APPROPRIATE TECHNOLOGY FOR AGRICULTURAL DEVELOPMENT

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NE/TECH

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INTRODUCTION

There has been much written on the topic of appropriate technology for LDC agriculture. The material ranges from advocacy of continued dependence on traditional technologies to proposals for rapid change to modern technologies. Some of the literature might be categorized as engineering writers proposing some improvement in performance which is often enough opposed by other literature written by the social scientist arguing against a change of technology on the grounds of the social problems that will be created. These stereotypes neglect the serious thought that engineers have given to the social problems as well as they neglect the serious concern that many social scientists have expressed with economic growth prospects in the absence of technological innovation.

The A.I.D. Occasional Paper on agricultural mechanization prepared by the Economics and Sector Planning Division of the Technical Assistance Bureau is a careful review of the literature.1/ It concludes that "increases in agricultural production will require increases in agricultural power and better utilization of available energy sources...The mechanization of agriculture is a continuous and inevitable process in economic development but one whose speed and direction can be altered by public policies and programs. There is no single indicator as to whether or not a particular machine is appropriate for a nation...Agricultural mechanization should be viewed as a part of modern agricultural production systems. Combined with new biological and chemical technologies...mechanization may enable more precise timing of operations and applications of chemical inputs so that the total biological, chemical and mechanical package results in an increase in output per acre with little, if any, reduction in total employment."

The USDA Foreign Agricultural Economic Report No. 27 titled "Changes in Agriculture in 26 Developing Nations" compiles the data in respect to agricultural workers, land productivity, machinery, fertilizer and improved varieties for several representative countries. (Table 1) The relevant point is that high productivity is a product of the mix of inputs used in the production process and in fact apparently requires

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1/ William C. Merrill, "The Impact of Agricultural Mechanization on Employment and Food Production", Occasional Paper No. 1, TA/AGR/ESP, 1975.

Table 1

Relation Between Agricultural Productivity, Labor Force, and Tractor Population in Selected Developing Countries

Country	Agr. Workers Per 100 Ha. (Arable)	Agr. Output Per Ha. (Arable)	Tractors Per 1000 Ha. Large	Tractors Per 1000 Ha. Small	Fert. Per Ha. Kg.	Improved Varieties % of Area
Japan	250.0	961	1.55	232.82	270.1	100
Egypt	166.7	643	4.28	NA	109.8	35
Taiwan	166.7	477	0.56	NA	190.0	95
Philippines	83.3	139	0.60	NA	9.0	NA
Pakistan	83.3	133	0.15	NA	5.7	5
India	83.3	91	0.21	NA	3.3	37
Israel	33.3	557	19.24	NA	85.2	NA
Mexico	24.4	110	1.96	NA	NA	98

Source: Changes in Agriculture in 26 Developing Countries -- Foreign Agriculture Economic Report No. 27-ERS, USDA

very high levels of all inputs including both agricultural workers and tractors; notably the case of Japan, but also significantly the case of Egypt. Of course it is apparent from the information for Israel and Mexico that tractors can provide power where the labor force is low. These data illustrate that input per unit of land is not necessarily reduced as a result of increased farm mechanization and that high productivity requires use of fertilizer and high yielding varieties as well as machinery.

Taking the position that mechanization is desirable and not inherently detrimental to labor, the question becomes how much machinery should be introduced. There is no simple means of quantifying the amount of machinery although total investment or total horsepower are commonly used for such measurements. These measurements however can be misleading where farmers have overinvested and are utilizing only part of the installed capacity. Of the two measures the use of installed horsepower seems to be the best indicator of level of mechanization and is used widely for cross comparison between countries and for time series analysis.

Giles compared horsepower per hectare and production per hectare for a number of countries and at two points in time as a means of considering the question of how much mechanization was appropriate 1/ (See Figure 1). Giles did not define production as a dependent variable with respect to power, but proposed that there is an interrelationship as noted in the subtitle of the figure. The tendency of this plot of data to follow the characteristic production function suggests that mechanization is an important input.

These studies and other provide some evidence that the strong interest of LDC's in acquiring farm machinery is responsive to an economic "felt need". Most of the LDC's have utilized IBRD, bilateral aid, or other foreign exchange resources to facilitate tractor and implement imports. In spite of the fact that tractor import programs have serious negative socio-economic effects they continue to enjoy an adequate base of support for sustaining a moderate level in a number of countries. Thus far there has been very little effort given to introducing intermediate technology which would simultaneously

