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ANALYSIS OF DEMAND FOR ELECTRIC POWER IN RURAL COMMUNITIES

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ANALYSIS OF DEMAND FOR ELECTRIC POWER IN RURAL COMMUNITIES

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I.
INTRODUCTION

Objectives of the Analysis

Any large scale plan for rural electrification presupposes an understanding of the demand curve for power which the system is likely to face. Such an understanding is necessary not only to determine the optimal size of the electric system but also to phase the building of generation and distribution capacity in coincidence with the growth of demand for the system's output. This, in part, is a reflection of the inherent economies of scale in the generation and distribution of electric power, and partly because of the interval which must necessarily elapse between the decision to build the capacity and the time at which it is actually available.

What is the quantitative nature of demand for power, both as a production input and as a final consumer good? And in what direction and at what rate the pattern of power demand is likely to change? These and related questions are important not only for planning of design and capacity, but also for evaluating policy measures and value judgments about the desired outcome of rural electrification programs. The questions have become more pressing since in many countries there is a strong political commitment to rural electrification programs, and increasingly large amounts of public funds are being allocated for this purpose. In any event, the matching of plant and distribution capacity to consumption requirements is not an easy matter in rural power systems where the plant utilization factor is notoriously low as a result of large spatial dispersion of consuming units and a low demand per connection. The absence of the knowledge of demand tends to widen the margin of error. This is all the more serious when one takes into account an almost complete absence of cost-reducing innovations in distribution and transmission of rural power supply.

A really comprehensive treatment of the problem would require one to set forth a precise functional relationship of power consumption to any one or several of economic indicators. This type of correlation has to be discovered and empirically tested in a number of cases before any generalization is made. The purpose of the present paper, however, is less ambitious. Our aim is not so much as to make universally valid empirical generalizations as to provide a framework within which particular situations can usefully be analyzed. A certain amount of empirical material has been included to permit quantitative analysis of the problem. Within the constraints imposed by conceptual and statistical difficulties, we have attempted to quantify the probabalistic range of demand for power in various components of the rural economy.

The prospects and problems of rural electrification in low income countries comprise a very diverse collection of situations. No one would, therefore, expect that exactly the same conclusions hold good for all countries and for all periods of time. Nevertheless, the characteristics that are common to the rural power supply systems are specified almost by definition: high cost of supply, low demand per installation, large dispersion of consumers, and generally poor load factors. But even in respect of these characteristics there are significant differences. Such diversity of circumstances, however, does not preclude systematic analysis, and it is possible to advance propositions of some generality and depth. But it is important that the heterogenity of situations and the width of generality with which our conclusions might be applied must be borne in mind.

Concepts and Methodology

An appraisal of conventional methods of estimating power demands in urban and industrial sectors led us to the conslusion that recourse to a simple correlation method in estimating rural power demand would not only be impracticable, but may also lead to erroneous conclusions. It was felt that the method of direct estimation of demand derived from an analysis of basic economic parameters in a number of samples offered certain advantages. It was clear, however, that such a method of statistical estimation would neither be completely unambiguous nor immune to controversy. But as a first approximation, it does afford an opportunity to arrive at reasonable postulates about the magnitude of demand.

On the basis of technical and economic data available and subject to specified alternative assumptions, we have developed estimates of demand for power in three sectors of rural economy--irrigation, processing of farm products, and domestic lighting. The assumptions in each case are based on what seemed most plausible in the light of existing and prospective developments in various regions of the world. The actual data used in estimation relates to three sample rural situations in India, a description of which is contained in Appendix A.

The concept of demand employed in the study is not the conventional one, in the sense of a schedule showing varying quantities demanded at varying prices. Demand here is momentarily independent of prices, and is almost a technological relation between potential needs and energy requirements. However, the estimates signify a potential market that can

initially be foreseen with an appropriate pricing policy. This definition of demand was dictated by certain vital considerations. In the first place, the derivation of a statistical demand curve in the conventional sense is always a difficult matter and is nearly impossible in the case of rural power--a commodity which in most cases is not presently traded on the market. Since availability is a test of demand, power (where not available) does not enter the market horizon of the consumer. Secondly, the cost and price parameters on the supply side themselves depend on the size of demand. Thirdly, the data on costs and prices of alternatives to secondary sources of power - human, animal, and organic waste materials - are largely untractable.

Nature of Demand Projections and Growth Trends

It proved possible on the basis of these estimates to develop a fairly complete picture of what power requirements are likely to be at four levels of centralization:

1. square mile of rural area
2. village of varying sizes
3. cluster of three villages, and
4. rural district comprising five villages.

The magnitude of demand at various levels has been quantitatively assessed, indicating the likely range of values.

The estimates are subject to varying degrees of error, and should be interpreted within reasonable probability limits. Inevitably, with more complete information, some of the values in our estimates may need revision. In the first place, although the methodology employed has proved satisfactory for present purposes, it could doubtless be improved; almost certainly, it can be extended to a larger sample. Secondly, the estimates, are tied to certain basic economic and technological relationships. Should any of these change, a corresponding adjustment in the estimates would be necessary. Our estimates, of course, do not pretend to assert a rigid relevance to any particular region. More appropriately they should be looked on as consumption levels likely to be obtainable at a certain stage of economic development. The need for constant revision as the level of development changes is, accordingly, clear.

Apart from the discussion of likely demand patterns, we have also commented briefly on the growth trend of power consumption in sample areas. In the present stage of analysis, it is almost impossible to state in specific terms what the growth trend is likely to be. The actual rate of consumption will depend not only on the growth of rural economy and the

rate of technological change, but also on the generation and distribution capacity that may be available. In all probability, demand for power, both as new applications and as increased consumption on existing installations, will rise. Their precise magnitude, however, cannot be projected. Whatever little we have said on this subject is, therefore, for purposes of exposition rather than prophecy.

We have analyzed limited historical data from one rural situation, and on the basis of this experience, have shown the projected growth of our own estimates. But this is only by way of demonstrating the mechanics of growth and no realistic relevance is claimed for them. Much of rural electrification in underdeveloped countries involves a complex process of change, adjustment and adaptation. Hence an aggregative approach toward any kind of forecasting is, at best, of doubtful validity. Even if it were possible to formulate a simple correlation between growth of power consumption and any of the economic indicators, this would not necessarily signify which is the independent and which the dependent variable.

In summary, our purpose was to ascertain the probabilistic shape of the rural power load curve in terms of time. The critical parameters of this diagram are a) its maximum ordinate, signifying peak demand for a short interval of time, and b) the area under the curve, representing total consumption of power during a specified period of time, usually a year. The relationship between the two parameters gives the probable value of the load factor. The projected value of the parameters at future periods of time gives the rate of growth of demand.

Summary Conclusions

The typology of power demand that we have constructed gives a well defined range within which demand parameters are likely to vary, depending on geographical area and population size. At the level of a self-contained village, the range is:

area (sq. miles)	population (nos.)	peak power demand (kw)
1.5 - 5.0	1735-3800	36 - 85

For instance, for a village of an average area of 5 square miles and a population of 3800, the demand is likely to be a peak of 85kw. At the lower end, for a smaller village of 1.5 square miles and 1735 people, the peak will average to 36 kw.

At the cluster level of three villages, the upper and lower limits are defined by a peak demand of 196 and 83kw. At the cluster of five villages, the range is 283 to 120kw.

In general, our survey reveals that the major component of demand is likely to be for irrigation purposes, and that commodity processing and household demands will initially be of a marginal nature. Any economic justification for extending electric power to rural areas, either through local generation or through long distance transmission from a grid is, therefore, dependent on the magnitude and distribution of the pumping load. More specifically, the choice of technology as between generation of electricity and direct mechanical power will largely rest on what happens to pumping loads. For instance, at the village level in one sample, the peak load for irrigation, processing and households is 115kw, 19kw, and 28kw respectively. In general, about 60 per cent of the load is claimed by irrigation alone. In a situation like this, commodity processing and household demands will only be peripheral to the total demand and will not significantly affect the load characteristics.

The jointness of generation and distribution costs in electricity supply from a centralized source is an important element in the cost schedule. The allocation of costs to individual users then becomes a complex matter, since power is supplied to several non-coincident demands from the same capacity. Given the nature of the cost function and demand estimates, generation of electric power for domestic lighting or agricultural processing alone will not be economically remunerative, unless power is supplied from a grid. In other words, revenues derived from the sale of domestic power or power for processing units will not cover the high cost of generation and distribution at the village level. Taken coincidently with power demand for irrigation, however, domestic and processing demands will represent marginal components of the total demand The fact that several demands will not always coincide in time makes it possible to supply them from a smaller capacity than otherwise. Once the major component of total cost has been charged to irrigation demand, the domestic and processing users can be charged at marginal cost which will be substantially lower than average cost in the initial stages of rural electrification.

II.
DEMAND FOR POWER IN IRRIGATION

Nature of Rural Demand for Power

In many underdeveloped countries there is a widespread recognition that programs of rural electrification are vital for alleviating the low-production and low-income situations, and are a positive incentive to economic growth. Partly as a result of this recognition, and partly for strong political commitments, rural electrification has become an accepted goal of public policy. Though considerable progress is currently being made in providing power extension to rural communities, the results are far from satisfactory from a commercial standpoint. The chief problems in this regard are:

1) the high cost of transmission and distribution of power;
2) the scattered and seasonal nature of the power load;
3) the low demand per installation;
4) the low per capita consumption.

