone, 1975

Labor Type	Number of Persons	Percent
Male		
Under 10 years	2	1.8
10 - 19 years	16	14.4
20 - 39 years	4	3.6
Over 39 years	0	0.0
Female		
Under 10 years	18	16.2
10 - 19 years	18	16.2
20 - 39 years	46	41.4
Over 39 years	7	6.3
Total	111	99.9

Source: Time and motion study of seventy hand pounding operations.

Table 4. Input-Output Relationships in Hand Pounding of Rice in Sierra Leone, 1975

	Sierra Leone	North[a/]	South[b/]
People Pounding			
Total Persons	1.61	1.6	1.7
	(0.75)	(0.9)	(0.7)
Adult Equivalent[c/]	1.31	1.3	1.4
Paddy Pounded (lbs.)	7.17	3.93	9.17
	(5.79)	(3.03)	(6.28)
Total Person Time (mins.) Per Pounding (Including Rest)	55.5	29.6	71.5
	(35.0)	(21.9)	(31.9)
Rest Time (%)	13.6	13.1	13.9
Quantity Pounded Per Adult Equivalent Per Pounding (lbs.)	5.47	3.02	6.55
Qt. Pounded Per Adult Equivalent Per Min. (lbs.)	0.167	0.172	.166
Form of Rice Pounded (%)			
Raw	61.1	43.6	78.6
Parboiled	38.9	56.4	21.4
Out-turn (Milling %)			
Raw Rice	68.0	62.0	69.3
	(12.6)	(13.4)	(11.5)
Parboiled Rice	69.4	69.3	70.5
	(7.4)	(4.5)	(11.5)
All Rice[d/]	68.4	65.4	70.2
	(11.1)	(9.3)	(11.2)
Percent Brokens[e/]			
Raw Rice	47.4	59.9	40.3
	(18.8)	(18.1)	(15.4)
Parboiled Rice	31.7	32.3	30.7
	(24.2)	(26.4)	(21.8)
All Rice[d/]	41.7	46.1	37.9
	(22.1)	(22.2)	(17.0)

[a/] Regions 1, 3, 5, 7.

[b/] Regions 2, 4, 6, 8.

[c/] Adult equivalent (over 19 years) = 1.5 youths (10 to 19 years) = 2 children (under 10 years).

[d/] Weighted mean.

[e/] Weight of grains less than three-quarters of whole grains as percent of total output.

Standard deviations are in parentheses below the figures to which they refer.

Source: Field Survey.

Table 4 also shows that the milling percentage is higher and percent brokens lower for hand pounded parboiled rice than hand pounded raw rice.

3.2. The Operation of Small Rice Mills

3.21. Capital Costs

The replacement cost (1974/75 prices) of small rice mills was about Le3,200 for the steel cylinder mill with a 15 h.p. diesel engine and Le2,450 for one with a 15 h.p. electric motor. These prices were respectively about 230 and 300 percent higher than prices reported by Spencer in 1966/67 [16]. The common type of the newly introduced rubber roller mills (Satake SB10) cost about Le5,900 with a 15 h.p. engine in 1974/75.

3.22. Labor Utilization

To effectively run and maintain a small rice mill only one semi-skilled operator is required. Additional workers may be needed to help with loading the mills' hopper or for bagging the rice.

Table 5 contains input-output figures for the same of small mills studied in 1974/75. The figures showed that the mills in Sierra Leone worked an average of 10 man-days a week, i.e., about 3 people (an operator and two laborers) worked at the mill each day it was open. There are regional differences, labor utilization being lower in general in the more efficient mills in the south. Hours of work per day also varied regionally, the national average being 5.2 hours per man-day.

3.23. Other Inputs

Table 5 also shows that proprietors on the average spent about Le2.51 per week on spare parts, i.e., about Le0.014 per bushel of rice

Table 5. Input-Output Relationships for Small Rice Mills in Sierra Leone, 1974/75

	Freetown Steel	North Steel	South Steel	North Rubber	All
	(Average Per Mill Per Week)				
Days of Work	4.32 (2.14)	3.22 (2.69)	4.01 (2.02)	2.08 (2.31)	3.56 (2.48)
Bushels[a] Raw Paddy Milled	11.75 (27.42)	43.30 (65.39)	36.26 (44.73)	5.55 (10.81)	29.76 (51.99)
Bushels Parboiled Paddy Milled	161.97 (138.29)	126.87 (222.40)	233.59 (280.41)	44.09 (73.64)	150.37 (212.90)
Total Paddy Milled (Bushels)	174	170	270	50	180
No. Customers Served	8.7 (5.9)	27.0 (27.6)	13.4 (9.2)	11.0 (7.8)	13.3 (15.5)
Man-days[b]	10.5 (8.5)	13.2 (11.1)	5.3 (3.1)	9.0 (6.4)	10.1 (8.7)
Man-hours[b]	45.7 (52.8)	112.9 (131.3)	12.2 (8.5)	16.7 (8.2)	52.3 (79.9)
Down Time (Hrs.)	2.1 (2.2)	3.2 (3.5)	3.2 (2.6)	2.8 (2.0)	2.8 (2.7)
Value of Spare Parts (Le.)	4.62 (11.92)	1.61 (7.20)	0.89 (6.59)	3.87 (15.52)	2.51 (9.74)
No. Mills in Sample	5	9	4	2	20

[a] 1 bushel = 60 lbs. husk rice.

[b] Operator + Apprentice + Hired Labor.

Figures in parentheses are standard deviations.

Source: Field Survey.

milled. Spare parts most often required were rollers for rubber roller mills and sieves for steel cylinder mills.

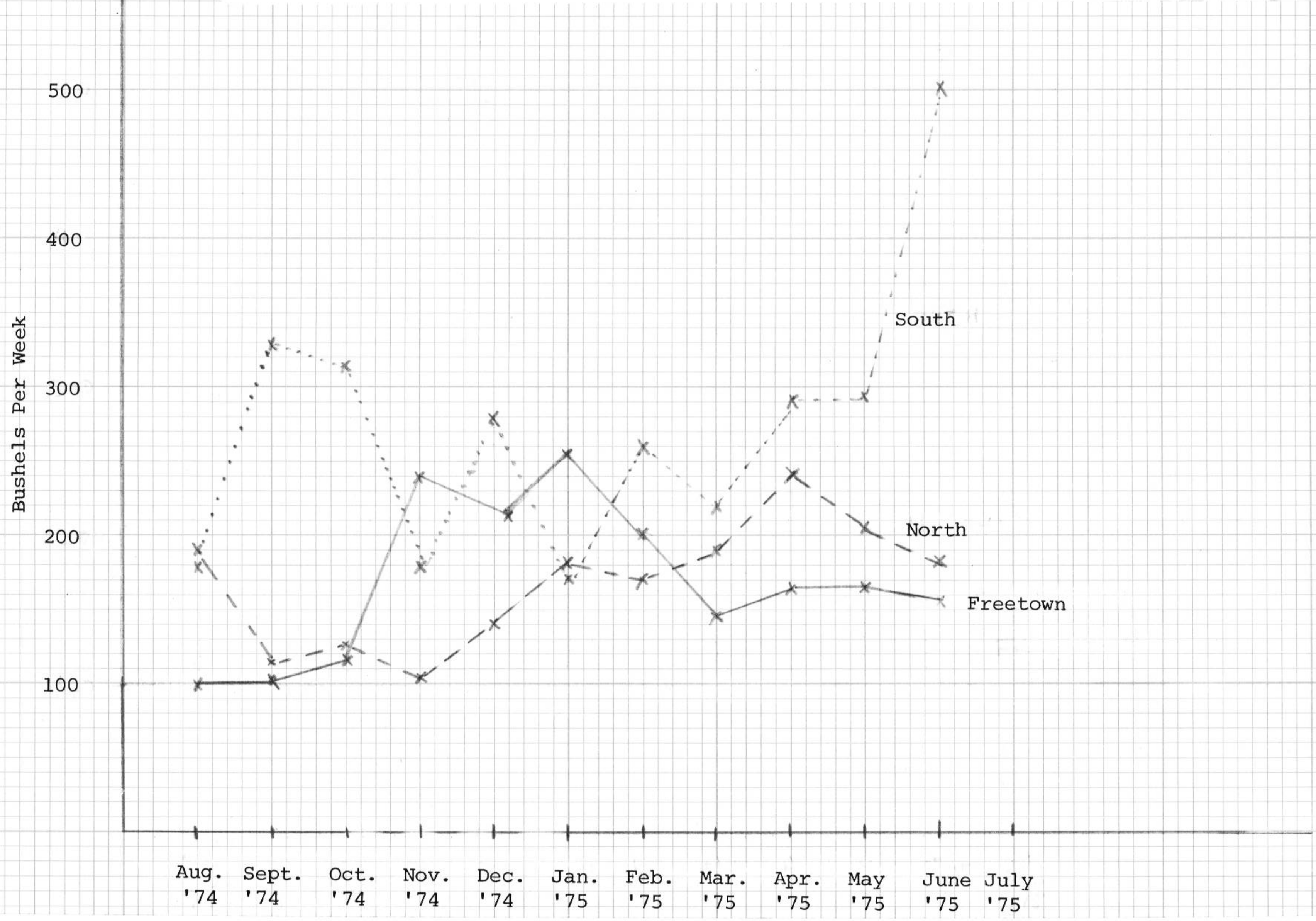
The 1974/75 survey showed that the rate of use of other inputs was similar to that in 1967. For electric powered mills electricity consumption was an average of 1.4 kilowatts per bushel (compared with 1.3 reported in 1967). Diesel consumption was one gallon for 18.9 bushels of husk rice milled (18.1 in 1967). Prices had of course increased. Diesel fuel which was about Le0.45 per gallon in 1967 was an average Le0.97 per gallon in 1974/75 and electricity charges were Le0.11 per kilowatt compared to Le0.10 in 1967.

3.24. Output

Table 5 shows that small rice mills in Sierra Leone milled an average of about 180 bushels of paddy per week during the 1974/75 season. If we define annual theoretical capacity for these mills as 250 days of one shift operation (eight hours per day) i.e., about 670 tons of paddy per annum, this means that the average mill in Sierra Leone operated at about 37 percent of theoretical one shift capacity. Mills in the south on the average operated at about 56 percent of annual capacity.

Figure 3 shows the monthly variation in quantity of paddy processed. The graphs show a slight upward trend in quantities processed throughout the survey period reflecting the increased production of rice between the 1973/74 and 1974/75 seasons. There is no clear seasonal pattern in the monthly variations except for the mills in Freetown. These mills follow the seasonal pattern described in 1967, i.e., peak months of operation during and soon after the harvest season (November through February) with a slack period during the growing season (June through October). But even for these mills the difference between slack and

Figure 3. Monthly Variation in Quantity of Rice Milled by Small Rice Mills in Sierra Leone, 1974/75



peak seasons (100 to 250 bushels per week) is not as pronounced as in 1967.