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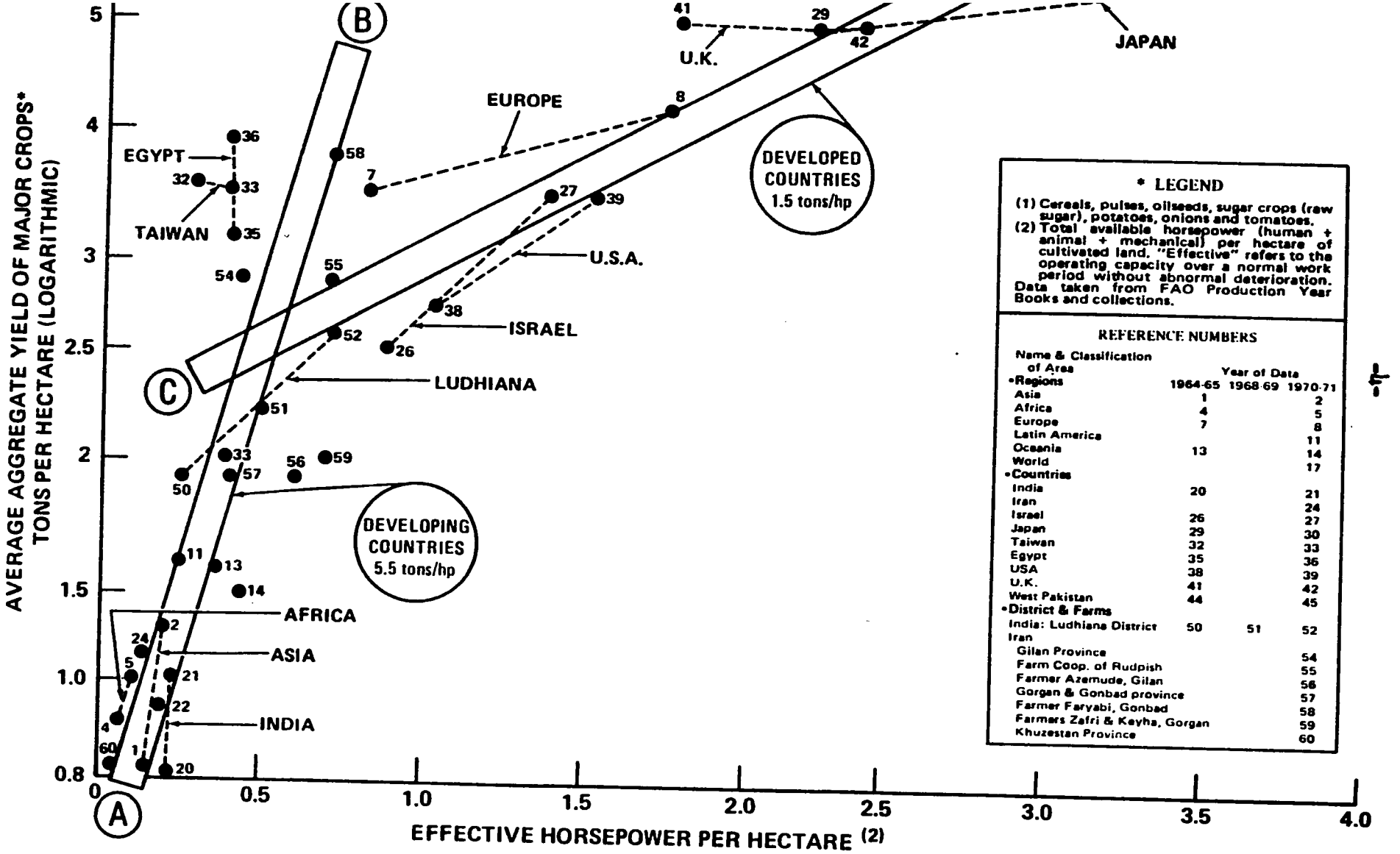
1/ G. W. Giles, "The Reorientation of Agricultural Mechanization for the Developing Countries," Agricultural Mechanization in Asia, Japan, 1975.



*** LEGEND**

(1) Cereals, pulses, oilseeds, sugar crops (raw sugar), potatoes, onions and tomatoes.
(2) Total available horsepower (human + animal + mechanical) per hectare of cultivated land. "Effective" refers to the operating capacity over a normal work period without abnormal deterioration.
Data taken from FAO Production Year Books and collections.

REFERENCE NUMBERS

Name & Classification of Area	Year of Data 1964-65	1968-69	1970-71
•Regions			
Asia	1		2
Africa	4		5
Europe	7		8
Latin America			11
Oceania	13		14
World			17
•Countries			
India	20		21
Iran			24
Israel	26		27
Japan	29		30
Taiwan	32		33
Egypt	35		36
USA	38		39
U.K.	41		42
West Pakistan	44		45
•District & Farms			
India: Ludhiana District	50	51	52
Iran			
Gilan Province			54
Farm Coop. of Rudpish			55
Farmer Azemude, Gilan			56
Gorgan & Gonbad province			57
Farmer Faryabi, Gonbad			58
Farmers Zafri & Keyha, Gorgan			59
Khuzestan Province			60

Source: G.W. Giles, "The Reorientation of Agricultural Mechanization for the Developing Countries"; Agricultural Mechanization in Asia, Shin-Norinsha Co., Tokyo, Japan; 1975.

maximize the response to the "felt needs" for tractors and minimize the detrimental socio-economic effects. A few notable efforts in this direction have pioneered this technology. These include:

(1) The Iron-Buffalo Project of the Irrigation Department in Thailand.
(2) The Small Tractor Evaluation Project in India.
(3) The Power Tiller Project of the International Rice Research Institute.
(4) Farming Systems studies of the international centers.