Because of the small size of farms and the high cost of delivered energy, the utilization of power has been relatively limited. As the load factor obtained on rural extensions is very low and the consumption of energy per installation is less compared with the urban-industrial connections, the revenue derived does not yield a reasonable return on capital invested. In most countries, rural electrification schemes generally perform at a financial loss which is being subsidized by higher returns from the sale of power to urban and industrial consumers. The schemes show over-all losses even when rates for rural power are extremely low. In Japan where considerable progress has been achieved in the field of rural electrification, utilization of electrical facilities is not at all intensive, as the actual results indicate. This is attributable to the fact that farm work varies according to season and that it comprises many different types of work that follow each other intermittently for a short period of time.[1] To take another example, the load per village in Taiwan is generally low: the present average connected load per rural

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[1] Hideo Matoba, Recent Trend of Rural Electrification in Japan, ECAFE Regional Seminar on Energy Resources, Bangkok, 1961.

customer is only 2.5 lamps and .05 HP motor, with an average yearly demand per customer of only 254 KWH.[2] In Colombia, where about 70 per cent of rural population theoretically has access to power from one source or another, the actual percentage of users is probably very small. In departments like Choco, Boyaca and Canca where the percentage of rural inhabitants is around 80 per cent, the connected load per person is less than 30 watts.[3]

At present electric revenues collected in rural areas are not sufficient to offset the cost of power supply. Inevitably, therefore, a heavy financial subsidy either from the government or from urban-industrial consumers is involved. Just to give an illustration of overt or hidden subsidies to power consumers in rural areas, we cite the case of Taiwan. In Taiwan, customers' payments in 1961 accounted for only 32 percent of the total cost of supply of rural power. The rural customers' share of the total cost has been consistently decreasing over the years--from 55 percent in 1954-55 to 32 percent in 1960-61. In a more meaningful sense, the customers' actual share would amount to much less than indicated by the above percentages, since they were given financial assistance by local governments in paying their electric bills.[4]

The above discussion suggests that the problem of rural electrification is, therefore, to reduce the capital and recurring cost of rural distribution and transmission so as to make the investment as remunerative as possible. Apart from this problem which is largely constrained by technological considerations, another task of comparable magnitude is the improvement of utilization and demand for power in rural areas. Such an improvement would mean a rise in load factor of rural extension and hence a better use of plant capacity.

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[2] Taiwan Power Company, Rural Electrification in Taiwan, ECAFE Regional Seminar on Energy Resources, Bangkok, 1961.

[3] Colombia Field Survey Report, 1963.

[4] Taiwan Power Company, op. cit.

Conceptual and Statistical Problems in the Measurement of Demand

Before attempting to construct a typology of demand for irrigation, a brief reference to the difficulties of demand forecasting in rural areas seems justified. A forecast of the size and character of the power market on which the planning of power installations has to be based in the first instance is always more difficult to establish in an underdeveloped country than in a developed one. Present consumption of electric power is low, the existing generation and distribution facilities are small and scattered, and statistical data are often incomplete or otherwise unsuitable for forecasting. In such situations, no simple functional relationship between the growth of income and growth of power consumption can be obtained. While the problem of power market survey in underdeveloped countries admits of no general solution, the forecast for large industrial and urban uses has at least a starting point based on some technological parameters. In plenty of cases there are definite industrial plans and firm growth projections which, in conjunction with known power intensities of various processes, can be improvised to establish upper and lower limits both for power consumption and for systems peak demand. The relevant indicators may have to be rather roughly estimated and may conceal large uncertainties, but the conceptual apparatus is fairly straight forward.

The forecast of the size and character of power market for rural consumers is usually much more difficult and uncertain. The demand aspect of the energy equilibrium tends to be obscure, since present demands in rural areas are in most cases non-existent. Little can, therefore, be deduced from the past behavior of demand in such circumstances. Further-more, for purposes of future projection the availability of power would in itself significantly affect the demand curve. However, the expectation that plenty of cheap power in rural areas will somehow lead to large-scale economic benefits is a misleading generalization for two reasons. In the first place, this observation does not take into account the potential extent of economic utilization of power and is solely concerned with the supply side. Secondly, the cost of power has very little to do with the rate of growth, except for power intensive industries. For most rural occupations the cost of power would represent only a minor proportion of total production costs.

Regardless of the inherent difficulties, estimation of demand is bound to be an essential feature of investment programming in rural electrification, as in other sectors of the economy. This is so because the supply of electric power, both as a final consumer good and as a production input, must keep ahead of demand, and because of the interval which must necessarily elapse between the decision to build the capacity and the time at which it is actually available. If the demand is under estimated and leads to production bottlenecks elsewhere, the cost of the

error may be reflected in the loss of productive capacity and output. The economies of scale and a generally lumpy character of investment in electric power industry may lead to a less than optimal size. If, on the other hand, demand is over-estimated, the cost of the error may be reflected in the amount of unnecessary resources invested in plants forced to operate at less than capacity, and thus at a higher unit cost.

Spheres of Power Demand in Rural Communities

An examination of actual and potention utilization in a number of countries (e.g., Japan, Great Britain, India etc.) suggest that the pattern of power utilization in rural communities is expected to resemble something like the following. (Table II. 1)

Our preliminary survey further reveals that power for pumping water will constitute the major utilization in the early stages of rural electrification if and when it is undertaken. This conclusion is also borne out by the historical course of rural electrification in Japan and in several western countries. Rural electrification in Japan was started mostly by applying electric motors as prime movers of irrigation equipment and minor agricultural machinery for the processing of rice grains. More than 90 percent of rural electrification is accounted for by the use of electric motors. Approximately a million units of small electric motors (1.8 KW on the average) are employed for agricultural purposes with a rated capacity of 177 million KW and an annual con sumption of 690 million Kwh.[5] The recent experience with the extension of electric power in agriculture in the state of Madras in India also confirms the above conclusion. In 1961, power consumption for agricultural pumping was 28.5 percent of the total power consumed in the state. The number of pumps connected to power in recent years has been rising on the average by about 35 percent per year, while the development of small industrial loads in rural areas has not been on the same scale.

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[5] Since the end of World War II, however, electricity is more widely employed as source of heat for agricultural and dairying purposes, for example, hot beds for bringing up seedlings, intensive cultivation of vegetables and chrysanthemums, incubation of poultry, pest extermination, sericulture etc. This has led to a continuing increase in the demand for electric power in Japan's rural economy. vide Hideo Matoba, Recent Trend of Rural Electrification in Japan, UN Economic Commission for Asia and Far East, Bangkok, October 1961.

Table II. 1

Listing of Actual and Potential Uses for Electricity in Rural Areas

Field of operation	Specific functions	Characteristics
Farm land	Irrigation, drainage, reclamation	Load seasonal and random
Cultivation	Watering, spraying of chemicals, crushing & mixing fertilizers, etc.	"
Processing of farm products	Crop drying, threshing, hulling, cereal milling grinding, fodder chopping, oil pressing, cane crushing, noodle making, cold storage, etc.	Most of the load will occur in daytime with no precise timings
Livestock and poultry	Incubation and brooding, cold storage of dairy products, ventilation and heating	No specified times
Rural crafts	Food manufacturing, canning, sugar refining, saw milling, etc.	Mostly daytime load
Domestic & barn uses	Cooking and lighting, space heating and cooling, water supply for humans & animals, radio and other small domestic appliances	Specified times
Municipal & social	Rural water supply, sewage disposal and water treatment, lighting of schools, medical uses, etc.	Load randomly distributed between day and night

This has, of course, been achieved by the availability of cheap power from the grid, low rates for pumping (7 np as against 24 np for domestic use) and the average population per village (1804) being fairly high. [6]

Potentional Application of Power in Irrigation

In most underdeveloped countries, human and animal powered devices constitute the major source of power for lifting of irrigation water. There has been some progress recently in the introduction of modern high speed centrifugal or propellor pumps which require either an internal combusion engine or an electric motor for their operation. The extremely slow progress in this direction may reasonably be attributed to the small size and scattered nature of farm holdings, availability of cheap labor, and generally poor incentives for technological change in farming occupations. Although a minimum of moisture is essential for plant growth, the use of irrigation water in underdeveloped countries is highly income-elastic up to the point where the marginal productivity of water applications approximates zero. In other words, the higher the incomes of the farmer, the more they are induced to provide artificial irrigation.

The efficiency and coverage of irrigation for various purposes, of course, depends on the efficiency of particular lift arrangements used. A wide range exists in the work capability of human workers and draft animals, depending on their type and size. The lift devices based on human and animal power generally require comparatively small capital outlay, but the application of energy is generally inefficient. For example, in the case of water lift by means of rope bucket, the animals spend energy on the return trip without doing effective work. The swing basket (used in many parts of India, China and Egypt) requires bracing of the body against both horizontal and vertical forces which results in low efficiency of operation. [7] On the other hand, water pumps powered by internal combustion engine, or by electric motor are highly efficient devices, as shown in Table II. 2. [8]

The description of relative efficiencies of various devices by itself does not suggest anything beyond the fact that electrically

6 Govt. of India, Central Water and Power Commission, Report of the Study Team on Rural Electrification in Madras, New Delhi, 1961.

7 M. S. Thacker, New Sources of Energy and Energy Development, United Nations Conference on New Sources of Energy, June 1961.

8 This table has been prepared from data contained in Aldert Molenear, Water Lifting Devices for Irrigation, Food and Agriculture Organization, Rome, 1956.

Table II. 2

Time required for lifting 100 ha-cm of water per year from a lift of 9 meters (app. 30 feet).