Another difference between mills in 1967 and those in 1974/75 is in the quantity of paddy milled per customer. In 1967 the average for three mills for which accurate information was available was 3.5 bushels per customer [16]. In 1974/75 the national average was 13.5 bushels, with a range from 6.3 bushels in the north to about 20 bushels per customer in Freetown and the south (Table 5). This change reflects the increased supply of rice in commercial channels in 1974 compared to 1967. Traders who are the main users of small mills were in control of larger quantities.

A much higher proportion of the total input of rice processed by small mills is parboiled than is the case for hand pounding. Table 5 shows that about 83 percent of all rice milled by small rice mills in Sierra Leone was parboiled compared with 39 percent for hand pounding (Table 4). Also in contrast to the marked difference between the percentages for handpounding in the north and south (Table 5) there is not much difference in the figures for the small mills in the north and south. The reason for this difference in the proportion of processed rice that is parboiled is that handpounded rice is mainly for home consumption while milled rice mainly moves in commerce and goes to satisfy urban demand. As shown by May-Parker [12] there is a marked preference for parboiled rice by the urban population of Sierra Leone. This preference is supported by the traders and sanctioned by official policy since parboiled rice yields a higher milling percent (out-turn) than raw (unparboiled) rice. This point is confirmed by the figures in Table 6, which also show that the quality of the clean rice produced,

Table 6. Recovery Rates Achieved by Small Rice Mills in Sierra Leone, February/March 1976

	Freetown Steel a/	North Steel	South Steel	North Rubber b/	All
Age mill (months)	43.05 (41.00)	50.02 (31.63)	53.76 (43.64)	24.00	46.58 (38.80)
Milling percent					
Parboiled	67.7 (2.9)	68.3 (3.2)	66.5 (5.5)	73.6 c/	67.7 (3.2)
Rough rice	64.5 (4.3)	66.9 (3.6)	66.3 (5.5)	67.0 c/	66.8 (3.5)
All rice d/	67.3 (3.2)	67.9 (3.3)	67.2 (4.6)	70.3 c/	67.5 (3.5)
Percent brokens					
Parboiled	16.7 (10.2)	16.3 (11.7)	18.1 (10.9)	3.2 c/	16.6 (10.6)
Rough rice	36.4 (16.0)	35.3 (8.4)	36.6 (10.5)	43.5 c/	36.3 (11.0)
All rice d/	18.9 (12.6)	21.1 (13.8)	27.0 (14.1)	23.4	21.0 (13.5)
Number of samples	80	43	25	2	150

a/ Engleberg steel cylinder mill.

b/ Rubber roller mill.

c/ Only one sample.

d/ Weighted mean.

Note: Figures in parentheses are standard deviations.

Source: Field Survey.

as measured by the percentage of broken grains, is improved by parboiling.

The recovery rates presented in Table 6 were obtained during a special field survey in early 1976 during which sample weighing were made at about fifty mills all over the country. The field survey revealed a national recovery rate of 67.5 percent, much higher than the 55 percent generally assumed by planners and foreign consulting firms which rely on eye estimations and occasional questions asked of operators who do not keep records. Again the average figures in Table 6 are quite close to the 66 percent reported by Spencer in 1967 [16]. A recovery rate of 67.5 percent is generally considered good for Engleberg type mills.[1] Because of the variability of the rice milled in terms of moisture content, variety and foreign matter content, all of which affect recovery rates, there is a wider variability in recovery rates and milled rice quality in terms of percentage brokens (Table 6). This quality control problem is one that will in all probability preclude the use of these small mills for processing rice for export despite the fact that the small rubber roller mills are capable of achieving recovery rates and milled rice quality similar to that observed in large modern rice processing plants.[2]

3.25 Returns

Table 7 presents costs and return figures for the mills studied. These figures showed that small mill owners earned an estimated annual

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[1]And is similar to the 66 percent (range 62-70 percent) reported by Collier et al. for Indonesia [5].

[2]The six Satake SB10 mills operated by the Sierra Leone Rice Corporation over the past four years have consistently yielded an out-turn of 72 percent and percent brokens less than five percent.

Table 7. Costs and Returns for Small Steel Cylinder Rice Mills in Sierra Leone, 1974/75

	Freetown	North	South
Bushels Milled	9,058	8,840	14,040
Costs (Le.)			
Capital[a/] 1. (at 10% interest)	503	657	657
2. (at 35% interest)	977	1,276	1,276
Building Rent[b/]	190	72	72
Electricity[c/]	713		
Diesel[d/]	--	454	750
Others (Repairs, Lubrication, Etc.)	300	376	335
Labor[e/]	313	275	110
Total 1. (at 10% capital)	2,019	1,834	1,924
2. (at 35% capital)	2,493	2,453	2,543
Per Bushel 1. (at 10% capital)	.22	.21	.14
2. (at 35% capital)	.28	.28	.18
Income (Le.)			
Milling Fees[f/]	3,170	3,094	4,914
Total Profit (Le.)			
1. (at 10% capital)	1,151	1,260	2,990
2. (at 35% capital)	677	641	2,371
Profit Per Bushel (Le.)			
1. (at 10% capital)	.127	.143	.213
2. (at 35% capital)	.075	.073	.169

[a/] Depreciation + Interest. Expected life of seven years. The 10 percent interest is the rate charged by the financial institutions. The 35 percent rate is a shadow rate used to represent the opportunity cost of capital. See section 5.4. for an explanation of how this rate was estimated.

[b/] Le15.80 per month in Freetown and Le6.00 per month in other areas.

[c/] Le0.11 per kw. and 1.4 kw. per bushel milled.

[d/] 18.9 bushels per gallon.

[e/] Le0.72 per man-day in Freetown and Le0.40 in other areas.

[f/] Le0.35 per bushel husk rice milled.

Source: Field Survey.

profit of about Le 1,200 in Freetown, Le 1,300 in the north and Le 2,990 in the south. The higher throughput of the mills located in the south enabled the proprietors to earn a higher economic profit.

Once again these figures confirm that small rice mills were in general operating more profitably than was the case in 1967.

3.3. The Operation of Large Rice Mills

As pointed out earlier the three large mills presently in existence in Sierra Leone are of the disc-sheller type and are old, the newest being about fifteen years old. The mills did not operate during 1974 or 1975 and the level of operation in the two years preceding that was very small.

3.31. Capital Cost

It is difficult to locate records that give the actual acquisition cost of the large mills. Table 8 contains a depreciation allowance for the mills but it is difficult to defend the figures. They were accounting figures used especially in 1968 onwards to write off the mills.

3.32. Labor Utilization

Information obtained from the Rice Corporation[1] indicate that thirteen to fifteen men are required to run each mill per shift. Three of these are skilled while the others are unskilled laborers.

3.33. Output

Table 8 illustrates the drop in capacity utilization of the three large Rice Corporation mills over the years. This was mainly due to

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[1] Personal communication with Arthur Davies, op. cit.

Table 8. Average Milling Costs of Three Large Rice Mills at Kissy, Mambolo and Torma Bum, Sierra Leone

	1965/66	1966/67	1967/68	1968/69	1969/70	1970/71
Tonnage of husk rice processed	8,724	2,162	3,920	4,122	2,966	1,895
<u>Fixed Costs (Le.)</u>						
Depreciation	15,648	17,195	16,368	24,904	24,946	25,148
<u>Operation costs (Le.)</u>						
Milling wages	77,485	43,784	32,421	35,607	27,192	25,410
Fuel, power, water	34,237	21,683	20,208	23,267	25,161	15,519
Plant repairs	--	502	1,735	8,418	6,713	12,284
Total	127,370	83,164	70,732	92,196	84,014	78,361
Processing cost per ton of husk rice (excluding office overheads, including par-boiling) (Le.)	15	38	18	22	28	41
Percent out-turn milled rice	61.75	61.56	64.97	58.73	64	47
Utilization of capacity in percent of annual theoretical capacity a/	50	12	22	23	17	11

a/ Theoretical annual capacity assumed to be 200 working days of 20 hours.

Source: Agrar-Und Hydrotechnic [1], table 4.5.

the inability of the Rice Corporation to obtain supplies of paddy due to its low floor price during the period, but was also due to the old age of the mills. All the rice milled is parboiled in the mechanical parboiling plants at the mills. Recovery rates are usually around 62 percent, with percent brokens between 5 and 10 percent, but as shown in Table 9 they dropped as low as 47 percent in 1970/71.

4. The Rice Processing and Transportation Model

In the preceding sections each of the four existing techniques have been described and evaluated separately in order to measure the effect of the choice of technique in rice processing on the Sierra Leone rice economy a processing and transportation model was developed. The purpose of the model is to determine the least cost rice processing methods and mill locations for Sierra Leone subject to production, transportation, demand and mill availability constraints under varying assumptions relating to factor and product prices as well as mill efficiencies.

The country is divided into eight resource regions each having a regional center and two large urban centers--Freetown and Kono (Figure 2). Dividing the country in this way facilitates computation of transportation and other model parameters.

The model has the form:

$$\text{Minimize } Z = \sum_{ij}\sum P_{ij}M_{ij} + \sum_{ij}\sum T_{ij}X_{ij} + \sum_{ij}\sum C_{ij}Y_{ij} + \sum_{j} I_j G_j + \sum_{ij}\sum Q_{ij}U_{ij} + \sum_{ij}\sum V_{ij}L_{ij} + N\sum_{ij}\sum F_{ij} - \sum_{j} E_j H_j \quad (3)$$

(Sum of variable cost of husk rice milling, husk rice assembly costs to mills, clean rice distribution costs to demand centers, imported clean rice costs, annual mill investment cost, labor and foreign exchange costs--less export receipts.) Subject to:

$$S_i \geq \sum_j X_{ij} \qquad (4)$$

(The quantity of husk rice sent for milling does not exceed the regional supply; supply equals production less allowance for seed and wastage.)

$$\sum_i \alpha_i M_{ij} = \sum_i X_{ij} \qquad (5)$$

(Regional husk rice milling equals the quantity sent to mills in the region.)

$$\sum_i \beta_i M_{ij} = \sum_j Y_{ij} \qquad (6)$$

(Regional clean rice output from mills equals the quantity sent to demand.)

$$D_j = \sum_i Y_{ij} + G_j \qquad (7)$$

(Regional demand equals the quantity of domestic clean rice sent to satisfy demand plus quantity of clean rice imported.)

$$\sum_i R_{ij} \geq \sum_i W_{ij} \qquad (8)$$

(Number of type i mills activated by the model for service in region j does not exceed the available supply. Applicable only in basic run.)