A review of official development plan documents and policy statements at political and administrative levels of LDC governments reveals that agricultural mechanization is a "No Man's Land" insofar as policy formulation is concerned. Occasionally one of these documents will briefly mention some farm mechanization program and related developmental objectives but these statements are commonly phrased in such generalities as to perpetuate the status quo rather than to improve the quality of development. There are some agricultural engineering programs in the new agricultural universities, there are some indigenous tractor manufacturing projects, a few animal implement development projects and a very few power tiller projects. Yet in spite of the ill-defined policy and no official program of support there are some items of agricultural machinery which are being developed and produced in numbers, notably irrigation pumps, threshers, flour mills, and small rice mills. One can conclude that there is both a latent demand and a latent adoption capability for certain machinery but the conversion of these latent characteristics to real and dynamic processes of agriculture development is frustrated by conflicting goals, inconsistent support and inadequate infrastructure.

Throughout the record of development of the last twenty years one can find numerous innovations of simple tools which have been attempted in a variety of contexts. Indeed it seems quite unlikely that one can name an improved agricultural tool which has not been tried some place at some time in an LDC. Many of these innovations have been miniscule in effort, that is a few animal-drawn plows provided to a few farmers, perhaps a thousand power tillers imported from Japan, an implement workshop provided under bilateral aid, etc. These efforts generally have advanced the state of knowledge about the performance of the various tools, yet most of these projects have not gotten beyond the

research phase. The Michigan State University study "Agricultural Mechanization in Equatorial Africa" documents both the extensiveness of such innovations and the limited impact that has resulted from these trials and experiments.1/ Other evidence of past efforts are discussed in the FAO Bulletin No. 67 titled "Farm Implements for Arid and Tropical Regions" and the CENTO Bulletin "Farm Tools and Implements". In other words, the evidence suggests that the LDC world is not readily able to "Beat a Path to the Door of the Inventor of a Better Mousetrap." The reason for minimal technological evolution appears to be an "inhospitable environment" rather than a missing ingredient.

In summary, the experience in innovation of mechanical equipment for agriculture demonstrates that it is indeed a complex task. There is too little known about the process and considerable difference of opinion about means and objectives. Any attempt to establish a new concept of appropriate technology must start from a fundamental analysis of the target group and potential beneficiaries in LDC agriculture, must include an analysis of alternative innovations and support systems, and then formulate comprehensive interventions which are fully compatible with available means and desired objectives.

1/ C. K. Kline, et al; "Agricultural Mechanization in Equatorial Africa", Michigan State University, 1969.

Spectrum of Farm Enterprises

Spectrum of Sizes

The statistical data of most nations, including LDC's, provides some description of the distribution in sizes of the farm enterprises of the country. These reports are not standardized and are not always current, but the data displays a wide range in farm sizes. Of course, land area is only one dimension of farm size. A piece of good quality, irrigated land may have 2-10 times the productivity of the rainfed and rough land that is being cultivated. There are also small-size farms that utilize purchased feed for livestock production as a means of increasing the total production of the enterprise. However irrigated land is approximately 20% of total cultivated farmland and livestock enterprises are relatively few in LDC's. Thus, while farm land area is only an approximate indication of farm size it is used in this study as an analytical proxy for size and for income potential of the farmer.

The data for Jordan illustrates the typical distribution of farm sizes (Table 2). Jordan has both irrigated, deep soils and very sandy, rainfed soils therefore representing a broad cross section of LDC conditions. Bangladesh with higher population density and extensive rice cultivation has a larger proportion of the total area in smaller farms. While some areas of Africa and Latin America with low population density and rainfed, poor soils have a higher percentage of larger farms.

Within the concepts of development held in the 1950's and early 60's it was expected that an increase in farm size would result from an economic advantage of the relatively larger units. The slow growth of off-farm employment opportunities plus the tremendous population pressure have been more than adequate to offset any economic forces toward larger farm size in most of the LDC's. A popular theme in today's development literature is "land reform" which would reduce the size of the larger farms however the political constraints on these programs have also proven to be formidable. Taking all things into consideration existing distribution of farm sizes is expected to continue for some time.

The continued predominance of small farms, however, is not a crucial constraint to technological innovation. An IRRI study pursued quite thoroughly the factor of size in relation to yield for the modern

Table 2

Farm Size Distribution for Hashemite Kingdom of Jordan

Farm Operating Units - 93,500

Farming Area - 1.24 million acres
(Includes West Bank of Jordan Valley)

Farm Size (Acres)	Farms (%)	Area (%)
Less than 2.5	36.4	3.4
2.5 - 12.5	35	16.4
12.5 - 50	24	40
More than 50	5	40

Source: Richard F. Nyrop; "Area Handbook for the Hashemite Kingdom of Jordan", U.S. Government Printing Office, 1974.