	Device	Time required in hours
A.	Self-emptying bucket operated with one pair of bullocks and one attendant.	1430
B.	Persian wheel operated with a pair of bullocks and one attendant.	1100
C.	Rope and bucket lift operated with two pairs of bullocks and three attendants.	600
D.	Turbine pump operated with a 25 hp electric motor at an overall efficiency of 60 percent, and a discharge of 2 cubic feet per second.	50

powered devices are technologically more efficient as far as the rate of discharge of water is concerned. Whether it is economically efficient also will depend on the comparison of alternative cost data. The calculation of meaningfull cost patterns, in turn, depends on the actual and potential demand configurations. For example, Persian wheel is relevant only when water requirements are in the range of 30 acre-feet per year to 100 acre-feet per year. When the water requirements are over 100 acre-feet (which is the usual capacity limit of a Persian wheel) cost comparison is drastically altered.

Even with a very high investment in equipment, the average cost per unit volume of water lifted becomes relatively low when the quantity of water required is large enough to permit long operation of the pump during the year. Once that threshold is reached, there is no ambiguity with regard to the economic efficiency of mechanical or electrical pumping. Whether there would be enough demand for irrigation to justify the investment then becomes the crucial question. The nature of the problem then calls for determining the extent to which the use of electricity in irrigation can be carried out on a sound commercial basis without subsidization.

Statistical Measurement of Demand Patterns in Irrigation

As a preliminary step toward estimation of demand for power in rural areas, we propose to construct a typology of irrigation demand in a number of representative samples. Unfortunately, the extent of statistical data and historical series on the behavior of significant parameters over time is limited and does not permit an unambiguous solution. Within these constraints, however, we shall attempt to define certain parameters of critical value and certain characteristics of the load diagram. No attempt is made to find a general solution to the problem because of its inherent complexity. The aim is to arrive at a range of values within which irrigation demand is likely to vary depending upon local and operating conditions. We emphasize the fact that the estimate of some parameters of the load diagram is much more crucial than that of others, and we propose to formulate two such parameters as defined below.

Our method of estimation--as distinct from the usual method of correlating power demand to one or more of macro-economic variables[8]

8 The absence of past experience and the possibility of technological innovation rule out the existence of any mathematical relationship between the use of power for irrigation and the index of agricultural production.

is based on a sample survey of patterns of irrigation demand. We have selected for detailed analysis three samples in three different regions of India for which adequate information was available.[9] The samples represent the most important and typical soil-water-crop complexes in the region, and taken together they would represent the major water requirement patterns in India as a whole. We believe that the economic structure of our different samples is as representative as possible of the conditions likely to obtain in the corresponding region. The calculations are based on actual data for the years 1954-55, and supplemented with more recent information with regard to certain variables.

We define the following parameters for measurement of a) rate of flow, and b) volume of water for irrigation.

Peak Irrigation Demand, expressed in acre-inches per hour per square mile of area.

$$PID = \text{ac-in/hour/mile}^2 \qquad (1)$$

Annual Irrigation Consumption, expressed in acre-feet per year per square mile of area.

$$AIC = \text{ac-ft/year/mile}^2 \qquad (2)$$

The computation of gross irrigation requirements is based on 'consumptive use factors' and has been adjusted for field irrigation efficiency of approximately 60 per cent. It should be noted that the characteristics of irrigation requirements will depend on a number of variables--for example, meteorological conditions--which are typically unpredictable, but have a substantial bearing on its ultimate dimensions. For this reason, we have enumerated a variety of demand patterns for each sample, as described below.

A. Assumed 100 percent irrigation of the total cultivated area, under fairly ideal conditions.
B. Assumed 100 percent irrigation of the total cultivated area, discounted for average rainfall.
C. Assumed 100 percent irrigation of the actual area presently irrigated. This percentage ranges from 18 percent in the Madras sample to 69 percent in the U.P. sample.
D. Assumed irrigation of actual area irrigated, discounted for average rainfall.

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[9] The primary physical and economic data used in our computations rely heavily on a number of studies in the economics of farm management in various States of India. The inquiry was initiated in 1954 by Govt. of India's Dept. of Agriculture. Appropriate references are included in the bibliography at the end of the paper. A description of the samples is contained in Appendix A.

It is believed that an analysis of the above patterns will reveal a fairly well-determined range within which the values of the parameters are likely to vary, depending upon local characteristics. The typology thus developed will serve as a working hypothesis of the quantitative nature of irrigation demand.

The computed results of our two parameters-peak irrigation demand and animal irrigation consumption under various specified conditions are summarized in Table II. 3. The values under various specified demand patterns define a range of magnitude which is subject to varying degrees of relevance, depending on local characteristics.

Table II. 3

Computed values of PID = acre-inches/hr/mi^2, and AIC = ac. ft/ yr/mi^2

Demand Patterns	Madras PID	AIC	UP PID	AIC	W. Bengal PID	AIC
A	3.670	1652.58	2.337	1029.08	3.904	1953.08
B	2.312	1276.23	1.240	654.07	1.081	995.05
C	0.651	269.20	1.735	720.50	1.513	487.13
D	0.60	205.00	1.50	228.00	.81	385.00

The irrigation requirement appears to be the highest for the West Bengal sample. This is explained by the fact that the chief crop in the area (paddy) requires continuous water-logging, the extent of crop rotation is substantial (3 paddy crops a year) and that rainfall, though substantial, is extremely erratic and uncertain.

Since efficient water usage is dependent on various economic and natural factors, it is evident that the demand parameters will show considerable variation from place to place and from year to year. For purposes of further refinements in our calculation, however, we need to select a preferred estimated value for the two parameters. Our selection of the preferred estimate in each case is based on the following assumptions.

1. Necessary irrigation--as determined by basic climatological data--is practiced on the total area under cultivation in each square mile of the sample area.

2. Sufficient water is available at all times to maintain favorable germination and growing conditions.

3. The fertility and chemical properties of the soil are such as to permit profitable use of irrigation.

4. Precipitation occurring during the growing season is not generally available for consumptive use by the crops, so that the irrigation requirements are not materially changed. In many areas, this may not be entirely true. A knowledge of local conditions will make it possible to adjust for these differences, without in any way changing the conceptual framework.

5. There is in existence a capacity and a willingness to invest in modern water application devices.

Bearing in mind the above assumptions, we select the following preferred estimates for our two basic parameters. The selection of the preferred values is based on assumed conditions of total irrigation of the cultivated area and an insignificant degree of reliance on natural precipitation. This is not very unrealistic since the rational behind artificial irrigation is to smooth out the natural irregularities.

Table II.4

Preferred Estimates of Peak Irrigation Demand and Annual Irrigation Consumption

Sample	PID = ac-in/hr/mi^2	AIC = ac-ft/yr/mi^2
Madras	3.670	1652.58
U.P.	2.337	1029.08
W. Bengal	4.904	1953.08

Having determined a) peak demand, and b) annual consumption estimates for irrigation, our next task is to compute the electric power requirements. We base our calculation on the assumption that for regularly irrigated areas, the system shall have the capacity to meet the peak moisture demands of each and all crops irrigated within the area for which it is designed. We further assume a total pumping head of 40 feet (this again may not be universally relevant, but can easily be adjusted to actual data). The assumed pump efficiency is 60 percent.

We start out by estimating theoretical horsepower requirement. The formula is

$$HP = \frac{\text{Discharge (GPM)} \times \text{Head (feet)}}{3960 \times \eta P}$$

where ηP is pump efficiency.

The kilowatt requirements are obtained by using the following equation.

$$KW = \frac{\text{Horsepower} \times .746}{\eta M}$$

where ηM is the motor efficiency.

According to standard engineering practice, we assume an 80 percent efficiency for HP requirements of 15 or less and a 90 percent efficiency for motors of over 15 HP.

Next we calculate the total anticipated kilowatt-hour consumption during the year. The formula is

$$KW = \frac{\text{Acre-inches annual consumption}}{\text{Discharge acre-inches/hr}} \times \text{Kilowatt}$$

The computed values for connected load (HP), peak demand (KW) and total yearly power consumption (KWH) are shown in Table II. 5

Table II. 5

Computed Values for Connected Load, Peak Demand, and Annual Power Consumption

Sample	Conn. Load (H)	Peak Demand (KW)	Annual Power Consump. (KWH)
Madras	28	23	123, 274
U. P.	17	14	75, 169
W. Bengal	38	31	145, 309

The time distribution of demand is important for the planning of generation facility. We have summarized the monthly distribution of total power consumption in Table II. 6. No account is as yet taken of the diversity between users of pumping equipment, but it can be easily incorporated into the basic parameters, once the number of consumers is determined. The derivation of total demand at various levels of centralization, e. g. village and cluster of villages, is carried out in the final chapter.

We emphasize again that these are tentative, and as yet highly speculative, measures of demand for power for irrigation. The problem of determination of the number consumers or connections per square mile of area has been assumed away. Once these factors

Table II. 6

Monthly Distribution of Power Requirements in KWH for Irrigation

Sample	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec	Aver.
Madras	10833	5530	4117	3335	14605	9131	10327	16422	11730	10902	13938	12397	10273
U.P	4438	6454	3626	2800	10248	10248	10248	5544	5502	7238	4438	4438	6264
W. Bengal	1860	1860	960	620	28024	28024	28024	28024	14787	15748	2201	1860	12109

are brought into the analysis, it may be necessary to modify some of the conclusions. However, some general comments can be made here. The actual data show a great concentration of farms in the lower-sized groups, and a highly skewed distribution of farm size. For instance, in the West Bengal sample, the average size of farm is 2.86 acres. Nearly 58% of the total number of farms have an average size of below 2.5 acres, while one-third of the total is even below 1.25 acres. Besides the smallness of holdings, the excessive degree of fragmentation further complicates the picture. Again, in our West Bengal sample, the average number of fragmentations per farming household is 9.4. This fundamental weakness in the structure of farms severely restricts the scope of efficient agriculture, and consequently, of rural power extensions.