$$M_{ij}, X_{ij}, Y_{ij}, G_j, L_{ij}, F_{ij}, H_j, W_{ij} \geq 0. \qquad (9)$$

In addition to the above constraints, the following accounting rows are used:

$$\text{total imports} = \sum_j G_j \geq 0 \qquad (10)$$

total exports = $\sum_j H_j \geq 0.$ (11)

To transfer mill investment costs (rehabilitation costs in the case of the three existing large mills), labor costs and foreign exchange costs to the objective function, the following rows are added:

$\sum_{ij}\sum U_{ij}M_{ij}$ = total mill investment or rehabilitation cost transferred to the objective function (12)

$\sum_{ij}\sum L_{ij}M_{ij}$ = total required man-days of labor transferred to the objective function (13)

$\sum_{ij}\sum F_{ij}M_{ij} + \sum_j JG_j - \sum_j KH_j$ = total required foreign exchange transferred to the objective function (14)

where:

P_{ij} = total variable milling costs for the quantity of husk rice milled by one unit of mill type i, including hand pounding, in region j

M_{ij} = number of milling establishments i, including hand pounding, in region j

T_{ij} = transportation costs per 10 tons of husk rice from supply in region i to mill establishments in region j

X_{ij} = quantity (10 ton loads) of husk rice shipped from supply in region i to mill establishments in region j

C_{ij} = transport cost per 10 tons of clean rice from mill establishment in region i to demand in region j

Y_{ij} = quantity (10 ton loads) of clean rice shipped from mill establishment in region i to demand in region j

I_j = cost of importing and transporting 10 tons of clean rice to demand in region j

G_j = quantity (10 ton loads) of imported rice shipped to demand in region j

Q_{ij} = capital recovery factor for mill type i located in region j

U_{ij} = investment of rehabilitation cost of type i mills in region j

V_{ij} = labor cost per man-day of labor type i employed in milling activities in region j

L_{ij} = man-days of labor type i employed in milling activities in region j

N = cost of foreign exchange

F_{ij} = foreign exchange requirement of mill type i constructed/ rehabilitated in region j

E_j = export bonus (export price less transport costs from region j to Freetown) of 10 tons of clean rice milled in region j

H_j = export (10 ton loads) of clean rice milled in region j

S_i = supply (tons) of husk rice in region i

α_i = husk rice input (tons) of mill type i

β_i = clean rice output (tons) of mill type i

D_j = demand for clean rice in rural or urban center j

R_{ij} = number of type i mills available in region j

W_{ij} = number of type i mills located in region j in the final solution

J = rice import price per 10 ton unit

K = rice export price per 10 ton unit.

The matrix schema is presented in Figure 4.

4.1. Milling Activities

Five rice processing technologies are considered in the model:

(1) traditional hand pounding,
(2) small steel cylinder mills,
(3) small rubber roller mills,
(4) new large rubber roller mills,
(5) existing large disc-sheller mills.

The first four types may be located in any (or all) of the eight resource regions and it is assumed that they will be distributed evenly throughout the region. Within the large urban regions of Kono and Freetown, however, it is assumed that only small and large mills may be located.

Minimize B = $\sum_{ij}\sum P_{ij}M_{ij} + \sum_{ij}\sum T_{ij}X_{ij} + \sum_{ij}\sum C_{ij}Y_{ij} + \sum_{j} I_j G_j - \sum_{j} WE_j H_j + \sum_{ij}\sum Q_{ij}U_{ij} + \sum_{ij}\sum V_{ij}L_{ij} + N\sum_{ij}\sum F_{ij}$

	RHS	M_{ij}	X_{ij}	Y_{ij}	G_j	H_j	U_{ij}	L_{ij}	F_{ij}
(Available Supply)	$5_i \geq$	*	10						
(Supply to Mills)	0=	α_i	10						
(Mills to Demand)	** 0=	β_i		-10		-10			
(Demand)	D_j=			10	10				
(Mill Supply)	*** $R_{ij} \geq$	1							
(Imports)	$0 \leq$				10				
(Exports)	$0 \leq$					10			
(Capital)	0=	U_{ij}					-1		
(Labor)	0=	L_{ij}						-1	
(Foreign Exchange)	0=	F_{ij}			J	K			-1

*Since husk rice transport to hand pounding has zero cost, the input coefficient, α_i, for this activity is entered here.

**Clean rice output here divided into grade 1 and grade 2; both available to satisfy domestic demand but only grade 1 available for export.

***For each of the three existing large scale mills, this RHS was set at ≤ 1.

The three existing large mills situated at Kissy, Mambolo and Torma Bum are assumed to be located in Freetown, regional center one (Rokupr) which is reasonably close to the actual site at Mambolo and regional center four (Torma Bum). There are a total of forty-one milling activities.

Tables 9 through 11 show the specifications and input requirements of the five milling technologies.[1] The value of the objective function used in each case is the variable operating cost. The initial capital cost figure for new large mills indicates the expense of new mill installations at 1974 prices whereas in the case of the existing large mills, the figure reflects anticipated rehabilitation costs. The mill investment costs do not include the costs of parboiling equipment or rice stores. Only milling and transport costs are considered in this model. The foreign exchange requirement for each mill is assumed to be 80 percent of the initial installation/rehabilitation cost.

With each activation of a small or existing large mill, the regional supply of mills is reduced. The 1974 small mill availabilities (supplies) which were used in the initial run are in Table 2.

A number of key assumptions in the model should be highlighted here. First of all the level of capacity utilization programmed for small mills (70 percent of one shift operation for 200 days a year) is almost twice the 37 percent observed during the field survey. Our justification for this assumption is that one of the primary goals of developing the model is to use it to decide whether there should be investment in additional milling facilities. It would appear unwise to assess the profitability of new facilities unless we assume they can

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[1] Information for all except the new large rubber roller mills were derived from figures obtained during field surveys. The information for the new technique (large rubber roller mills) was obtained from a report of an economic study of the rice milling industry in Sierra Leone [1]. Large rubber roller mills are not currently in operation in Sierra Leone.

Table 11. Annual Budget of Large Rice Mills in the Sierra Leone Rice Processing and Transportation Model a/

	Existing Disc Sheller	New Rubber Roller
Variable costs (Le.)		
Building rent	1,000	1,000
Diesel (@ Le1.00/gal.)	11,614	16,593
Oil (A Le3.50/gal.)	648	648
Repairs b/	11,000	11,000
Overhead c/	4,650	5,704
Total	28,912	35,225
Labor (man-days)		
Skilled d/	1,620	1,620
Unskilled e/	4,800	1,200
Capital (Le.)		
Mill & equipment	20,000 f/	110,000
Expected life (years)	5	5
Input (tons)	5,600 g/	8,000 h/
Output		
Milling %	64	72
Grade of rice	2	1
Tonnage of rice	3,584	5,760
Foreign exchange requirement (Le.)	16,000	88,000

a/ 1974/75 prices used.

b/ 10 percent of investment in new mill.

c/ 20 percent of variable costs.

d/ Three men per shift, two shifts per day, 270 days per year (fixed labor force).

e/ For existing: 12 men per shift, 2 shifts per day, 200 days per year. For new: 3 men per shift, 2 shifts per day, 200 days per year.

f/ Rehabilitation of existing mills.

g/ 67 percent of annual theoretical capacity of 8,400 (200 days x 20 hours x 2.1 tons).

h/ 100 percent of annual theoretical capacity. This assumption is altered in some runs.

Source: For existing mills calculated from table 8 and information provided by Arthur Davies, Ibid. For new mills, calculated from Agrar-Und Hydrotechnick [1].

operate at a reasonable capacity. The effect of varying assumptions about capacity utilization in the new large rubber roller mills on the optimum solution of the model are discussed later.

Secondly, the recovery rates used for the new large mills (72 percent) is higher than that used for small mills and hand pounding. As pointed out already the differences in recovery rates between hand pounding, small steel cylinder and rubber roller mills reflect difference observed during field surveys. In general the figures are higher than those used by Agrar Und Hydrotechnic. But can a quasi-government institution such as the Rice Corporation be expected to match the private enterpreneurs operating small mills, and achieve recovery rates close to the engineering potential of the mills? Examination of the recovery rates reported for the large steel mills (Table 8) would lead one to doubt that it could. On the other hand, the small mills operated by the Rice Corporation have achieved recovery rates as high as those achieved by private entrepreneurs. As will be shown later the model is highly sensitive to the recovery rate assumed.

Table 12 shows the 1974 regional distribution of husk rice supply which is constraining in equation (4) above.

4.2. Husk Rice Paddy Transportation Activities

A total of 184 husk rice transportation activities are in the model. They are of two types--intra-regional and inter-regional transportation.

4.21. Intra-regional Husk Rice Transportation

Transportation of husk rice to the hand pounding activity in the same region is at zero cost, i.e., it is assumed that there is no assembly

Table 12. Regional Distribution of Available Paddy Supplies in Sierra Leone in 1974/75

Region	Area	Paddy Supply[a/]	Density
	(Sq. Mi.)	(Tons)	(Tons/Sq. Mi.)
1. Scarcies	981	28,577	29.13
2. Southern Coast	1,320	21,647	16.40
3. Northern Plains	2,227	57,704	25.91
4. Riverain Grasslands	1,065	13,533	12.71
5. Bolilands	1,781	31,373	17.62
6. Moa Basin	4,633	80,239	17.32
7. Northern Plains	10,155	91,366	9.00
8. Southern Plains	4,475	100,764	22.52

[a/]Production less seed requirements (60 lbs. per acre) and losses (10 percent).

Source: Calculated from WARDA [23].

cost for the hand pounding activity. There is also no transport of husk rice from available supply in one region to hand pounding in another.

For the purpose of estimating the cost of husk rice assembly from a production region to a mill located within the same region, regional rice supply densities were calculated, making the assumption that regional rice supply was evenly distributed within the region (see Table 12). For each type of mill, the required assembly area and radii were then calculated based on mill capacity assuming, as stated above, that the mills are evenly scattered throughout the region (Table 13). Assembly cost within the estimated assembly radii were then calculated by assuming that for distances up to 5.4 miles, headloading only will be used. For distances greater than 5.4 miles, it is assumed that the rice will be headloaded for the first 4.9 miles and then transported by truck the rest of the distance over poor laterite roads.

The following transport rates, derived from 1974 Road Transport Corporation figures were used:

(1) For headloading, a rate of Le 1.47 per ton per mile was used assuming that a laborer carries one bag of husk rice (150 pounds) about six miles per day and is paid Le 0.60 per day.

(2) A tarmac road rate of Le 0.055 per ton per mile is used when rice is transported by truck over tarmac roads only.

(3) A good laterite road rate of Le 0.063 per ton per mile is used when rice is transported by truck over a distance having a combination of tarmac and laterite roads.

(4) A poor laterite rate of Le 0.145 per ton per mile is used when truck transport is on laterite roads only.