varieties after which they concluded that their observations followed, "no consistent pattern among villages." "Many factors influence yield, and these factors may be positively or negatively related to farm size." 1/ A study of Indian farmers concluded that there was relatively little difference in adoption of technology among progressive farmers whether large land owners or small holders. 2/ Among the less-progressive farmers there was some tendency for smaller farmers to be more conservative, but there was no evidence that they were unable to use improved technology. In a further study of the small farmer group the Indian research team found the mid-range of small farmers to have the highest production in terms of yield per hectare and were the most efficient producers in terms of all resources used. 3/

A number of countries have experimented with arrangements for small farmers to hire or rent the use of tractors and equipment. The FAO Bulletin No. 85 "Multi-Farm Use of Agricultural Machinery" laid out quite complete guidance for establishing such a service facility. Few tractor and equipment hiring services have endured very long for a variety of reasons. The more successful hiring operations were found in Thailand and Malaysia where private operators developed a thriving business activity in the late 1960's. Chancellor and a team of investigators surveyed both tractor owners and users of this service and found these operations of questionable viability. 4/ The services were suited to very small farmers, but the returns to the capital invested were not adequate to cover depreciation or provide for further expansion. Chancellor noted that Malaysian farmers were purchasing two-wheel tractors instead of continuing to use the more economically efficient tractor hire service. The evidence indicated that the tractor hire service was a useful phase in mechanization, but only for a limited period as farmers gained familiarity with the machines. Farmers strongly desire private ownership and management of equipment and are willing to use somewhat less economical units in order to gain advantages from independent farm operation.

1/ _____, "Changes in Rice Farming in Selected Areas of Asia," International Rice Research Institute, 1975.p. 37.

2/ _____, "Changing Agriculture and Rural Life in a Region of Northern India," U.P. Agricultural University, 1969.

3/ _____, "Problems and Prospects of Small Farmers in Two Regions of Uttar Pradesh in 1969-70," U.P. Agricultural University, Dec. 1971.

4/ W. J. Chancellor, "Mechanization of Small Farms in Thailand and Malaysia by Tractor Hire Services," American Society of Agricultural Engineers, 1970.

Technological Differentiation

The statistical information for other descriptive features of LDC agriculture is less precise than for farm size. However for purposes of coming to grips with the identification of appropriate technology it is essential to investigate insofar as possible all differentiating factors for the farm enterprises in the developing countries.

1. Accessibility to Inputs and Markets

The LDC's have some roads and a limited market economy therefore some farmers have accessibility to the market place. But we also know that the road systems are poor and do not serve some farmers. We also know that some technologies are more dependent on the market place. Therefore one could in theory draw concentric circles around the existing market places which describe the boundaries of territories within which different kinds of technologies are appropriate. It is often found that a larger farmer is able to travel somewhat farther to the market place, but very little is known about the trade-off between size and mobility in relation to market access. One may also find that the distribution of farm sizes may be somewhat affected by proximity to the market place or geographic features; that is, there are a large number of very small vegetable tracts near many major cities, and the poorer quality land is often provided relatively few roads.

Analytical tools are being developed which can play a role in describing market access. At the theoretical level E.A.J. Johnson has attacked the problem 1/ and at the agricultural planning level A. T. Mosher has provided a helpful perspective. 2/ An illustration of the gradient of market accessibility is provided in Table 3.

1/ E. A. J. Johnson, "The Organization of Space in Developing Countries", Harvard University Press, 1970.

2/ A. T. Mosher, "Creating a Progressive Rural Structure" The Agricultural Development Council, 1969.

Table 3

Distance from any Market of Kanpur Region Villages[1/]

Distance	Percent of Village	
1 mile or less	19.2%	
1-3 miles	21.9	
3-5 miles	16.9	
Sub-Total		57.8%
5-10 miles	24.3	
10 miles and more	17.9	
Sub-Total		42.2%
Total		100.0%

In this case, of the 11,000 Kanpur region villages 4,600 now have no road connection of any kind. To design a technology for villages with no road connection would provide an appropriate technology for only 40% of the population.