In summary, the peak power demand for irrigation is likely to vary between 23 KW and 31 KW per square mile of rural area, depending on particular soil crop complex.

III.
DEMAND FOR POWER IN AGRICULTURAL PROCESSING

The present chapter is concerned with the use of electric power in the processing of agricultural commodities. The primary objectives of the study are (1) to identify the lines of activities where the potential use of power for agricultural processing can be visualized, and (2) to develop quantitative estimates of power requirements and consumption in different types of processing activity in a number of sample situations. Most of the statistical material used in this chapter relates to the same three samples described earlier in the last chapter.[1] Since little is known of the actual experience of farms where power has been in use for sometime past, this preliminary study employs certain assumptions which are considered realistic from a technical point of view. Although we do not preclude the consideration of "non-processing" small scale industries in later stages of our inquiry, the following analysis is restricted to those farm processing activities for which a local market exists. The use of power in agricultural processing alone will necessitate a major technological and economic adjustment in many rural communities.

Nature of Processing Activity in Rural Areas

An average farmer in a low-income area is not likely to be aware of the possibilities for mechanizing the processing of various crops. Although the use of electrical equipment on farms is extremely limited, there are situations where farmers could utilize equipment for a wider variety of purposes than they do now. Substantial research of an engineering and economic nature is needed to demonstrate the extent of promising possibilities that exist in this direction. However, a beginning can be made in areas where well-defined possibilities already exist. There are areas where no efficient processing facility of any kind exists. If there is a sufficient marketable surplus to support the setting up of processing units in such areas, this venture may serve a definite need. In other situations, a number of small uneconomic processing units may be in existence, thus depriving themselves of the economies of scale. If so, there may exist an opportunity to reduce the unit cost by increasing the scale of operation. Where the quantities produced by an individual farmer are too small to justify

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[1] A geographical and economic description of the samples is contained in Appendix A.

investment in processing equipment, it may be possible to develop co-operative arrangements of an economic size.[2]

The processing equipment used by a majority of farmers in under-developed areas is highly inefficient and labor-intensive.[3] The output of these facilities-run either by hand or by bullock power-is hardly sufficient to justify production on any scale larger than for family use. Production for a market economy would thus require the introduction of mechanized techniques and the use of power. Consequently, the practical possibility of significantly broadening the base of processing activity in rural communities depends, to a large extent, on a) the actual availability of power and b) the price at which it might be supplied. But since the price at which power can be supplied to rural areas in itself significantly depends on the size and nature of demand, the present attempt at measurement of power demand is momentarily independent of prices. At further stages of our analysis we will comment more fully on the resulting demand schedule for power as a curve of quantities demanded at different prices.

At this stage of our enquiry, it is not possible to more than barely sketch the nature of potentialities and to indicate the magnitude of power requirements for a few major processing activities, assuming that power can be supplied at reasonable prices. The particular processing activity or activities suitable in a given area will in general be determined by locational considerations. To be utilized in any of the numerous ways[4], electricity must first be converted into

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[2] The question of cooperative arrangements is tied with the size of the market and the scale of processing operations. For instance, for husking and milling of paddy, large-sized sheller plants with a handling capacity of 2 tons per hour give better milling efficiency than small-sized rubber-roller shellers with a capacity of 3/8 ton per hour. The larger sized units requiring about 38 HP motor are, however, beyond the means of most individual farmers. But a number of small farmers can combine to invest in the large sized unit. For some recent experience, see Planning Research & Action Institute, An Introduction to the Integrated Cooperative Credit, Marketing & Processing Units of Agricultural Produce in Uttar Pradesh, PRAI Publication no. 156, Lucknow, August 1958.

[3] We do not imply here that labor-intensive techniques are necessarily inefficient.

[4] The US Dept of Agriculture has enumerated more than 400 different applications of electric power on American farms, vide US Dept of Agriculture, Use of Electricity on Farms - A Summary Report of Ten Area Studies, Wash, D.C., Nov. 1956.

light, heat or motive power. The process of installing electrically operated equipment requires large investments in machinery and wiring, besides power costs. Further, a farmers' decision to invest in any particular piece of equipment involves diverse considerations in addition to a constraint imposed by availability of funds. These considerations may reflect a desire to increase labor productivity, to improve quality of product, to meet the demands of larger market and to ensure the timeliness of operations.

In most situations, there is a direct relationship between the extent of mechanization of processing activities and the income of the operators. Within broad limits, rural communities with a larger investment in processing activities can expect to have a larger real income than those with small or no facilities for processing. In many low income areas, a farmer's commercial interests usually end when he sells his produce in an unprocessed form to a middleman. Except within the immediate environs of the village community, he does not share in transactions with the ultimate consumer. This is reflected in a correspondingly lower return from farming occupations. If the farmer has access to mechanical equipment for processing, he can increase his total returns from land. It is believed that the margin between farm prices and selling prices of processed commodities is sufficiently large to allow a reasonable return on investment. However, with present data at our disposal, it is not possible to isolate and measure the costs and benefits relating to the use of electricity for commodity processing.

On the cost side, one needs information on the initial cost of equipment and wiring, recurring costs and rates of interest. On the returns side, one needs to know the output of the processing activity and the prices at which it can be sold. The profitability of any particular processing activity can then be directly deduced. A simple approach is to calculate the discounted value, for a given period of time, of the difference between future sales income and costs. Representing this discounted value at the initial moment of time by K the formula is

$$K = (c_1 - y_1)(1 + r_1)^{-1} + (c_2 - y_2)(1 + r_2)^{-2} + \\ + \ldots\ldots + (c_n - y_n)(1 + r_n)^{-n} - A_o$$

or in summation

$$\sum_{j=1}^{n} (c_j - y_j)(1 + r_j)^{-j} - A_o$$

where A_o = initial investment cost, C_j = annual operating cost for n years, Y_j = annual sales income for n years, and r = rate of interest.

The choice of interest rate for discounting is critical, since it would significantly affect the investment criteria. Since the rural sectors in underdeveloped countries are generally capital-scarce, one should normally use a shadow rate of interest which is higher than the market rate. In India, for example, the shadow rate of interest may range between 12 to 20 percent.

Technical Data on Potential Applications

Conceivably, a group of rural processing industries can be set up at several levels of centralization, ranging from an isolated village to a group of villages and from a small town to an industrial district. The choice of any particular level of centralization will be dictated by locational considerations, whose complexity precludes any discussion in this preliminary analysis. Given the level of centralization, however, the two relevant questions are a) what size of plant and what production techniques are optimal for the processing of a particular commodity, and b) whether there is a large enough market to absorb the output of such a plant. While substantial research is needed to determine the full range of possibilities, it is clear that small commodity processing units can serve as a first step to mechanized production in villages[5]. Whatever limited data is available seems to suggest that initially the use of power in agriculatural processing (as compared with village-based industry) has a wider potential[6]. Examples of these resource-based processing activities are hulling and polishing of rice, milling and grinding of cereals, crushing and refining of sugar cane, pressing and

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[5] Historical evidence of a limited character suggests that initially the use of power in small industries was largely concentrated in commodity processing. For instance, see Tokutaro Yamanaka and Yoshio Kobayoshi. The History and Structure of Japan's Small and Medium Industries, Tokyo 1957.

[6] It can be argued that many consumer goods with a high income and price elasticity in rural areas-such as textiles, bicycles, mechanical toys, etc. - require a scale of manufacture substantially larger than could be sustained at the village level. The possibility of such products being exported to urban consumption points in direct competition with town-based industry is non-existent. Not only the scale disadvantages, but the inadequacy of transport arteries between village and urban centers will rule out any such possibility. The role of villages in development of industry can, however, be visualized as that of an intermediary link between raw materials and the final manufacture. Even this would seem to be limited to those particular lines where certain intrinsic economies in village production can be assumed. For a partial discussion see Dhar & Lydall, The Role of Small Enterprises in Indian Economic Development, Asia Publishing House, Bonbay 1961.

expelling of oilseeds, grinding and chopping of fodder, and so forth. Whatever the composition, it would economically be more efficient for a processing unit to undertake multiple activities to allow a better utilization of plant facilities throughout the year and thus spread overhead charges.

One obvious starting point is the assumption that the food-and-fiber crops complex of the region will largely determine the choice of activity, provided a marketable surplus exists. The knowledge that mechanized processing units can be set-up may alter the crop complex in line with the commercial interests of the farmer. Thus he can plan his agricultural program to grow that proportion of crops that would maximize his total returns from the land. In addition to agricultural processing, the use of electric power can be reasonably anticipated in the provision of certain services for the local market. Examples of such services are iron smithy shops and repair facilities for agricultural implements and machinery. The suggested applications of power for agricultural processing and for certain services drawn from the experience of several countries including Japan are summarized in Table III. 1. This description is only suggestive of the many possibilities that exist in this field. Doubtless, there would be many others.

The mechanical and electrical equipment for these processing activities is generally available in varying sizes and specifications. The selection of a particular type and size of machinery will be dictated not only by technological specifications but also by the size of markets. Many of these machines are already in operation in Japan and other Asian countries. While complete information on this count is not readily available, some estimates can be made with regard to the size of installation and anticipated power consumption. Information on these characteristics is summarized in Table III. 2.

Statistical Measurement of Demand Patterns

On the basis of statistical data from the three samples described earlier, we now attempt to measure quantitatively the extent of potential power use in agricultural processing at the village level. We proceed by ascertaining the total quantity of agricultural data relating to crops, area under cultivation and yield per acre. The total quantity of produce potentially available for processing is given by the product of the average village area and the total produce per square mile of area. The results are shown in Table III. 3.