Regional husk rice assembly radii and costs are given in Table 13.

4.22. Inter-regional Husk Rice Transportation

All husk rice transported out of a region for milling in another region is assumed to move in three stages. The paddy is first transported to the regional center, from there to the center of the region where processing will take place and from there to the mills in that region. Figure 5 illustrates this movement.

In the first stage husk rice shipped to the regional center is assumed to originate away from the regional center at a distance equal to .7 of the regional center-perimeter radius (R). Given the assumption of even distribution of husk rice supply, shipments of husk rice are assumed to come to the regional center from a point which divides regional supply areas (assumed to be circular) in half (.7R). Husk rice transported to the center is assumed to be transported by headload, at the headload rate of Le 1.47 per ton per mile for the first 4.9 miles and by truck thereafter at the poor laterite rate of Le 0.145 per ton per mile. Table 14 shows the regional radii (R). First stage transport costs within the supply area i to the regional center are designated as "Cost 1."

Table 15 shows stage 2 transport costs between regional centers and from regional centers to the existing large scale mills, taking into account road type (laterite, tarmac or both) and using the appropriate transport rates. Truck transport only is assumed to be used.

To calculate the third stage transport costs from the regional centers to the mills, the radii of Table 14 are again used since, like production, mills are assumed to be evenly distributed throughout the region, and placing them on the .7 radius will locate them at the midpoint of the area of the region. Transport from regional center to the

Figure 5. Schematic Representation of Interregional Paddy and Clean Rice Transportation in the Sierra Leone Rice Processing and Transportation Model

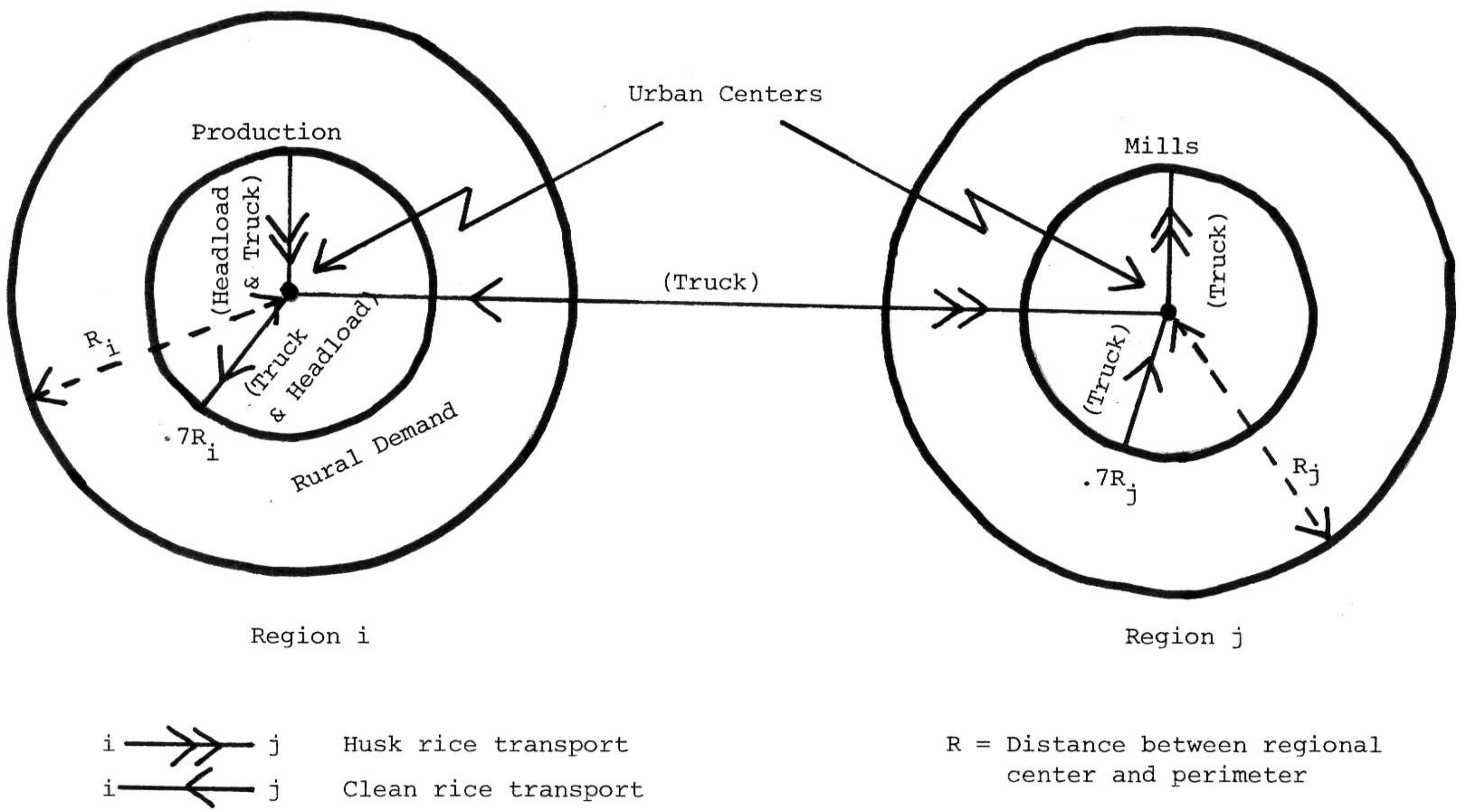

Table 15. Second Stage Interregional Road Distances (Miles) and Truck Transport Costs (Leone Per Ton) Between Regional and Urban Centers in the Sierra Leone Rice Processing and Transportation Model

Miles \ Leones/ton	1 Rokupr	2 Bonthe	3 Port Loko	4 Tormabum	5 Makeni	6 Kenema	7 Kabala	8 Bo	U_1 Freetown	U_2 Kono
1 Rokupr[a/]		12.40	2.06	12.20	5.58	11.41	16.58	8.88	6.24	11.03
2 Bonthe	233		10.96	7.69	11.41	6.67	22.41	4.14	14.63	11.55
3 Port Loko	35	198		7.46	3.52	6.67	14.52	4.14	4.18	8.97
4 Torma Bum	214	53	179		7.91	5.85	18.91	3.32	11.13	10.73
5 Makeni	99	156	64	137		7.12	11.00	4.59	6.49	5.45
6 Kenema	205	120	170	101	128		18.12	2.53	10.34	4.88
7 Kabala	175	232	140	213	76	204		11.71	17.49	16.45
8 Bo	159	74	124	55	82	46	158		7.81	7.41
U_1 Freetown[b/]	111	216	76	197	118	188	194	142		11.94
U_2 Kono	198	200	163	181	99	80	175	126	217	

a/ Existing Mambolo mill assumed to be located in Rokupr.

b/ Existing Kissy mill assumed to be located in Freetown.

mills is assumed done solely by truck at the poor laterite rate. These costs for each region are given in Table 14 as "Cost 3." The inter-regional cost of assembling rice from a region i to a mill in region j is therefore the sum of costs 1 through 3.

4.3. Clean Rice Transportation Activities

Milled rice from the processing centers is assumed to be made available to four categories of domestic demand--demand of the rural area in which the mill is located, demand of the urban area in the same region, demand of the urban areas of other regions and demand of rural areas of other regions. The regional centers are assumed to represent urban demand centers for the region, with the exception of region 4 which has no urban demand. Table 16 shows rice consumption requirements in each of the seventeen demand areas. Annual per capita rice consumption is assumed to 240 pounds [23]. Rural demand is assumed to be evenly distributed over a region. There are 527 clean rice transport activities divided, as before into intra-regional and inter-regional shipments.

4.31. Intra-regional Clean Rice Transportation

Hand pounded rice is assumed to be distributed to rural demand within the same region at zero transport cost. Rice milled at small or large mills is assumed to be distributed to rural demand within the same region at an expense equal to the cost per ton of assembling the husk rice from that production region.

To calculate shipping costs to the regional urban center, all milling activities, including hand pounding, are assumed to be located on the .7 radius described earlier and shown in Table 14. Again, this is done owing to the asssumption that milling and hand pounding activities

are evenly distributed throughout the region. Assuming truck shipment only, the appropriate cost from Table 14 is "Cost 3."

4.32. Inter-regional Clean Rice Transportation

Figure 5 also illustrates the inter-regional clean rice movement which is the opposite of husk rice transport and results in the same costs per ton mile.

4.4. Rice Import Activities

To allow for rice importation, seventeen import activites were added. In the basic run the import cost is assumed to be the 1974 import price (CIF Freetown of Le 407.10) plus Le 4.50 per ton transfer cost to the warehouse. To this is added the transport cost from Freetown to each of the demand areas discussed above to arrive at the appropriate objective function cost. Rice importation uses foreign exchange. To take account of this the import price of rice is also put into the foreign exchange row.

4.5. Rice Export Activities

Milled rice is divided into two grades based on the percentage brokens; that having less than five percent brokens (new large mill output) is designated as grade one rice while milled rice having greater than five percent brokens (hand pounding, small mills and existing large mills output) is called grade two rice. Only grade one rice is available for export.

To insure that milled rice will be used to satisfy domestic demand before being exported, the export price is assumed to be 80 percent of the import cost. The objective function cost, entering as a negative number in the cost minimization framework, is this export price net of transport cost from the new large mills in each region to Freetown, the port for export shipments. There are ten export activites, which also generate foreign exchange (the export price).

4.6. Mill Investment Activities

There are no investment activites for hand pounding since the mortars and pestles are assumed to be used up within one year of intensive use, i.e., acquisition costs of mortars and pestles are treated as variable cost. To include costs of new mill construction and old mill rehabilitation in the objective function, the initial capital costs of construction/rehabilitation of activated mills are multiplied by the appropriate capital recovery factor (Q_{ij}) assuming a given interest rate (r) and expected mill life (n). The capital recovery factor is the annual payment (debt service) that will repay a Le 1.00 loan in n years with compound interest on the unpaid balance. It is given by the following formula:

$$Q_{ij} = \frac{r(1+r)^n}{(1+r)^n-1} \tag{15}$$

As will be seen later this formulation allows capital to be shadow priced quite easily.

4.7. Labor Use Activities

Several classes of labor are defined. For each of the eight rural resource regions there is a different labor class and wage rate for hand pounding labor, small mill skilled and unskilled labor and large mill skilled and unskilled labor reflecting the differences in the level of sills required for hand pounding and to run small and large mills. Recognizing rural-urban wage differentials [4, 18], separate labor classes were also defined for the large urban centers Freetown and Kono, i.e., small mill skilled and unskilled and large mill skilled and unskilled. Labor rates are assigned to the existing large mills according to their assumed location.