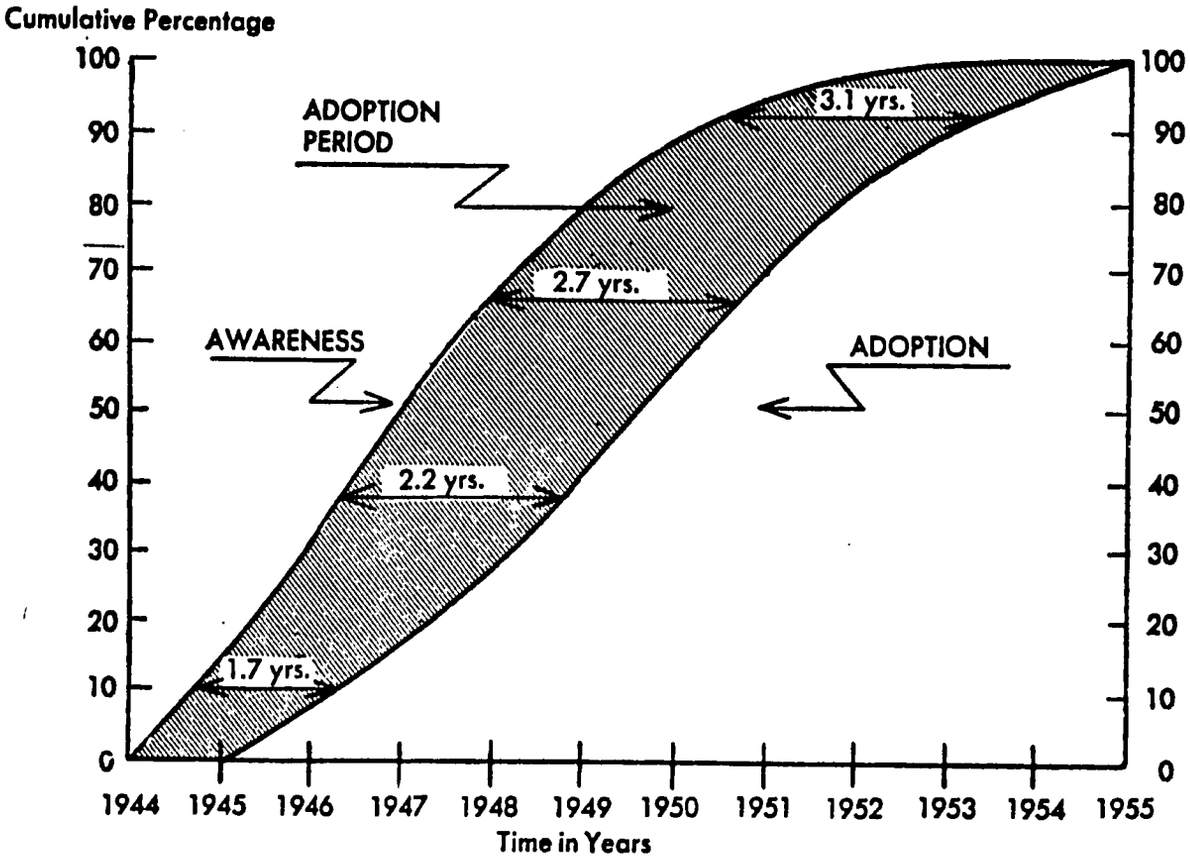
2. Management Capability and Attitude

The relatively well developed U.S. extension service can introduce technology so as to reach only 10% of the farmers in a year (Figure 2). From this case it is notable that few, if any, farmers adopt a new practice the first year and the 30% level of adoption takes four years while the 100% adoption requires more than ten years.

1/ Johnson; page 194.

FIGURE 2.

ADOPTION PERIOD FOR IOWA FARMERS ADOPTING 2,4-D WEED SPRAY BY YEAR



The shaded area in this figure illustrates the aggregate adoption period between awareness and adoption of 2,4-D weed spray. Awareness proceeds at a more rapid rate than does adoption. This suggests that relatively later adopters have a longer average adoption period than do earlier adopters. For example, there are 1.7 years between 10 per cent awareness and 10 per cent adoption, but 3.1 years between 92 per cent awareness and 92 per cent adoption.

Source: A reanalysis of data originally gathered by Beal and Rogers (1960, p. 8). Used by permission.

In a study of Indian farmer response to new technology it is reported that in five years the use of chemical fertilizer increased from 50% to 98% of all progressive farmers, the use of HYV seed increased from 10% to 97% of the progressive farmers and the use of machinery increased from 19% to 33% of the progressive farmers.1/ Among "less progressive farmers" the use of fertilizer increased from 24% to 70% of the group, the use of HYV seed increased from 2% to 49% and the use of machinery increased from 8% to 11% of the farmers over the five year observation period. The definition of "progressive" or "less progressive" as used in this study was independent of size of farm operation. These studies confirm the existance of considerable difference among LDC farmers in their response to different types of technology.

Dalrymple's study of the impact of the Green Revolution technology provides further insight into the adoption process for LDC agriculture. 2/ Some LDC's react quite promptly; i.e., Pakistan and India for wheat, Pakistan and Philippines for rice (Figure 3). It is interesting to note that the area of HYV's seems to have leveled out at 50-60% of total area suggesting that HYV's are not yet available for all agro-climatic conditions. The figure also illustrates that the rate of adoption is much slower in some countries, perhaps reflecting a less effective extension service, conservatism of farmers, poor market incentives or some other factor.

Education is simply acknowledged here as another factor that has a significant effect on farmers adoption of technology and a factor that is not uniformly possessed by all farmers. There are also differences in cultural sanctions upon departures from tradition, yet here again there are significant differences among the farm population in their individual practice of cultural, social or other custom.