Technical and operating data on agricultural processing machinery in underdeveloped countries is very scarce. However, in certain countries there is limited experience with processing by means of

Table III. 1

Listing of Applications of Electricity for Agricultural Processing

Processing Activity	Commodities
Rice hulling and polishing	Paddy, rice, wheat, barley
Cereal milling and grinding	corn, pulses
Cotton ginning	Cotton
Oilseeds pressing and expelling	Groundnut, mustard, linseed
Sugar cane crushing and refining	Sugar cane
Tea processing	Tea
Coffee drying and processing	Coffee
Fiber processing	Jute, Cotton
Tobacco curing	Tobacco
Noodle making	Wheat, corn, barley
Fodder chopping and grinding	Sorghum, horse-grain, maize, oil cakes etc.
Sawing and planing of forest products	Teak and industrial timbers, firewood
Poultry hatching and brooding	Chicken, turkeys
Tanning and leather making	Animal hides
Repairing and servicing	Minor agricultural implements, electric motor, diesel & gasoline engines

Table III. 2

Technical Characteristics of Agricultural Processing Machinery

Process or Operation	Equipment	Motor Rating (HP)	Output (Lbs/hr)	Power Consumption (KWH/100 lbs)
Oil Pressing & Extraction	Hydraulic Press			
	Large	22	1,500	1.3
	Medium	16	1,000	1.5
	Small	8	130	4.5
	Screw Expeller			
	Large	20	2,000	1.0
	Medium	15	1,000	1.5
	Small	5	100	5.0
Rice Hulling	Disc Sheller (German)	25	2,400	0.8-1.0
	Japanese Rubber Roller Sheller	3	300	2.0-2.5
Cereal Milling	Large	20	800	1.5-2.0
	Small	5	180	2.0-3.0
Cotton Ginning	Large	20		
	Small	5	78	2.75-3.2
Fodder Chopping	Rotary Cutter	2-10		.25-1.0
Sugar Cane Processing	Crusher Refining Pan	3-15		.50-3.0
Tea Processing	-	-	-	-
Coffee Curing	-	-	-	-

Table III. 3

Estimates of Agricultural Produce Available for Processing at the Village Level

Sample	Crops Grown	Acreage per mile (acres)	Yield per acre (lbs)	Yield per mile^2 (tons)	Aver. village area (Mi^2)	Total Produce per Village (tons)
Madras	Paddy	25	1.886	24	5.0	120
	Cereals	341	820	140		700
	Groundnut	39	1.148	22		110
	Cotton	45	711	16		80
	Fodder					60
U.P.	Paddy	45	1.230	28	3.0	84
	Cereals	321	902	145		435
	Sugarcane	115	29.247	1.683		5.049
	Cotton	7	640	2		6
	Fodder	102	574	29		87
W. Bengal	Paddy	467	1.500	350	1.5	525
	Cereals	60	820	25		38
	Oilseeds	20	710	7		11
	Fodder					55

electrically powdered devices. Our computations with regard to size of motor and anticipated power consumption per ton of raw commodities processed are derived from data from various countries including Japan. While it is necessary to emphasize the inadequacy of data, some cross checking assures us that our computed values indicate the relevant range of magnitude. The power requirement data is summarized in Table III. 4.

As will be seen in Table III. 4, the horsepower requirements on the lower side are preferred because the scale of activity involved at the individual village level is likely to be small. This inference is supported not only by the fact that total quantities available for processing in sample villages are relatively small but also by actual experience. For example, average KW capacity for processing of farm products in Japan's rural economy was recently reported to be only 2.46 KW. For rice threshing alone it was even less--nearly 1.15 KW.[7] In any case, this is a defensible assumption if our aim is to bring about further year-round utilization of plant capacity. However, consideration of a cluster approach may favor the use of higher KW capacity, since the economies of scale at that level of centralization are likely to be significant.

Our estimates for peak power demand and annual consumption are given in Table III. 5. In calculating the peak KW requirements we have used a motor efficiency of 0.85 and a diversity factor of 1.2. The diversity factor is defined as the ratio of the sum of maximum power demands of the component parts of any load to the maximum simultaneous demands of the load as a whole. The aggregate demand for a group of connected loads is expressed as power delivered at the shaft. Thus the maximum aggregate demand in KW for agricultural processing is defined by

$$D_P = \frac{Chp \times .746}{\eta_m \times cf_p}$$

where Chp is the total connected load, .746 is the KW conversion factor, cf_p is the diversity factor, and η_m is the motor efficiency.

Similarly, the annual power consumption in KWH is the product of KW demand and hours of operation. The KWH demand for the village is the summation of KWH demands for individual processing operations.

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[7] Matoba, H. Recent Trend of Rural Electrification in Japan, ECAFE Committee on Industry and Natural Resources, Bangkok 1961 (unpublished).

Table III. 4

Estimates of Power Requirements for Agricultural Processing Operations

Processing Operation	Connected Load (H. P.)		Power Consumption (KWH/TON)
	Range	Pref.	
Rice hulling	25-3	3	15
Cereal milling	20-5	5	50
Oil pressing	22-5	5	118
Groundnut shelling	22-5	5	118
Cotton ginning	25-10	10	100
Sugarcane crushing	15-3	6	5
Fodder chopping	10-2	3	5

Table III. 5

Estimates of Annual Power Consumption in Agricultural Processing

Sample	Processing Operation	Connected Load. (H. P.)	Peak Aggregate Demand (KW)	Annual Hrs. of Operation (Hrs.)	Annual Power Consumption (KWH)
Madras	Rice hulling & husking	3		800	2,400
	Cereal milling	5		7,000	35,000
	Oil pressing & groundnut shelling	5		2,200	11,000
	Cotton ginning	10		800	8,000
	Fodder chopping	3		100	300
	Total	26	19		56,700
U. P.	Rice hulling & husking	3		560	1,680
	Cereal milling	5		4,350	21,750
	Sugarcane crushing	6		5,050	25,250
	Cotton ginning	10		60	600
	Fodder chopping	3		145	435
	Total	27	20		49,725
W. Bengal	Rice hulling & husking	3		2,625	7,875
	Cereal milling	5		380	1,900
	Oil pressing	5			275
	Fodder chopping	3		92	
	Total	16	12		11,348

The consolidated peak demand and annual power consumption for the village in the three sample areas is summarized in Table III.6. It remains to show at what times of the year the above load are likely to occur. It is clear that a very substantial part of the load will occur after the harvesting season and might continue until the next cropping season. In cases, however, where we have assumed a relatively smaller size of motor, the processing activity may continue for the larger part of the year. This is an important assumption but the results can be modified if it is necessary to assume a larger size of installation. This latter modification may be necessary where the activity is analyzed at the level of cluster of villages rather than an individual village or where it is necessary to increase the capacity to satisfy seasonal market requirements. On the basis of our assumption, however, the major processing activity in a region, like hulling and threshing of paddy in a predominantly paddy growing area, will occur regularly throughout the year. In any event, this would be the desired distribution of load to ensure further utilization of plant facility and improve the power load factor. The distribution of annual power consumption on a monthly basis is shown in Table III.7. Most of these will be daytime loads, assuming an average working day of 8 hours.

In summary, our computations show that peak power demand for agricultural processing is likely to vary between 12 and 19 KW, for an average village size of 1.5 to .5 square miles. These figures, of course, refer to our sample villages and no universal relevance is claimed for them. The size and nature of power demand for processing leads us to the conclusion that, by itself, it may not be sufficient to justify investment in generation and distribution of electric power at the village level. Taken coincidentally with power demand for irrigation, however, it will represent marginal additions to the total demand, and can be phased in off-peak hours. This conclusion will not necessarily hold if power is drawn from a grid.

Table III. 6

Consolidated Peak Demand and Annual Power Consumption for Agricultural Processing at the Village Level

Sample	Ave. Village Area (Sq. Mi.)	Ave. Population Per (Nos.)	Total Connected Load Per Village(HP)	Peak Power Demand (KW)	Annual Power Consumption(KWH)
Madras	5.0	3,825	26	19	56,700
U.P.	3.0	2,814	27	20	49,725
W. Bengal	1.5	1,480	16	12	11,348

Table III. 7

Monthly Power Consumption for
Agricultural Processing

Sample	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total (KWH)
Madras	7,420	7,420	4,753	4,753	2,917	2,917	2,917	2,917	4,017	3,717	3,717	7,420	56,700
U.P.	3,917	3,917	3,917	3,917	3,917	3,917	3,917	3,917	3,917	5,792	4,757	3,917	49,752
West Bengal	788	1,738	1,783	788	788	-	-	-	275	788	788	2,086	11,348

IV.
DEMAND FOR POWER FOR DOMESTIC LIGHTING

It is well known that a large proportion of domestic energy requirements in low income rural areas are met from secondary fuels. Their relative contribution to total energy use is apt to vary from region to region, but their general preponderence over primary sources of energy is quite clear. For instance, in Indian rural households, firewood and cattle dung constitute the major source for heating and cooking while kerosene is generally used for lighting. The very low energy consumption figures in rural households are a reflection of low real incomes and the relatively high cost of primary sources of energy. In some areas where cattle dung and vegetable refuse are used in large proportions the utilization of energy is relatively inefficient, probably because these sources are regarded as "free goods" and are used inefficiently. Moreover, since most of these secondary sources of energy come from home production, the family budget studies do not show the correct outlay on energy consumption.

Continuing our analysis of probablistic demand for electric power in rural communities, we now set out to estimate domestic power requirements. As in other sectors, we rule out an attempt to establish any single relationship between power consumption and any of the economic indicators like real income or money expenditures.