Labor requirements are given in Tables 9 through 11. Required man-days of each type of labor within each region are summed for all mills activated, multiplied by the appropriate wage rate and transferred directly to the objective function. This formulation allows labor to be shadow priced easily if necessary.

In all runs of the model reported in this monograph the wage rates per man-day were as follows: for hand pounding Le 0.39; for small mills outside Freetown and Kono, unskilled Le 0.60, skilled Le 0.99; for small mills in Kono and Freetown, unskilled Le 0.99, skilled Le 1.20; for large mills at all locations, unskilled Le 0.99 and skilled Le 1.50. The Le 0.39 per man-day used for hand pounding was the mean wage paid by rural households for female labor hired during the 1974/75 crop season [18]. It is substantially lower than the government minimum wage of Le 0.99 per day.

4.8. Foreign Exchange Activity

As already mentioned it is assumed that 80 percent of the initial investment costs in small and large mills is foreign exchange cost. Rice importation also uses foreign exchange while rice export generates foreign exchange. The foreign exchange activity allows foreign exchange to be shadow priced and transferred to the objective function.

5. Results of Policy Runs Using the Rice Processing and Transportation Model

In the rest of this monograph the results of using the rice processing and transportation model to determine the effects of alternative policies on employment and incomes in the rice processing industry are described.

5.1. Run 1: The Basic 1974 Situation

The first run of the model is a basic run, the aim of which was to simulate the 1974 conditions. Wage rates and prices were set at the 1974 level and interest on capital was assumed to be 10 percent (Table 17), the rate charged by most financial institutions in Sierra Leone. Constraints on the number of existing and new large mills that could be in the optimum solution were set equal to zero and the number of small mills were constrained at a maximum of 268 distributed as in Table 2 with a maximum of 30 being rubber roller mills. These mill availabilities and distribution were therefore those observed in 1974/75.

Table 18 shows the number and type of rice processing facilities in the optimum solution.[1] About 41,000 hand processing facilities (man-years) were activated and 140 small mills out of a possible total of 268 were activated. About 5,000 tons of rice were imported to satisfy domestic demand. The objective function value was about Le 8.5 million, with foreign exchange costs of Le 2.5 million.

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[1]The regional locations of the processing facilities are presented in Appendix 2.

Table 17. Model Parameters in Different Runs of the Sierra Leone Rice Processing and Transportation Model

	Run								
	1,2,3	4	5	6	7	8	10	11	12
Milling percentage									
Hand pounding	68.4	68.4	68.4	68.4	68.4	68.4	68.4	68.4	68.4
Small steel mills	67.5	67.5	67.5	67.5	67.5	67.5	67.5	67.5	67.5
Small rubber mills	70.0	70.0	70.0	70.0	70.0	70.0	70.0	70.0	70.0
Large steel mills	64.0	64.0	64.0	64.0	64.0	64.0	64.0	64.0	64.0
Large rubber mills	72.0	72.0	72.0	72.0	72.0	72.0	72.0	70.0	70.0
Capacity utilization									
Small mills	70.0	70.0	70.0	70.0	70.0	70.0	70.0	70.0	70.0
Large steel mills	67.0	67.0	67.0	67.0	67.0	67.0	67.0	67.0	67.0
Large rubber mills	100.0	100.0	100.0	100.0	100.0	67.0	67.0	100.0	100.0
Interest rate	.10	.35	.10	.35	.35	.35	.35	.35	.10
Rice import price CIF Freetown (Le.)	407.10	407.10	246.50	246.50	246.50	246.50	407.10	246.50	407.10
Rice export price F.O.B. Freetown (Le.)	325.68	325.68	197.20	1972.0	197.20	197.20	325.68	197.20	5.68
Foreign exchange premium[a/]	0	0	0	0	.20	0	0	0	0

[a/] Percent by which 1974 shadow exchange rate (Leones per U.S. dollar) is above the official exchange rate, i.e., the rate by which the financial cost of foreign exchange (Leone) should be increased to get to the economic (shadow) cost of foreign exchange.

Table 18. Number and Type of Rice Processing Facilities, Employment and Incomes in Optimum Solutions of the Sierra Leone Rice Processing and Transportation Model

	Run Number							
	1 & 2	3	4	5	6	7	8 & 11	10
Objective function value a/ (Le. million)	8.45	6.14	7.14	6.65	7.23	7.56	7.32	7.40
Net foreign exchange (Le. million)	2.49	1.88	2.00	3.30	1.87	1.51	2.29	3.19
Rice imports (000 tons)	5.06	0	0	0	.17	1.27	2.14	0
Rice exports (000 tons)	0	8.40	5.21	1.02	0	0	0	2.07
Number of establishments								
Hand pounding b/	40,807	0	9,911	9,911	27,153	35,757	27,153	11,614
Small steel mills	110	0	0	0	0	0	0	0
Large disc mills	0	0	0	0	0	0	0	0
Small rubber mills	30	236	235	675	160	43	367	508
Large rubber mills	0	42	31	3	13	12	0	16
Employment (000 man-days)								
Rural unskilled	12,242	0	2,973	2,973	8,657	10,727	8,657	3,484
Urban unskilled	1	50	37	10	16	14	4	18
Urban skilled	35	122	105	174	60	29	92	144
Total	12,278	172	3,115	3,157	8,732	10,770	8,753	3,647
Incomes c/ (Le. 000)								
Rural unskilled	4,774	0	1,160	1,160	3,376	4,185	3,376	1,359
Urban unskilled	1	49	35	8	15	14	2	16
Urban skilled	35	153	128	174	69	38	91	152
Total	4,810	201	1,323	1,341	3,460	4,236	3,469	1,527

a/ Processing costs + transport costs + rice import cost - rice export returns.

b/ Man-years.

c/ Wages of people employed.

Table 18 also shows the employment and income of wage earners in the optimum solution.[1] About Le 4.8 million is earned by rural labor compared to about Le 0.035 million earned by urban skilled and unskilled labor. About 12.2 million man-days of employment is provided in the rural areas compared with 0.036 million man-days in urban areas.

Figure 6 shows the inter-regional transportation of rice that is implied in Run 1. There is no inter-regional transport of husk rice. Husk rice is processed within its region of origin and clean rice transported. The two large urban demand centers, Freetown and Kono, are the major recipients of inter-regional rice shipments. In general rice shipped to these areas originates in surrounding regions.

The optimum solution obtained above is of course a normative solution, i.e., it indicates what "ought" to happen under the conditions specified in the model. To the extent that there are inefficiencies in the rice processing industry the actual situation would be different from that predicted in the model. But the situation depicted in Run 1 of the model is similar to what actually occurred in 1974. For example the 140 small mills predicted in Model 1 imply that there is excess capacity of small rice mills. Allowing for the fact that for reasons already given, small mills were programmed to operate at 67 percent capacity while they actually operated on the average at about 37 percent of capacity, the rice milled in the 140 small mills would need to be milled by about 280 small mills. There were 268 enumerated in 1974/75.

In actuality there was some inter-regional transportation of rice in 1974/75. This was necessary to feed mills located in Freetown and

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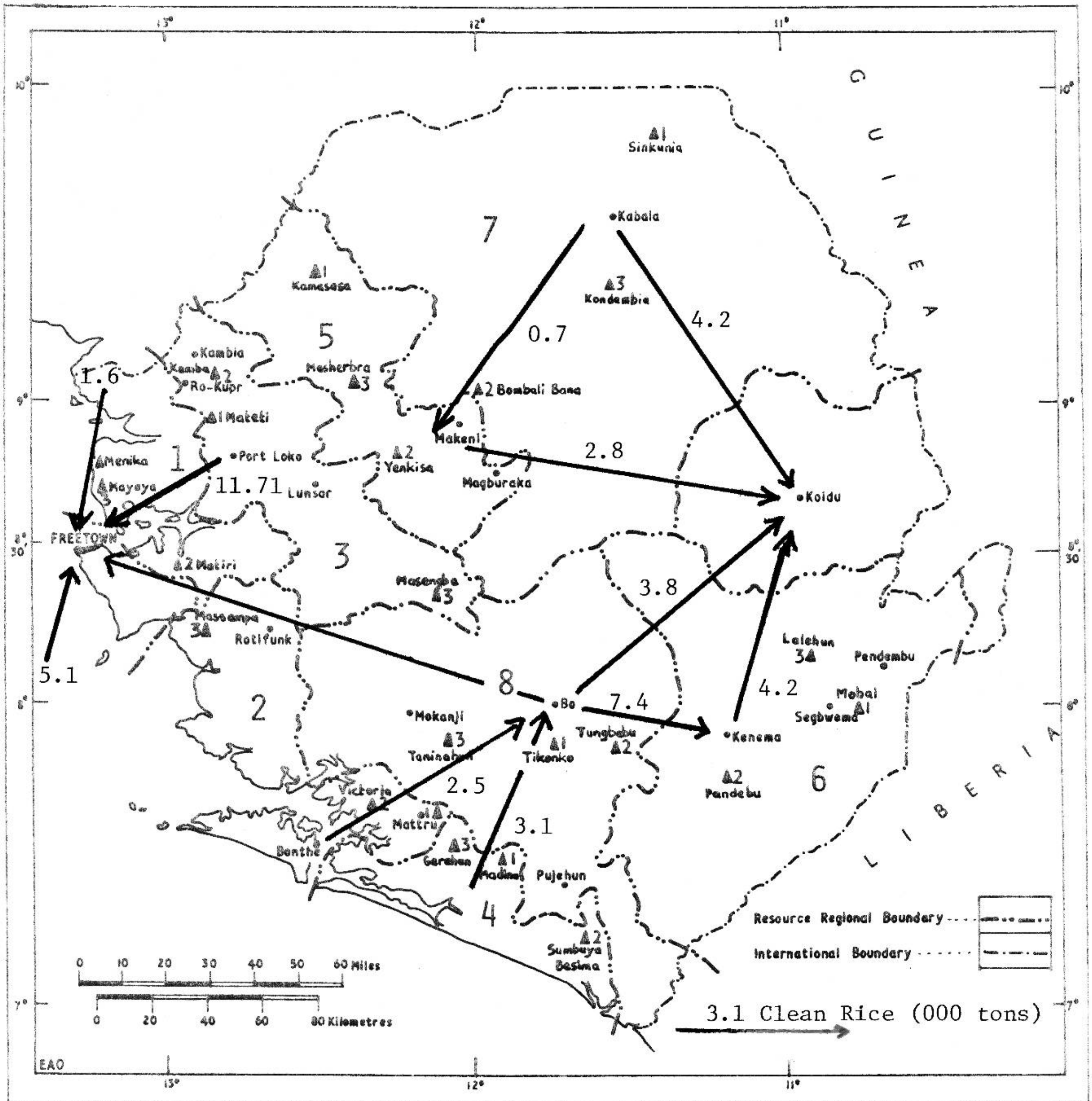
[1] The regional distribution of employment and wages are in Appendix 3.