3. Effects of Agro-Climatic Factors

A zone map for the U.S. Midwest as prepared by a seed company for purposes of recommending the right seeds to farmer customers and illustrates another differentiating factor of technology (Figure 4). The basis for these zones is average weather and the known soil and topography of the region. This type of map reflects years of

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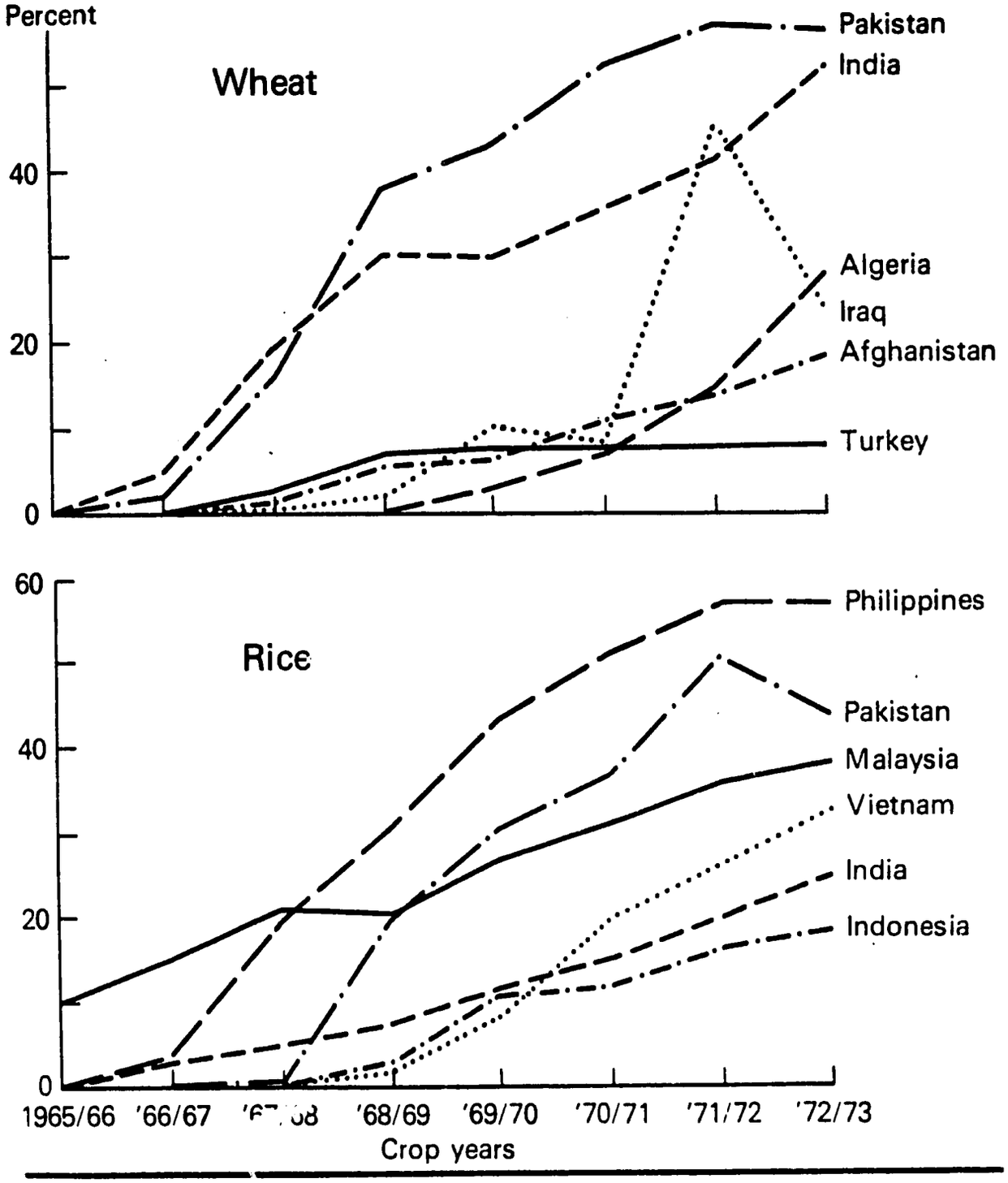
1/ _____, "Changing Agriculture and Rural Life in a Region of Northern India", U.P. Agricultural University, 1969.

2/ Dana G. Dalrymple, Measuring the Green Revolution: The Impact of Research on Wheat and Rice Production, Economic Research Service, USDA, 1975.

FIGURE 3

Proportion of total area planted to high-yielding varieties



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experience. By and large the agro-climatic information of the LDC's is insufficiently developed to draw similar maps for these countries.

The matter of evaluating technology is further complicated by seasonal variations in weather. The rainfall data for Ankara, Turkey is provided to illustrate the variation and interdependence of annual rainfall, the monthly rainfall and also the resultant crop yields (Table 4). The farmers, particularly those without irrigation, understand quite well their dependence on the weather and are inclined to reserve judgement on new technology until they have seen the performance in several years, including a poor year. This type of reserved judgement is too easily confused with a traditional outlook or mistaken for the farmers polite rejection of the technology.

Agricultural Diversity Requires a Range of Technology

The existence of agricultural enterprise diversity is included within the generic terminology used to describe various types of farms that combine to make up the agriculture sector. There may be plantations, family farms and part-time farmers as one example of classification. There are also livestock enterprises, cash crop enterprises, or mixed farming enterprises. In spite of this common recognition of differences in types of farming there has been a tendency to think of the small farmers in the LDC's as a large number of essentially similar units. The problem is to use factors of differentiation in a system for categorizing small farms and defining their best production technology.