The potential power market in household sector may be visualized both in terms of power requirements for cooking and lighting. Our present analysis is, however, confined to power demand for lighting alone. This is because power demands for cooking and heating purposes in many rural areas will continue to remain marginal for a fairly long time. To the extent that such cases would be the exception rather than the rule, our general analysis will not be affected by their exclusion. The fact that it is costly to obtain electrical appliances sets definite limits to the extent to which a substitution from cheaper local fuels to electricity can take place. The level of rural incomes has to be sufficiently high to permit the purchase and use of electrical appliances. The experience of the United States and Western European countries suggests that the use of electrical appliances becomes widespread only when family incomes reach around $500.00 a year. The very low incomes ($50.00 to $150.00 a year) of rural areas in our enquiry will, therefore, rule out any significant power use for household appliances, except in the very long run. But even this relationship of time to the process of acquiring appliances is relevant only when incomes have reached a certain minimum threshold. The major component of power

demand in village households is, therefore, likely to be domestic lighting. The provision of electric lighting in rural households can be an important factor in improving the living standards and in bringing the amenities of urban life to the rural population. In fact, this basic prospect of domestic electification usually underlies public programs to build rural power lines. However, strictly from a narrow point of view, domestic power consumption may not contribute appreciably to increase in productivity of the rural sector, except indirectly through a rise in living standards.

In what follows, we attempt to define a range of values within which household demands are likely to fall. Our estimates, like before, are bases on actual economic data of three sample rural areas. Each household is treated as a single consuming unit. Certain assumptions are made about lighting requirements for the households, based on an analysis of basic economic conditions and certain inherent "indivisibilities" of consumption. As in previous chapters, the estimated demand patterns are not in the nature of demand curves, but signify a potential market that can initially be built up with an appropriate price policy. Although we will not discuss price policy in this paper, we may hint that marginal cost pricing may support substantially lower rates for domestic power, once the major costs of generation and distribution have been attributed to irrigation and processing uses of power, but this may not rule out a certain element of subsidy based on rate discrimination between urban and rural consumers of power.

Analysis of Present Consumption Patterns

In general, kerosene burnt in hurricane lanterns, constitutes the major source of domestic light in these areas representing about 90% of the total domestic lighting. The amount of kerosene consumption would thus seem to represent a fair index of present demand for domestic lighting. We have translated the kerosene consumption into electrical units (KWH) to have some idea as to what it involves in terms of power units and to make the figures more nearly comparable with our own estimates later in the paper. We must, however, warn that this conversion of kerosene consumption into KWH is only very rough since the efficiency of kerosene as a lighting fuel is not known and has not been accounted for. In any case, the adjustment for fuel efficiency will reduce the KWH equivalents. The conversion is based on the formula

$$KWH = k/cals \quad 1.163 \times 10^{-3}$$

where k/cals stands for kilogram-calories. The computed values of conversion relating to our sample areas are given in Table IV.1

Table IV. 1

Conversion of Kerosene for Lighting to KWH Equivalents

Sample	Average area per village mi^2	No. of households per village	Average family size	Kerosene Consumpt. per household per yr. (gals)	k/cals per yr. per household	Kwh per yr. per household	Kwh per day per household
Madras	5.0	850	4.5	6.1	231,800	269,583	0.80
U.P	3.0	502	5.5	4.5	171,000	198,873	0.60
West Bengal	1.5	262	6.2	6.8	258,400	300,519	0.85

Since these figures do not take account of the fuel efficiency, they are not very helpful as parameters for estimating power consumption.

Estimates Based on Present Kerosene Consumption

A better way of visualizing the present consumption is to take account of the money outlay on kerosene consumption. We assume here that money outlay presently allotted to kerosene is potentially available for expenditure on electric power for lighting. This gives us, ceteris paribus, the amount of power that could be bought for the same outlay if a substitution takes place. This ignores temporarily the capital costs of such a substitution in terms of wiring and lamps. Our computations yield the following results. From this we could derive the

Table IV.2
Estimates of Demand for Electric Illumination Based on Cash Outlay for Kerosene Lighting [1]

Sample	Cash outlay on kerosene per household per yr. (RS)	Amount of electric power that could be bought alternatively per household per yr. (KWH)	per day(KWH)	Amount of KWH per year per village
Madras	18.30	36.60	0.10	31,110
U.P.	13.50	27.00	0.08	13,554
West Bengal	20.40	40.80	0.11	10,689

peak demand for the individual household and the normal peak demand for the village. The peak demand for village is given by

$$D_h = \frac{(d_h \cdot n_h)}{1000 \cdot cf_h}$$

where D_h is village peak household demand in KW, d_h is household peak demand in watts, n_h is the total number of households, and cf_h is the diversity factor. Since demand is measured here in delivered units at the consumption point, the efficiency of L-V lines has been

[1] Based on an average price of kerosene of Rs 3.00 per gallon and RS 0.50 per KWH delivered.

ignored. Similarly the annual energy consumption is given by

$$E_h = \frac{(d_h \cdot n_h) \times \text{hours}}{1000.}$$

Our demand estimates indirectly derived from money expenditure on kerosene are summarized in Table IV. 3. We have assumed an average of 4 hours use every day (say from 6pm to 10pm). Since the number of lamps in the village will be quite large, we have used a diversity factor of 1. 10. The results appear to be fairly representative of the situation in many underdeveloped areas. The historical data from electrified villages in Pakistan shows an initial connected load of 24 watts per capita for domestic lighting, and a connected load of 14. 5 KW average per village.[2] The average connected load for lighting per rural customer in Taiwan is 2. 5 lamps and .05 HP motor capacity, with an average demand per customer of about 160 watts. The total yearly consumption of power (including motor operation) averages 254 KWH per customer.[3]

Table IV. 3
Estimates of Connected Load, Peak Demand, and Annual Power Consumption for Illumination Based on Cash Outlay for Kerosene Lighting

	Connected Load		Peak Demand		Power Consump.	
Sample	household watts	village KW	household watts	village KW	household watts	village KWH
Madras	25.00	21.25	25.00	19	36.60	31,025
U. P.	20.00	10.04	20.00	9	27.00	14,658
W.Bengal	28.00	7.34	28.00	7	40.80	10,716

Estimate of Demand Based on Direct Measurement

. Since the purpose of this report is to identify a range of values within which demand is likely to fall, we also make an alternative set of estimates for domestic requirements of power. This set of estimates is based on certain assumptions about the minimum connected load that

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[2] Agency for International Development, Public Works Division: Evaluation of the Presentation Report on the Village Electrification Project prepared by Miner & Miner International Inc for WAPDA, September 1960 (unpublished).

[3] Taiwan Power Company: Rural Electrification in Taiwan, ECAFE Seminer on Energy Resources. December 1961 (unpublished).

a family of given size is likely to require. We also take into account certain technical indivisibilities of consumption units, since electric bulbs are available only in certain discrete sizes and the price does not generally vary in a linear fashion with the size of the lamp. In other words, the unit price of a lamp may be the same for bulbs 15, 20 or 25 watts. In such a case, the consumers are likely to buy the larger size of bulb. This is quite plausible in cases where consumption is limited to one or two bulbs in the family. Moreover, once a household is provided with an electric lighting facility, the consumption of power tends to go up relatively to the previous mode of lighting. In view of these considerations, our previous estimates seem to be on the lower side. In the West Bengal sample, for instance, a connected load of 28 watts for an average family size of 6.2 is very inadequate, since this comes to 4.5 watts per capita, which is unusually low, as the data from certain electrified villages indicate. The following estimates are based on the assumption of 40 watts connected load per family and an average of 4 hours daily use. The reason for assuming a constant connected load between the samples is that per capita income is lower in larger family size, so that the influence of larger family size is offset by lower incomes. We are using a diversity factor of 1.2, since the diversity amount consumers is likely to be higher than in the previous estimate. The computations are summarized in Table IV.4.

Table IV.4
Estimates of Peak Demand and Annual Power Consumption for Illumination Based on 40 Watts Per Household

Sample	Connected Load		Peak Demand		Power Consump.	
	household watts	village KW	household watts	village KW	household KWH	village KWH
Madras	40	34.0	40	28	58	49,100
U.P.	40	20.0	40	16	58	29,116
W. Bengal	40	10.5	40	9	58	15,196

To recapitulate, we have made two alternative sets of estimates for power demand in rural households, one based on present kerosene consumption for lighting and the other based on certain assumptions about consumption patterns in the event that electric power is available. These two estimates thus give us a probablistic range within which actual initial demand is likely to fall. The quantitative magnitude of this range for the village is summarized in Table IV.5.

Table IV. 5
Range Estimates of Connected Load, Peak Demand, and Annual Power Consumption for Illumination [4]

Sample	Connected Load (KW) Range	Peak Demand (KW) Range	Annual Power Consump. (KWH) Range
Madras	21--34	19--28	31,025--49,100
U.P.	10--20	9--16	14,658--29,116
W. Bengal	7--11	7--9	10,716--15,196

Thus, our estimates show that for a substantially large village of 3800 people, the demand for domestic lighting may vary between 19 and 28 KW. While for smaller size rural communities, peak demand may range from 9 to 16 KW, depending on size and number of households. The area, population and density data for sample villages is shown in Table IV. 6.

Evidently, the total domestic power demand is relatively small, considering the number and dispersion of households in sample villages. On a per capita basis, for instance, it works out to only 8.9, 7.2 and 6.4 watts respectively for the three rural configurations. Since the number of households in each case is fairly large (850, 502, and 262), the distribution and transmission costs of power will constitute a fairly substantial part of the total cost. Our immediate inference, therefore, is that revenues derived from the sale of domestic power alone will not cover the high cost of generation and distribution of electricity at the village level. But once the major part of total cost has been attributed to power for irrigation, domestic power may be supplied at the margin. Since the domestic lighting loads will occur for a specified period in the evening, they can be properly phased with other components of the load. This conclusion may, however, be modified if power is supplied from an extensive grid system.