Figure 6. Interregional Movement of Rice in the Sierra Leone Rice Processing and Transportation Model: Run 1



Kono urban areas. But the importance of such processing activities has declined over the years (31 mills in Freetown in 1967 against 19 in 1974). The actual situation therefore appears to be tending towards the normative situation depicted in Run 1 (no rice mills in the large urban centers Freetown and Kono).

The normative solution obtained in Run 1 is therefore believed to be "realistic," i.e., the predictive value of the model is believed to be good. In further runs of the model, parameters are altered to simulate alternative policies and the model used to predict changes in type, number and location of rice processing facilities and the resulting effect on efficiency, employment and incomes in the rice processing industry.

5.2. Run 2: Should the Old Large Mills be Reactivated?

The second run of the model was designed to determine whether it was economical the rehabilitate the three existing large Rice Corporation mills.

The parameters in Run 2 of the model were exactly the same as in Run 1 but in Run 2, the constraint on existing large mills was changed from zero to a maximum of one at Torma Bum, Mambolo and Kissy.

The optimum solution obtained was the same as that obtained in Run 1, i.e., the existing large mills did not enter the optimum solution, indicating that they could not compete with hand pounding or small rice mills. They do not enter the optimum solutions in any of the subsequent runs. The conclusion we must draw is that for the most efficient use of resources in Sierra Leone the existing large rice mills should not be rehabilitated at a cost of Le 20,000 each.

5.3. Run 3: How Competitive Would Efficiently Run New Large Mills Be?

The third run of the model was designed to determine whether a new technology (large rubber roller mills) could compete with the existing technologies (hand pounding, small steel cylinder and rubber roller mills and large disc sheller mills) and what effect they would have on rural employment and incomes.

The parameters in Run 3 of the model were the same as in Run 1 and 2 (Table 17). In Run 3 the zero constraints on the number of large rubber roller mills that could enter the optimum solution were removed (converted to ≥ 0).

Table 18 shows that compared to the basic Run 1, the objective function value was reduced by about Le 2.3 million. Instead of about 5,000 tons of rice imports in Run 1, about 8.400 tons are exported in Run 3. Since this export generates foreign exchange, the foreign exchange cost in Run 3 is about Le 0.6 million less than in Run 1. Hand pounding is completely replaced by large rice mills, 42 of which are in the optimum solution. The number of small mills increases from 140 to 236 all of which are rubber roller mills. Small mills are only competitive in Regions 3 and 8 in which they replace all hand pounding, large mills entering the solution in all other regions (Appendix 2).

Reflecting the shift to the more capital intensive technology, rural employment drops drastically from 12.4 million man-days to zero while urban employment increases from 36.4 thousand man-days to 170 thousand man-days. Overall employment in the rice processing industry drops from 12.3 million to 0.2 million man-days. With this drop in employment wages earned in the industry decrease from Le 4.8 million to Le 0.2 million.

Under the conditions specified in this run,[1] the new rubber roller mills are shown to be more efficient than the other techniques and are therefore able to replace the existing techniques in all but two regions. Forty-three of them completely replace hand pounding and steel cylinder mills resulting in a small foreign exchange saving as export of rice replaces imports. But rural employment and wages in the rice processing industry would be drastically reduced.

There is not inter-regional transport of husk rice. Freetown obtains its supplies from the Northern and Southern Interior Plains and Koidu mainly from the Northern Plateau and the Moa Basin. Kenema obtains additional supplies from the Southern Coastal Regiona and the Riverain Grasslands. The 8,400 tons of rice exported originate from the Southern Interior Plains (Region 8).

5.4. Run 4: Effect of Shadow Pricing of Capital

In preceding runs of the model the interest charge on capital was 10 percent. This is roughly the rate charged by financial institutions in Sierra Leone. There is every indication that this rate does not represent the true cost of this scarce resource to the Sierra Leone economy. For example in a comparison study of medium term loans obtained by fishing households from the informal sector, allowing for observed default rates, etc., an interest rate of 43.25 was estimated. Assuming that the slightly longer term capital needed by rice mills would carry an interest rate which is 80 percent of medium term loans leads to an interest rate of about 35 percent. This is the interest rate used as a

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[1]The reader should keep in mind the fact that the large mills are programmed to operate at 100 percent capacity utilization and to obtain 72 percent recovery rates.

shadow cost of capital in this run of the model. All other parameters are the same as in previous runs (Table 17).

Comparing Runs 3 and 4, Table 18 shows that the effect of using a shadow interest rate of 35 percent is to reduce the number of large rice mills that enter the optimum solution from 42 to 31. The number of small mills stays about the same while 9,911 hand pounding establishments are introduced. Hand pounding replaces one large mill in the Riverain Grasslands and ten large mills in the Northern Plateau (see Appendix 2). The effect of these changes is a Le 1 million increase in the objective function value. There is also an increase of Le 118,000 in foreign exchange cost, reflecting a 3,200 ton drop in rice exports. There is a slight drop in urban employment as some large mills drop out of solution, but this drop is more than compensated for by a large increase in rural employment. Consequently employment in the rice processing industry is about 3 million man-days higher in Run 4 than in Run 3, while labor wages are about Le 1.1 million higher.

5.5. Run 5: Effect of Reduced Rice Prices

The import and export rice prices used in all preceding runs of the model were those that prevailed in 1974. Long run projections of international market prices of rice by the World Bank and other institutions indicate that 1974 prices were much above the trend. In fact, international rice prices in 1975 were already much lower than the 1974 prices [2], and 1980 prices are expected to be about 60 percent of 1974 prices.

In Run 5 of the model import and export prices are programmed at 60 percent of the 1974 prices. All other parameters are at the same level as Run 3 (Table 17). This run of the model was therefore designed to test the effect of reduced and more normal rice prices on the optimum solution of the model.

Comparing Runs 3 and 5, Table 18 shows that the objective function value is increased by about Le 500,000. Rice exports are reduced by about 7,000 tons and foreign exchange costs increase by Le 1.4 million. The number of large rice mills in solution drop from 42 to 3 and the number of small mills increase by 440. Basically then, small rice mills and hand pounding in Regions 4 and 7 replace large mills (Appendix 2). Comparing Runs 4 and 5 show that the number of large mills in solution is more sensitive to rice prices than to the cost of capital. Reducing the rice prices apparently causes the large mills to lose much of the advantage they have as a result of their higher milling-out percentages. It is no longer as important as before to save rice by using a highly efficient technique.

The level of employment and labor wages is virtually the same for Runs 4 and 5 despite the difference in the technological mix.

5.6. Run 6: Combined Effect of Higher Capital Cost and Lower Rice Prices

In Run 6 the rice prices were set at the expected lower figure used in Run 5 and the interest rate on capital shadow priced at 35 percent (Table 17).

As is shown in Table 18 the combined effect of higher capital cost and lower rice prices is to reduce the number of small rice mills in solution and increase the amount of hand pounding that takes place. Thirteen large mills enter into solution. The largest concentration of large mills was in Region 8. Hand pounding enters the solution in six of the eight regions (Appendix 2).

With the large reduction in small mills in solution and the substitution basically of hand pounding for mechanical milling of rice, there is a drop in foreign exchange costs which at Le 1.87 million is the lowest of any run so far. But the objective function value of Le 7.23 million is only exceeded by that in Run 1, the basic constrained solution. The economy is almost in perfect balance with only 171 tons of rice imported.

With the increased level of hand pounding, rural employment and rural wages increase drastically (Table 18). The level of employment at 8.73 million man-days and wages at Le 3.46 million are the highest obtained in any of the unconstrained runs.

5.7. Run 7: Effect of Shadow Pricing Foreign Exchange

The Leone, the currency of Sierra Leone, is pegged to sterling at 2:1. It has therefore been floating downwards with the Pound relative to other international currencies in the past two years. Because of the flexible exchange rate the Leone probably has not been far out of line with other currencies. The only reason that would lead one to shadow price foreign exchange in this situation is, if one suspects that the Leone is not pegged to sterling at the right rate. The fact that the balance of trade is in perpetual deficit would lead one to suspect that the Leone is slightly overvalued. No computation of the shadow foreign exchange rate was available to the authors and none was attempted in this study.

Run 7 was designed to test the sensitivity of the model to shadow pricing of foreign exchange, using a shadow premium of 20 percent, i.e., assuming that the Leone was overvalued, relative to sterling by 20 percent. All other parameters were the same as in Run 6.

Comparing the results of Runs 6 and 7 (Table 18) we see that the effect of shadow pricing foreign exchange is mainly the replacement of small roller mills by hand pounding. Only one large mill drops out of solution but, small mills are reduced from 160 to 43 while hand pounding increases by about 8,000 establishments. Both small and large rice mills use foreign exchange. It would appear that the higher rice recovery factor programmed for large mills relative to hand pounding is enough to allow them to compete with hand pounding while the lower recovery rate of small mills does not allow them to compete effectively. Rice saved by using more efficient mills has an opportunity cost of the import price of rice.

Employment and wages in Run 8 are the highest of any of the unconstrained runs (Table 18). Shadow pricing of foreign exchange in addition to shadow pricing of capital therefore further increases rural employment and incomes in the rice processing industry.

5.8. Runs 8-10: Effect of Reduced Mill Capacity Utilization

In all the runs so far large mills have been assumed to be operating at full capacity (20 hours per day for 200 days a year). It has been shown that large mills enter the optimum solution, even with a shadow interest rate as high as 35 percent. In order to determine the effect of a lower level capacity utilization on the competitiveness of new large mills, the model was run with large mills operating at 67 percent rather than 100 percent of capacity.

In Run 8 (35 percent interest rate, low rice prices) the large mills dropped out of solution completely. They were replaced by small rubber roller mills which increased from 160 in Run 6 (large mills at 100 percent capacity) to 367. Hand pounding was unaffected remaining at

27,153 establishments, so that rural employment and wages were unaffected.

In Run 9, the interest rate was dropped to ten percent. The large mills did not enter the solution. Instead small rubber roller mills increased further to 725, replacing hand pounding in all except Regions 4 and 7. Rural employment dropped by about 6 million man-days compared to runs 6 and 8.

In Run 10, the price of rice was increased to the high prices prevailing in 1974/75 (Table 17). With the higher rice prices, the large mills entered the optimum solution. Thirty-six were in solution when the interest rate was set at 10 percent, dropping to 22 when capital capital was shadow priced at 20 percent. With the increase in cost of capital some large mills were replaced by hand pounding with corresponding increase in rural employment. The number of small mills stayed constant at about 498.