1. The Differentiation in Management of Farm Enterprises

Barraclough's study of the Agrarian Structure of Latin America describes three categories of farmers in relation to their selection and utilization of technology. 1/ The Barraclough categories are:

(1) Sub-family: Farm size is not adequate to support a family and the enterprise is managed for marginal supplementary income.

(2) Family: Farm size is sufficient to provide a family

1/ Solen Barraclough, "Agrarian Structure in Latin America", Lexington Books, 1973.

FIGURE 4

ZONE MAP

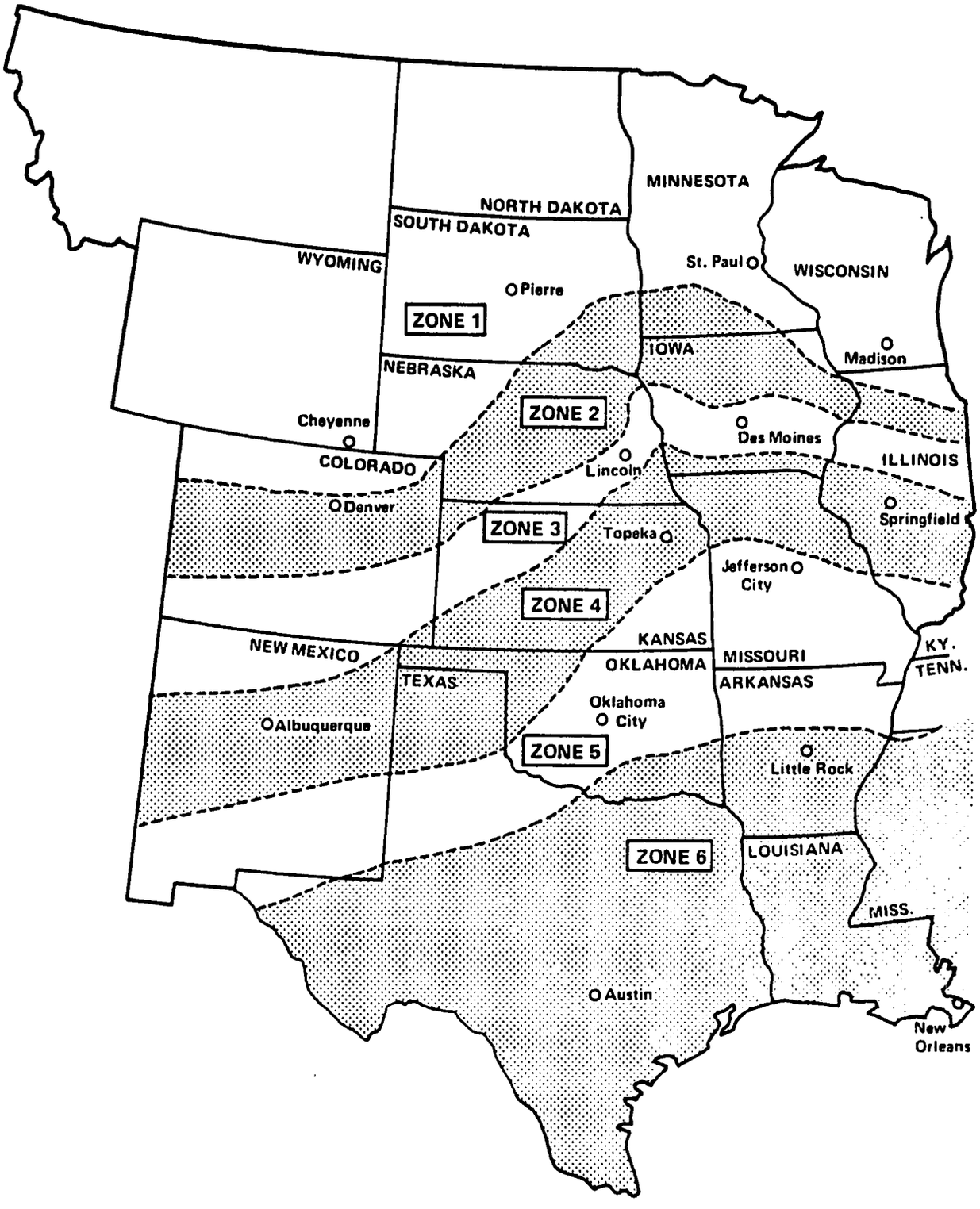


Table 4

PRECIPITATION IN ANKARA
(in mm.)

Years	Annual Precipitation September to August	October	November	April	May	June	Wheat Yield Kg./Ha.
1959-60	327.9	17.8	35.4	48.8	27.5	42.5	1,064
1960-61	365.3	31.7	22.2	11.0	33.0	121.9	720
1961-62	400.0	26.7	5.6	20.4	25.7	9.5	841
1962-63	656.1	30.3	9.6	82.5	121.5	22.9	1,375
1963-64	392.6	28.4	10.6	14.2	40.1	58.2	1,059
1964-65	410.4	-	41.0	47.2	62.4	14.6	1,097
1965-66	380.7	10.4	41.3	49.2	64.1	16.8	1,278
1966-67	358.6	7.7	19.2	82.7	53.8	11.1	1,502
1967-68	438.8	10.9	30.6	49.6	40.7	64.8	1,216

an average standard of living and the farmer attempts to increase farm productivity.