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[4] Values from the previous tables are rounded off for this summary.

Table IV.6

Characteristics of Sample Villages in Madras, Uttar Pradesh and West Bengal

Sample	Average village area (mi^2)a	Average population density per mile (nos)b	House-holds per village (nos)	Average family size (nos)	Income per capita (RS)c	Average population per village (nos)	Annual population increase (%)
Madras	5.0	810	850	4.5		3800	
U.P	3.0	938	502	5.5	198.47[d]	2762	1.8
West Bengal	1.5	1260	262	6.2		1735	

a. Square miles
b. Numbers
c. Indian Rupees
d. Relating to year 1958-59 at 1948-49 prices

V.
CONCLUSIONS

Recapitulation and Synthesis

The three preceding chapters have defined and estimated the potential power requirements in irrigation, processing of agricultural commodities, and in domestic illumination. The task of this final chapter is to integrate the demands of individual sectors into system's demand for the village as a whole, as well as for a cluster of villages.

The total energy consumption (Kwh) for the various levels of centralization is represented by the summation of energy consumption of all classification of consumers, (plus conveyance losses) for any given period of time. However, the system's peak demand may not necessarily be the summation of peak demands of various consumers, since there will be some diversity in the time of occurrence of peak loads. It is, therefore, necessary to apply a suitable coincidence factor to the summation of peak demands in order to arrive at the estimated system's peak demand. This would be the total load on the sub-station carrying both farm and non-farm loads, either at the village or the cluster level.

To recapitulate the analytical framework of the preceding chapters, we summarize as follows. The demand for power applications in irrigation was developed on the basis of the following parameters.

$$PID = ac.in./hr/mi^2, \text{ and} \qquad (1)$$

$$AIC = ac.ft./hr/mi^2 \qquad (2)$$

where PID refers to peak water demand for irrigation and is expressed in acre-inches per hour per square mile of geographical area, and AIC refers to annual water consumption for irrigation per year per square mile. The horsepower requirements for pumping necessary quantities of water were derived from the formula

$$HP = \frac{GPM \times Head}{3960 \times \eta p} \qquad (3)$$

where GPM refers to gallons per minute, and ηp is the efficiency of pumping equipment.

The peak power demand and annual power consumption for irrigation were then developed on the basis of

$$D_i = \frac{HP \times .746 \times mi^2}{\eta m \times cf_i} \qquad (4)$$

and

$$E_i = Kw\ (hrs)\ (mi^2) \qquad (5)$$

where D_i is the peak power demand for irrigation, E_i the annual power consumption, cf_i the diversity factor, η_m the motor efficiency of converting electrical to mechanical energy, and mi^2 is the average village area.

The demand for power in agricultural processing was determined analogously, as expressed in

$$D_p = \frac{HP \times .746}{\eta_m \times cf_p} \qquad (6)$$

where D_p refers to peak power demand for processing, η_m is the motor efficiency, and cf_p is the diversity factor between users.

Similarly, the demand for power for household lighting is derived in the form

$$D_h = \frac{dh \times nh}{1000 \times cf_h} \qquad (7)$$

where D_h refers to peak kilowatt demand for household lighting, dh is household peak demand in watts, hh is the number of households in an average village, and cf_h is the diversity factor between household demand.

The peak demand for all types of users at the village level is derived by the summation of peak demands for individual sectors, and corrected by the system's coincidence factor. Thus

$$D_v = \frac{HP \times .746 \times mi^2}{\eta_m \times cf_i} + \frac{HP \times .746}{\eta_m \times cf_p} + \frac{dh \times nh}{1000 \times cf_h} \cdot \frac{1}{cf_v} \qquad (8)$$

or simply,

$$D_v = \frac{D_i + D_p + D_h}{cf_v} \qquad (9)$$

The total energy consumption annually at the village level is simple

$$E_v = E_i + E_p + E_h \qquad (10)$$

Finally, the derivation of demand at the level of a cluster of villages is shown by

$$D_{cv} = \frac{D_v (V)}{cf_s} \qquad (11)$$

where D_{cv} refers to peak demand at the level of a cluster of villages, V is the number of villages in the cluster, and cf_s is the diversity factor between transformers or sub-stations serving the cluster.

The numerical values of demand at various levels of centralization are summarized in Tables V.1 and V.2. The derivation of peak demand at the village level is based on a diversity factor of 1.9. The cluster demand has been computed for 3 and 5 villages, based on a diversity factor of 1.3 and 1.5 respectively.

The foregoing analysis does not include power requirements for various small scale industries (besides agricultural processing activity) that may be set up in the area. We have deliberately excluded this aspect from our analysis because a full discussion of small scale industries will lead us far outside the scope of the present paper. Similarly, the power demands for social and educational purposes, like street illumination and community radio centers are also not considered. The demand for these components can, however, be easily incorporated in further stages of the enquiry. In general, during initial stages of rural electrification, power demand for social and community purposes is likely to be marginal to the total village demand. To that extent, our conclusions will not be materially affected by their exclusion.

Growth of Demand Over Time

The prospect of the growth of power demand and consumption over time needs some discussion. In this analysis we have refrained from projecting any time pattern for the growth of demand simply because the data at our disposal do not justify any such exercise. For reasons mentioned elsewhere in the paper, the margin of error in projecting growth is likely to be considerable. Hence any assumptions as to what this growth trend is likely to be is not possible. The method of relating the growth of power consumption to growth of incomes in rural areas is not only difficult to establish but also deceptive. This method can only be useful where time series are available for a fairly long period, and where some degree of correlation has been observed to exist between the two variables. However, one can describe the mechanics of growth in general and hazard a few projections by way of demonstration of the process.

Table V. 1

Estimates of Electricity Demand for Individual Villages

Sample	Irrigation			Processing			Domestic			Total Demand at Village Level			
	Connected Load (HP)	Peak Demand (KW)	Annual Consumption (KWH)	Connected Load (HP)	Peak Demand (KW)	Annual Consumption (KWH)	Connected Load (HP)	Peak Demand (KW)	Annual Consumption (KWH)	Connected Load (HP)	(KW)	Peak Demand (KW)	Annual Power Consumption (KWH)
Madras	140	115	616270	26	19	56700	34	28	49100	166	34	85	722, 170
U. P	51	42	225504	27	20	49725	20	16	29116	78	20	41	304, 345
W. Bengal	57	46	217963	16	12	11348	11	9	15196	73	9	36	244, 407

Table V. 2

Estimates of Electricity Demand for Clusters of Villages

Sample	Cluster of 3 Villages				Cluster of 5 Villages			
	Connected Load (HP)	Connected Load (KW)	Peak Demand (KW)	Annual Consump. (1000 KWH)	Connected Load (HP)	Connected Load (KW)	Peak Demand (KW)	Annual Consump. (1000 KWH)
Madras	498	102	196	2167	830	170	283	3611
U.P.	234	60	95	913	390	100	137	1522
W. Bengal	219	27	83	733	365	45	120	1222

The growth of power consumption that one can expect to follow in rural areas will not be dramatic. This may range from near stagnation to modest growth in many areas and even some deceleration in areas where population continues to migrate heavily to urban clusters. In general, the power consumption is hinged to the level of real income and its growth over time. On this count, the growth prospects do not appear to be too dramatic, because personal incomes in rural communities will not be significantly higher in the immediate future. In many countries, the growth of rural incomes has not been propitious, while high population growth and severe unemployment of resources have been reflected in rather stagnant living standards.

However, it is the essence of the electric power market to react fast to minor changes in income up to a certain point -- both by building up a solid pattern of consumption and by stimulating future demand for new uses. The existence of a "demonstration effect" in relatively undeveloped areas would seem to invite a sizable rate of growth of power consumption after the initial threshold is reached. This pattern of rising demand, however, would do little to offset the disparity between rural and urban consumers of power, because highly quickened growth can only be foreseen in urban sector. Yet, rationalization of public policies on a long term basis, which could follow from some form of planning could help to achieve a substantial rate of growth. Just what this rate would be is, again, one of the imponderables.

The inadequacy of historical data does not permit us to project the future course of growth with any measure of confidence. But just to demonstrate the mechanics of growth process, we attempt the following projection based on limited data from a ten year period from 23 electrified villages in West Pakistan.[1] Analytically, the growth of power rated capacity and consumption can be related to

a) the increase in consumption of existing consumers as a result of increases in income, changes in consumption increase in productivity demonstration effect, substitution for less efficient fuels etc, and

b) the rate of growth of new consumers.

The fact that a disparity would exist between the average consumption of existing consumers and the initial level of consumption of new consumers will introduce a certain element of complexity in the analysis.

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[1] Telecommunications Branch, PWD: Evaluation of the Presentation Report on the village Electrification Project prepared by Miner & Miner International Inc. for WAPDA, Sept. 1960, Wash., D.C. (unpublished)

But given the initial consumption and the observed or assumed rate of growth of each group of consumers, the problem can be formulated in an analytical manner. In this analysis, however, we will not attempt to derive the formula. We will merely show what the total average yearly consumption will be after discrete periods of five and ten years respectively, if the growth process follows the pattern indicated by the historical data at our disposal.