5.9. Runs 11 and 12: Effect of Reduced Recovery Rates

In runs 8-10 it was assumed that the new large mills would achieve a milling-out percentage of 72 percent. As pointed our earlier, the Rice Corporation, which is likely to operate such mills in Sierra Leone was not able to come close to achieving the design recovery rate for the large mills it has operated in the past, although it has more recently been able to operate its small mills at close to design specifications. Prudence would dictate that we examine the effect of less efficient operation of the large mills on the optimum solution of the rice processing model.

In runs 11 and 12 the milling-out percent for large rubber roller mills was reduced to 70 percent, the same as for small rubber roller mills. In Run 11, capital was shadow priced at 35 percent and the lower rice prices used (Table 17). The solution was exactly the same as in run 8, i.e., no large mills, 367 small rubber roller mills and, 27,153 hand pounding establishments.

Dropping the interest rate on capital to 10 percent and increasing rice prices to the high 1974/75 prices (run 12) had no effect on the number of large mills in solution.

Runs 8-12, therefore show that the number of large mills in the optimum solution of the rice processing and transportation model is highly sensitive to assumptions about capacity utilization and milling percentage. If we assume that the large mills would not achieve a recovery rate higher than that achieved by small rubber roller mills (70 percent then large mills would not enter the optimum solution even if capital is opted at the low financial rate of 10 percent and high rice prices prevail. If capacity utilization drops as low as 67 percent the large mills will remain competitive only if high rice prices prevail. The critical variable for the large rubber roller mill is therefore the rice recovery rate achieved.

6. Summary and Conclusions

This monograph examines the economics of rice processing in Sierra Leone with emphasis on employment. If has been shown that four techniques of rice processing currently exist in Sierra Leone, i.e., traditional hand pounding, small steel cylinder mills, small rubber roller mills and large disc-sheller mills.

Field surveys have shown that the large disc-sheller mills are the least technically efficient of the existing techniques with 64 percent recovery of clean rice compared to recovery rates of 68.4 percent for hand pounding, 67.5 percent for small steel cylinder mills and 70 percent for small rubber roller mills.

Hand pounding is the most labor intensive technique. It is usually performed by females with male participation usually limited to less than 20 percent of labor time provided mainly by young boys under the age of twenty years. Field survey results show that about 10.2 pounds (4.6 kgs.) of husk rice are pounded per person per hour. This figure is similar to the 11 pounds (5.0 kgs.) per person per hour reported in surveys in Indonesia [5]. The estimate of fourteen to twenty hours per ton for hand pounding of rice given by Agrar-Und Hydotechnik in their study of the rice milling industry in Sierra Leone is therefore a gross overestimate and gives undue advantage to the hand pounding technique relative to the other techniques.

Small rice mills in Sierra Leone operated at about 37 percent of capacity in 1974, earning an estimated return of between 12.7 and 21.3 cents per bushel milled when capital is charged at the financial rate of 10 percent per annum and 7.5 to 16.9 cents when capital is shadow priced at 35 percent. The highest returns were earned by mills in the southern province. In general small mills in Sierra Leone were more profitable in 1974 than they were in 1967.

The proportion of rice milled by small mills that was parboiled was about 84 percent. This rice was destined mainly for urban consumption. This percentage is higher than the 40 percent observed when rice was hand pounded indicating that rural areas consume more unparboiled rice than urban households. Rice recovery rates averaged 67.5 percent a figure similar to the 66 percent (range 62-70 percent) reported for Indonesia [5].

The existing large mills have not operated in the last few years. When they last operated they incurred large losses.

In order to measure the effect of the choice of technique in rice processing on employment and incomes in Sierra Leone a linear programming model was developed. The model incorporates five techniques of rice milling, the existing four and new large rubber roller mills, at each of ten possible regional locations. The objective function of the rice processing and transportation model is the sum of variable costs of husk rice milling, husk rice assembly costs to mill, clean rice distribution costs for demand centers, imported rice costs, annual mill investment costs, labor and foreign exchange costs, less export receipts. Unlike previous attempts at analyzing the choice of technique issue, this model therefore incorporates consideration of location effects. The model is formulated in a way that it is easy to alter output and input prices.

Policy runs using the model lead to the following conclusions:

(1) When capital is costed at the low financial interest rate of 10 percent and the high rice prices that prevailed in 1974 are used, large rubber roller mills operating at 100 percent capacity and achieving 72 percent recovery rates dominate other techniques although small rubber mills also enter the solution. Processing and transportation costs are lowest, but rural employment and labor wages in the rice processing sector are completely eliminated.

(2) Shadow pricing capital at its estimated opportunity cost of 35 percent and reducing rice prices to a lower level, more in line with expectations through 1980 reduces the number of large rice mills in solution and increases drastically the amount of hand

pounding that remains in solution. Rural employment is only slightly reduced from the constrained run simulating actual 1974 conditions.

(3) Rice prices have more of an effect on the number of large mills in the optimum solution than does the shadow price of capital. With high rice prices the technical efficiency of the large mills, in terms of higher out-turn of rice, is accentuated. With lower rice prices and cheap capital small rice mills predominate.

(4) The number of large mills in the optimum solution is highly dependent on the efficiency of their operation. A two percent reduction in recovery rates, from 72 to 70 percent removes all large mills from solution, even at low capital costs and high rice prices. The model is slightly less sensitive to the level of capacity utilization. Large mills remain in solution when high rice prices are assumed, even with capital shadow-priced at 35 percent, but drop out when low rice prices are programmed, even with an interest rate of 10 percent.

(5) The small steel cylinder mills and the large disc-sheller mills are not in any of the unconstrained optimum solutions. They are replaced by small or large rubber roller mills, and hand pounding. This indicates that they are less efficient under all circumstances investigated and will be superseded in the future.

In this study we have developed a model for consideration of the choice of technique in rice processing. The methodology allows us to explicitly incorporate consideration of rural employment and income effects of the choice of technique. The study is also based on a much improved data base, model parameters being derived mainly from field surveys.

Applying the model to policy analysis in Sierra Leone leads to the general conclusion that employment and the incomes of the rural poor would be drastically reduced by policies which encourage cheap capital. Up to 40,000 full time jobs would be lost in Sierra Leone is such a policy is pursued. Pricing capital at its social oppotunity cost and labor at its actual cost (not at the government stipulated minimum wage rate) and taking transportation costs into consideration leads to investment decisions which maintain rural employment and wages. Optimum development policies for the rice processing industry would require continued investment in a mix of technologies including hand processing small and large rubber roller mills. But investment in large rubber roller mills would be justified only if it can be guaranteed that they will achieve rice recovery rates of about 72 percent. Policy makers are therefore urged to tread carefully on this issue and to start by investing in no more than one large mill which should not be located in Freetown or Kono and which can be used to determine what actual recovery rates are achievable.

Supporting the results of studies in Indonesia, which considered milling costs as well as rice prices [4, 20, 22], but not location effects, and a study in Ghana [8] which considered size and locational effects but only examined one technique, we conclude that the social rate of discount used in analysis affects the technique(s) that are optimum. In addition we find that the level of rice prices and the efficiency of operation of the different techniques is more important than the shadow price of capital or foreign exchange. Under most conditions the optimum solution is likely to incorporate a mix of techniques from labor intensive hand pounding, through less labor intensive small rice mills to more capital intensive rubber roller mills. Policy makers in Sierra Leone, as well as other less developed countries should consider locational as well as input and output costs in making decisions relating to choice of technique in rice processing. The rice processing and transportation model developed in this study has provided a mechanism for such analyses in Sierra Leone.

Appendix 1.
List of Chiefdoms in the Eight Rural Resource Regions
into Which Sierra Leone Was Divided

Study Region	District	Chiefdom
1	Port Loko	Koya
		Kaffu Bullom
		Loko Masema
	Kambia	Mambolo
		Samu
2	Moyamba	Bumpe
		Kagboro
		Ribbi
		Timdel
	Bonthe	Dema
		Imperri
		Jong
		Sitia
3	Port Loko	Bure
		Buya Romende
		Maforki
		Marampa Masimera
		T. M. S. Dibia
	Kambia	Binle Dixing
		Magbeme
		Masungbala
	Tonkolili	Yoni
4	Bonthe	Bendu Cha
		Bum
		Kwamebai Krim
		Nongoba Bullom
		Sogbini
		Yawbeko
	Pujehun	Kpaka
		Mano Sakrim
		Panga Krim
		Yakemo Kpukumu Krim
5	Kambia	Bramaia
		Tonko Limba

Study Region	District	Chiefdom
	Bombali	Bombali Sebora
		Gbanti Kamaranka
		Libeisaygahun
		Makari Gbanti
		Sanda Tenraran
	Tonkolili	Kholifa
		Kholifa Mabang
		Malal
		Sanda Magbolonto
6	Kenema	All Chiefdoms
	Kailahun	Dia
		Jaluahun
		Jawi Lower
		Jawi Upper
		Luawa
		Malema
		Mandu
		Pejewa
		Penguia
		Upper Bembera
		Yawei
	Pujehun	Barri
		Peje
		Makpele
	Kono	Gorama Kono
		Nimi Koro
		Nimi Yema
		Tankoro
7	Kono	Fiama
		Gbane
		Mafindo
		Gbense
		Kamara
		Lei
		Sando
		Soa
		Toli
		Gbane Kando
	Koinadugu	All Chiefdoms
	Bombali	Biriwa
		Pendembu Gowahun
		Magbaiamba
		Paki Masabong
		Safroko Limba
		Sanda Loko
		Sela Limba
		Tambaka

Study Region	District	Chiefdom
	Tonkolili	Bonkolenken
		Kafe Simiria
		Kalasogoia
		Kunike
		Kunike-Barina
		Sambaia
		Tane
	Kailahun	Kissi Kama
		Kissi Teng
		Kissi Tongi
8	Bo	All Chiefdoms
	Moyamba	Bagruwa
		Banta
		Banta Mokelle
		Dasse
		Fakunya
		Kaiyamba
		Kamajei
		Kongbora
		Kori
		Kowa
	Pujehun	Gallinas Perri
		Malen
		Panga Kabonde
		Soro Gbema
	Bonthe	Kpanda Komo

Appendix 2.
Size and Location of Rice Processing Facilities in the Optimum Solutions of the Sierra Leone Rice Processing and Transportation Model

Region	Run Number							
	1 & 2	3	4	5	6	7	8 & 11	10
	Number of Establishments							
Region 1 (Scarcies)								
Hand pounding	2,816	0	0	0	0	2,816	0	0
Small steel mills	0	0	0	0	0	0	0	0
Large disc mills	--	0	0	0	0	0	0	0
Small rubber mills	11	52	52	64	52	11	64	64
Large rubber mills	--	1	1	0	1	0	0	0
Region 2 (S. Coast)								
Hand pounding mills	2,130	0	0	0	1,703	1,703	1,703	1,703
Small steel mills	6	0	0	0	0	0	0	0
Small rubber mills	0	0	0	32	0	0	14	0
Large rubber mills	--	3	3	1	1	1	0	1
Region 3 (N. Plains)								
Hand pounding	5,783	0	0	0	0	4,085	0	0
Small steel mills	0	0	0	0	0	0	0	0
Small rubber mills	14	76	76	121	76	0	124	124
Large rubber mills	--	3	3	0	3	3	0	0
Region 4 (Riverain)								
Hand pounding	1,016	0	1,016	1,016	1,016	1,016	1,016	1,016
Small steel mills	10	0	0	0	0	0	0	0
Large disc mills	--	0	0	0	0	0	0	0
Small rubber mills	0	0	0	10	10	10	10	0
Large rubber mills	--	2	1	0	0	0	0	1
Region 5 (Boliland)								
Hand pounding	3,091	0	0	0	3,091	3,091	3,091	0
Small steel mills	3	0	0	0	0	0	0	0
Small rubber mills	5	0	0	67	9	9	9	57
Large rubber mills	--	4	4	0	0	0	0	1
Region 6 (Moa Basin)								
Hand pounding	8,368	0	0	0	8,368	8,368	8,368	0
Small steel mills	13	0	0	0	0	0	0	0
Small rubber mills	0	1	1	155	0	0	13	155
Large rubber mills	--	10	10	1	1	1	0	1
Region 7 (N. Plateau)								
Hand pounding	9,587	0	8,895	8,895	8,895	8,895	8,895	8,895
Small steel mills	14	0	0	0	0	0	0	0
Small rubber mills	0	0	0	10	10	10	27	0
Large rubber mills	--	12	2	1	1	1	0	2
Region 8 (S. Plains)								
Hand pounding	8,016	0	0	0	5,783	5,783	5,783	0
Small steel mills	64	0	0	0	0	0	0	0
Small rubber mills	0	107	107	216	3	3	106	107
Large rubber mills	--	7	7	0	6	6	0	10
Freetown								
Small steel mills	0	0	0	0	0	0	0	0
Large disc mills	--	0	0	0	0	0	0	0
Small rubber mills	0	0	0	0	0	0	0	0
Large rubber mills	--	0	0	0	0	0	0	0
Kono								
Small steel mills	0	0	0	0	0	0	0	0
Small rubber mills	0	0	0	0	0	0	0	0
Large rubber mills	--	0	0	0	0	0	0	0
Sierra Leone								
Hand pounding	40,807	0	9,911	9,911	27,153	35,757	27,153	11,614
Small steel mills	110	0	0	0	0	0	0	0
Small rubber mills	30	236	235	675	160	43	367	508
Large rubber mills	0	42	31	3	13	12	0	16

Appendix 3.

Predicted Employment and Wages in the Optimum Solutions of the Sierra Leone Rice Processing and Transportation Model

Region	Run Number					
	1 & 2		3		4	
	Man-days	Wages (Le.)	Man-days	Wages (Le.)	Man-days	Wages (Le.)
	(000)					
Region 1 (Scarcies)						
Rural unskilled	844.80	329.47	0	0	0	0
Urban unskilled	.10	.06	1.35	1.13	1.35	1.13
Urban skilled	2.65	2.62	13.06	12.93	14.18	14.60
Region 2 (S. Coast)						
Rural unskilled	639.00	249.21	0	0	0	0
Urban unskilled	.06	.04	3.25	3.21	3.25	3.21
Urban skilled	1.50	1.48	4.38	6.58	4.38	6.58
Region 3 (N. Plains)						
Rural unskilled	1,734.90	676.61	0	0	0	0
Urban unskilled	.14	.08	4.11	3.78	4.11	3.78
Urban skilled	3.50	3.46	23.48	25.56	23.48	25.56
Region 4 (Riverain)						
Rural unskilled	304.80	118.87	0	0	304.80	118.87
Urban unskilled	.10	.06	2.03	2.01	.68	.67
Urban skilled	2.44	2.42	2.74	4.11	.91	1.36
Region 5 (Bolilands)						
Rural unskilled	927.30	361.65	0	0	0	0
Urban unskilled	.08	.05	4.71	4.66	4.71	4.66
Urban skilled	2.16	2.14	6.35	9.53	6.35	9.53
Region 6 (Moa Basin)						
Rural unskilled	2,510.40	979.06	0	0	0	0
Urban unskilled	.13	.08	12.00	11.88	12.00	11.88
Urban skilled	3.32	3.29	16.33	24.43	16.33	24.43
Region 7 (N. Plateau)						
Rural unskilled	2,876.10	1,121.68	0	0	2,668.50	1,040.72
Urban unskilled	.14	.08	13.70	13.56	1.90	1.88
Urban skilled	3.50	3.46	18.49	27.74	2.55	3.82
Region 8 (S. Plains)						
Rural unskilled	2,404.80	937.87	0	0	0	0
Urban unskilled	.64	.38	8.68	8.24	8.68	8.18
Urban skilled	16.00	15.84	37.10	41.97	37.10	41.97
Freetown						
Urban unskilled	0	0	0	0	0	0
Urban skilled	0	0	0	0	0	0
Kono						
Urban unskilled	0	0	0	0	0	0
Urban skilled	0	0	0	0	0	0
Sierra Leone						
Rural unskilled	12,241.93	4,774.35	0	0	2,973.30	1,159.59
Urban unskilled	1.39	.83	49.84	48.47	36.68	35.39
Urban skilled	35.07	34.72	121.93	152.85	105.28	127.85
Total	12,278.39	4,809.90	171.77	201.32	3,115.26	1,322.83

(Continued)

Appendix 3 - Continued
Predicted Employment and Wages in the Optimum Solutions of the Sierra Leone Rice Processing and Transportation Model

Region	Run Number					
	5		6		7	
	Man-days	Wages (Le.)	Man-days	Wages (Le.)	Man-days	Wages (Le.)
	(000)					
Region 1 (Scarcies)						
Rural unskilled	0	0	0	0	844.80	329.47
Urban unskilled	.04	.38	1.35	1.13	.10	.10
Urban skilled	16.02	15.86	14.18	14.60	2.65	2.65
Region 2 (S. Coast)						
Rural unskilled	0	0	510.90	199.25	510.90	199.25
Urban unskilled	1.35	1.22	.99	.98	.99	.98
Urban skilled	9.30	9.92	1.33	1.99	1.33	1.99
Region 3 (N. Plains)						
Rural unskilled	0	0	0	0	1,225.64	478.00
Urban unskilled	1.42	.94	4.11	3.78	3.23	3.20
Urban skilled	30.48	30.32	23.48	25.56	4.36	6.54
Region 4 (Riverain)						
Rural unskilled	304.80	118.87	304.80	118.87	304.80	118.87
Urban unskilled	.09	.06	.10	.06	.10	.06
Urban skilled	2.44	2.41	2.44	2.41	2.44	2.41
Region 5 (Bolilands)						
Rural unskilled	0	0	927.30	361.65	927.30	361.65
Urban unskilled	.67	.40	.09	.05	.09	.05
Urban skilled	16.83	16.66	2.16	2.13	2.16	2.13
Region 6 (Moa Basin)						
Rural unskilled	0	0	2,510.40	979.06	2,510.40	979.96
Urban unskilled	2.73	2.10	.93	.92	.93	.92
Urban skilled	40.42	40.83	1.25	1.88	1.25	1.88
Region 7 (N. Plateau)						
Rural unskilled	2,668.50	1,040.72	2,668.50	1,040.72	2,668.50	1,040.72
Urban unskilled	1.30	1.25	1.30	1.25	1.30	1.25
Urban skilled	4.11	4.90	4.11	4.90	4.11	4.90
Region 8 (S. Plains)						
Rural unskilled	0	0	1,734.90	676.61	1,734.90	676.61
Urban unskilled	2.16	1.30	7.23	7.15	7.23	7.15
Urban skilled	54.06	53.52	10.57	15.42	10.57	15.42
Freetown						
Urban unskilled	0	0	0	0	0	0
Urban skilled	0	0	0	0	0	0
Kono						
Urban unskilled	0	0	0	0	0	0
Urban skilled	0	0	0	0	0	0
Sierra Leone						
Rural unskilled	2,973.30	1,159.59	8,656.71	3,376.12	10,727.24	4,184.53
Urban unskilled	10.36	7.65	16.10	15.32	13.97	13.71
Urban skilled	173.66	174.15	59.52	68.89	28.87	37.92
Total	3,157.32	1,341.39	8,732.33	3,460.33	10,770.08	4,236.16

(Continued)

Appendix 3 - Continued
Predicted Employment and Wages in the Optimum Solutions of the Sierra Leone Rice Processing and Transportation Model

Region	Run Number			
	8 & 11		10	
	Man-days	Wages (Le.)	Man-days	Wages (Le.)
	(000)			
Region 1 (Scarcies)				
Rural unskilled	0	0	0	0
Urban unskilled	.64	.38	.64	.38
Urban skilled	16.02	15.86	16.02	15.86
Region 2 (S. Coast)				
Rural unskilled	510.90	199.25	510.90	199.25
Urban unskilled	.14	.08	.99	.98
Urban skilled	3.53	3.49	1.33	1.99
Region 3 (N. Plains)				
Rural unskilled	0	0	0	0
Urban unskilled	1.24	.74	1.24	.74
Urban skilled	30.96	30.65	30.96	30.65
Region 4 (Riverain)				
Rural unskilled	304.80	118.87	304.80	118.87
Urban unskilled	.10	.06	.68	.67
Urban skilled	2.44	2.41	.91	1.36
Region 5 (Bolilands)				
Rural unskilled	927.30	361.65	0	0
Urban unskilled	.09	.05	1.50	1.03
Urban skilled	2.16	2.13	15.27	15.59
Region 6 (Moa Basin)				
Rural unskilled	2,510.40	979.06	0	0
Urban unskilled	.13	.08	2.73	2.10
Urban skilled	3.32	3.28	40.42	40.83
Region 7 (N. Plateau)				
Rural unskilled	2,668.50	1,040.72	2,668.50	1,040.72
Urban unskilled	.27	.16	1.90	1.88
Urban skilled	6.78	6.71	2.55	3.82
Region 8 (S. Plains)				
Rural unskilled	1,734.90	676.61	0	0
Urban unskilled	1.06	.64	8.68	8.18
Urban skilled	26.60	26.33	36.98	41.79
Freetown				
Urban unskilled	0	0	0	0
Urban skilled	0	0	0	0
Kono				
Urban unskilled	0	0	0	0
Urban skilled	0	0	0	0
Sierra Leone				
Rural unskilled	8,656.71	3,376.12	3,484.07	1,358.79
Urban unskilled	3.67	2.19	18.36	15.96
Urban skilled	91.81	90.86	144.44	151.89
Total	8,752.19	3,469.17	3,646.87	1,526.64

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