The computations that are summarized in Table V. 3 show the growth of KWH consumption respectively for the 5th and 10th year after electrification. The installed capacity and peak demand will undoubtedly grow with a rising annual consumption, but we refrain from making any assumptions in this regard. In the initial period, however, there is likely to be a certain amount of excess capacity in users equipment which will be utilized more fully over future years, so that the effect on peak demand can be ignored in the first approximation.

Table V. 3
Illustrative Projections of Power Consumption for Sample Areas[1]

Sample	First year KWH/year (000)	Fifth year KWH/year (000)	% Growth over 5 years	Tenth year KWH/year (000)	% Growth over 10 years
Madras	722	1,710	136	2,557	50
U.P.	304	720	"	1,077	"
W. Bengal	244	578	"	866	"

[1] Average population per village for the first year is as follows: Madras - 3,800; U.P. - 2,762; and W. Bengal - 1,735.

APPENDIX A

Description of Sample Areas

Madras sample

The sample consists of 32 villages in the districts of Coimbatore and Salem. Salem district lies between 11° and 12° 55' of the northern latitude and 77° 28' and 78° 50' of the eastern longitude. The Coimbatore district is situated 10° 12' and 12° 20' of the northern latitude and 76° 56' of eastern longitude. The average elevation ranges from 1200 feet to 3000 feet above sea level.

The weather is generally dry from January to March. The months of April and May are very hot, the temperature rising to 97° to 98°. June to September is the period of extensive rains from the southwest monsoons. The mean annual temperature for the two districts is as follows:

	Maximum	Minimum
Salem	93.3	73.0
Coimbatore	89.2	71.3

The annual rainfall ranges between 35 to 45 inches. Because of uncertainty of rainfall, the area is liable to long droughts and frequent scarcit conditions.

The soil of the area may be broadly classified into red and black soils. The red soils that are widely prevalent may be further classified into red loam and red sand, according to their texture. Similarly, the black soils are found in three classes depending on their texture and composition, namely, clayey, loamy and sandy. The surface soil in the area is thin and the sub-soil consists of raw and semi-decomposed rock. The soils are very well drained because of adequate natural draining facilities.

The principal sources of irrigation are wells, rivers, and tanks. The following table shows the relative importance of various sources:

Canals	12.1%
Tanks	9.5%
Wells	75.4%
Others	3.0%

The land utilization pattern in the sample villages is as follows:

Number of villages	40
Total area in square miles	202.01
Cultivated area in acres	75.748
Percentage of cultivated area to total geographic area	58.4%
Proportion of area irrigated to cropped area	17.9%

Out of the area under crops, a large proportion amounting to about 75% is devoted to raising of food crops. The major food crops are paddy and cereals (cholam, cumbu, ragi, etc.). Non-food crops consist of oil-seeds and cotton to a large extent and tobacco to a small extent. The relative percentages of different crops to the total cropped area are:

Paddy	3.9
Cholam	22.2
Cotton	6.3
Ragi	7.8
Groundnut	6.1
Cumbu	23.3
Others	30.4

The periods of sowing and harvesting of different crops are as follows:

Crop	Season	Sowing	Harvesting
Paddy	1st crop	May-June	Aug-Sept
	2nd crop	Aug-Sept	Dec-Jan
	3rd crop	Dec-Jan	Mar-Apr
Cholam	1st crop	May-June	Aug-Sept
	2nd crop	Aug-Sept	Dec-Jan
	3rd crop	Oct-Nov	Mar-Apr
Cotton		Sept-Oct	Mar-June

Crop	Season	Sowing	Harvesting
Ragi	1st crop	May-June	Aug-Sept
	2nd crop	Dec-Jan	Mar-Apr
Groundnut		Jul-Aug	Nov-Dec
Tobacco		Oct-Nov	Feb-Mar
Sugarcane		Feb-Apr	Mar-Apr

U.P. Sample

The investigation relates to two contiguous districts in western U.P. -- Meerut and Muzaffarnager. The area is surrounded by River Ganges and Yamuna. The land of the region is level, alluvial plain. The drainage is from north to south, the slope being very gradual throughout. The entire area covered by the two districts, except for small tracts under "khadar" (bushy shrubs) is very fertile. The soil is fine loam with proper tillage and manuring.

The average rainfall during 1949-1953 was 34.74" and 29.74" in Meerut and Muzaffarnagar districts respectively. Of the total rainfall, about 85% occurs between April 1 and October 31st and about 10% between December and February. Winter rainfall is generally adequate and regular, though at times it is deficient in October and November, when it is critically needed for sowing and germination of winter crops. On the whole, the rainfall in the region is fairly precarious. The region, therefore, largely depends on irrigation through artificial means.

The normal mean temperature of the region is about 76.75°, January being the coldest month with a mean temperature of 57°, and May and June the hottest months with a mean of about 90.5°.

The chief means of irrigation in the area are:

	Percentage Share
Government Canals	51.66%
Tubewells	14.30%
Masonry Wells	23.40%
Private Canals	0.07%
Tanks	0.10%
Others	0.47%

The irrigated area forms 65.4% of the net cultivated area in Meerut and 56.29% in Musaffarnagar, the percentage for the region as a whole being 61.88%.

The land utilization statistics for the region show that net area sown is 76.54% of the total geographical area. The area under forests, pastures and fallow land is negligible. The proportion of cultivable waste other than fallow is 5.33%.

The distribution of cultivated area under different crops shows that sugarcane, wheat, gram, maize and fodder are the major crops grown in the area. More than 1/4 of the gross cropped area is under wheat. The next highest percentage area is claimed by fodder crops (17.75%). Sugarcane accounts for nearly 15% of the gross cropped area. The double cropped area forms 33.75% of the net sown area. Paddy is a relatively unimportant crop and accounts for only 4.6% gross cropped area.

The use of artificial irrigation is fairly extensive. Nearly 91% of the area under sugarcane is irrigated. Nearly 75% of the area under wheat is grown with artificial irrigation, and about 79% of area under cotton is an irrigated one, although it is a rainy season crop.

The sowing and harvesting periods for various crops that are fairly homogeneous for the region as a whole are given below:

	Crop	Sowing	Harvesting
Khrif	Sugarcane	Feb-Apr	Nov-May
	Cotton	2nd wk. May to 2nd wk. June	1st wk. Sept. to 2nd wk. Nov.
	Maize	Middle of June to end of July	Middle of Sept. to middle of Oct.
	Juar	Middle of May to middle of July	1st wk. of July to 2nd wk. of Sept.
	Paddy (early)	Middle of May to middle of June	Middle of Sept. to 2nd wk. of Oct.
	Paddy (late)	End of June to end of July	2nd wk. of Oct. to end of Nov.

	Crop	Sowing	Harvesting
Rabi	Wheat	Middle of Oct. to middle of Nov.	April
	Barley	Middle of Oct. to middle of Nov.	April
	Gram	2nd wk. of Sept. to 2nd wk. of Oct.	3rd wk. of March to 1st wk. of April
	Pea	End of Oct. to end of Nov.	March

Water application practices

Sugarcane: The number of irrigation application varies between 4 to 6 applications of 6" depth each.

Wheat: Two or three water applications of 4" depth each.

Gram: Usually requires no irrigation but one application of 3" depth is frequently given in January.

Paddy: The cultivation of paddy is done generally in the low-lying areas of the region which receive relatively a higher amount of rainfall. The number of applications varies from 2 to 3 of 5" depth in years of normal rainfall, but may go up to 5 or 6 in dry years.

Maize: Generally no irrigation is given but in very dry years 2 or 3 applications of 4" may be necessary.

Cotton: Cotton needs irrigation before ploughing is done in early June. After that 2 or 3 irrigations may be necessary.

West Bengal

The sample consists of two districts in West Bengal, namely, Hoggly and 24 Parganas. They are located on the southwestern part of the Presidency Division of West Bengal and lie between 21° 31' and 89° 6' east longitude. The topography of the area is more or less flat with characteristics common to deltaic lands. The climate is hot and moist with high percentages of humidity during the greater part of the year. The mean maximum temperature for the region is 83.4° while the mean minimum temperature is 56.1°. The average rainfall for six years from 1949 to 1954 is 60.1 inches for

Hoogly and 60.3 inches for 24 Parganas. In normal years the amount of rainfall is sufficient for the production of various crops grown in the region. Perhaps this explains the lack of irrigation facilities in the area.

The soils of the sample area can be classified into 3 classes: Loamy, sandy and clayey. The variation in the type of soil for the region is quite considerable, while the clayey and loamy types are generally prevalent, being 45.4 and 30.3 per cent respectively.

The proportion of irrigated land in 1950 was 13.8% of total cropped area in Hoggly and 2.4% in 24 Parganas. The main sources of irrigation are canals, tanks, wells, and ditches. Their relative importance in the area is:

Government	5.12%
Private Canals	30.00%
Tank	44.00%
Wells	00.50%
Others	25.00%

The land utilization pattern differs from district to district, but on an average 65% of the area is under cultivation.

Paddy is the most important crop in the region. Of the three varieties of paddy--ans, aman and boro--aman or winter paddy is the most extensive. Besides paddy, other food crops such as wheat, barley, potato and oilseeds are also grown in the area, but their importance in the economy of the region is almost insignificant. Among the cash crops, jute and tobacco are grown, of which jute is by far the most important. The percentage area under various crops is as follows:

Crop	% of cropped area
Paddy	75
Jute	12
Pulses	7
Oilseeds	3
Sugarcane	1
Tobacco	1
Wheat	3

The normal sowing and harvesting seasons for the crops grown in the sample villages are as follows:

Crop	Sowing	Harvesting
Paddy		
Ans	May and June	September and October
Aman	July and August	October-December
Jute	May and June	September and October
Sugarcane	March and April	February and March
Pulses	October and November	January and February

APPENDIX B

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