(3) Multi-family: Management is designed for profit maximization and selection of technology may be modern and for export markets.

These farming units were studied in some detail and Barraclough's summary report is an interesting analysis of performance and efficiency of LDC agriculture. The data for Columbia is illustrative. (See Table 5 and 6). After omission of the plantation sub-sector there remains a differentiation among the small farms in selection of technology and its management which has similarity with the farm enterprises of other LDC's. One is struck by the relatively high land use efficiency of the family farm enterprise which produces some 45% of total production from 25% of the land area. Another factor which stands out in this display is the tremendous difference in labor productivity among these enterprises.

Table 5

Farm Size Distribution for Columbia

Form of Management	Total Families (%)	Land (%)
Large Multi Family	1.1	44.5
Med. Multi Family	4.0	25.1
Family	26.3	24.5
Sub. Family	55.8	5.5
Administrative and Landless	12.8	

Source: Barraclough p. 177

Table 6

Farm Performance in Columbia

Form of Management	% of Total Agr. Land	% of Total Work Force	Production	Relative Value Per Ha. Agr. Land	(Sub-Family at 100%) Per Ha. Cultivated Land	Per Worker
Large Multi-Family	45	4	15	7	80	995
Medium Multi-Family	25	7	19	19	84	753
Family	25	41	45	47	90	418
Sub-Family	5	58	21	100	100	100

Source: Barraclough p. 26

2. The Differentiation in Farm Power and Equipment Practices

Balis' investigations of farm mechanization in India included farm size as a factor in the selection and use of equipment. The small number of tractors and their brief history of use in India and other LDC's make it difficult to precisely establish the optimum size range for alternative sources of tillage power, yet the field reports are remarkably consistent and comparable among countries. There is a general tendency for the optimum size of rice farms to be 15-30% smaller in size for any given power unit, while dryland or rainfed farms are perhaps 15-50% larger than the composite farm size distribution of Table 7. The two groups designated as small tractor farms are presently served by 2-6 bullock pairs.

From the above presentation it is apparent that each of these farm power technologies is of essentially equal importance in terms of agricultural production potential because the land area under command of each farm size group is approximately the same. Note also that the potential market for the small-scale technology is sufficiently large to justify several factories. This market size could allow for even further specialization in design. If we think in terms of a ten-year life for farm machinery and acceptable factory annual production levels of 5-10,000 units per year per factory, India could eventually have 100 bullock implement factories and 85 small tractor factories. The unfortunate fact is that a large amount of effort has been invested in the debate of bullock vs. tractor power rather than formulation of a strategy to provide both kinds of units according to the particular advantage of the various farm enterprises.

Up to this point we have found that size of enterprise may be of major significance in selection of technology and the range of sizes even in the LDC's is of such breadth as to require several technologies. There are additional factors of diversity such as access to markets, farm management objectives, agro-climatic potential. There is no alternative to thinking in terms of many technologies with this complexity of the agriculture sector. The following sections deal with the trends in agricultural production, the apparent bottlenecks that are developing in the agricultural production enterprises, the external constraints on technological innovation and the resultant implications in identification of appropriate technology.

Table 7

ALL-INDIA FARM POWER SPECTRUM

Farm Size (Acres)	Power Source	Farms Number (thousands)	Farms Percent	Area (percent)
0 - 5	Hired	31,076	62.3	19.0
5 - 10	Bullocks	9,646	19.3	20.3
10 - 25	Small Tractors	6,843	13.7	30.8
25 - 50	Small Tractors	1,795	3.6	17.9
50+	Large Tractors	514	1.0	11.8

Source: John S. Balis, The Utilization of Small Tractors in Integrated Agricultural Development, Cornell Agricultural Economics Staff Paper, 1974.

The Green Revolution Technology Trend

There is no question that the "Green Revolution" has had a major impact and is continuing to permeate the agriculture of the LDC's (Figure 3). The Green Revolution is more than the Mexican Wheat and IRRI Rice for those are simply features of new agriculture. Agricultural Scientists are now investing heavily in research for technologies capable of significant yield increases for other crops and they anticipate that LDC farmers are capable of considerable judgement in handling more complex technology. In order to use an expanding technology it will be necessary to better understand the demands placed upon the production and supporting systems.

Seasonal Work Patterns and Multiple Cropping

Farming has always been seasonal work and farmers chose management practices which optimize the seasons of work in terms of availble resources. Many farmers do not plant all of their land in the crops of highest return simply because they cannot handle the work load. For a number of operations there is a ten-day period that enables maximum production and delay may mean a loss in production of 5% for each day of delay outside that period. Some of the HYV technology has been found to be more sensitive, than traditional varieties.

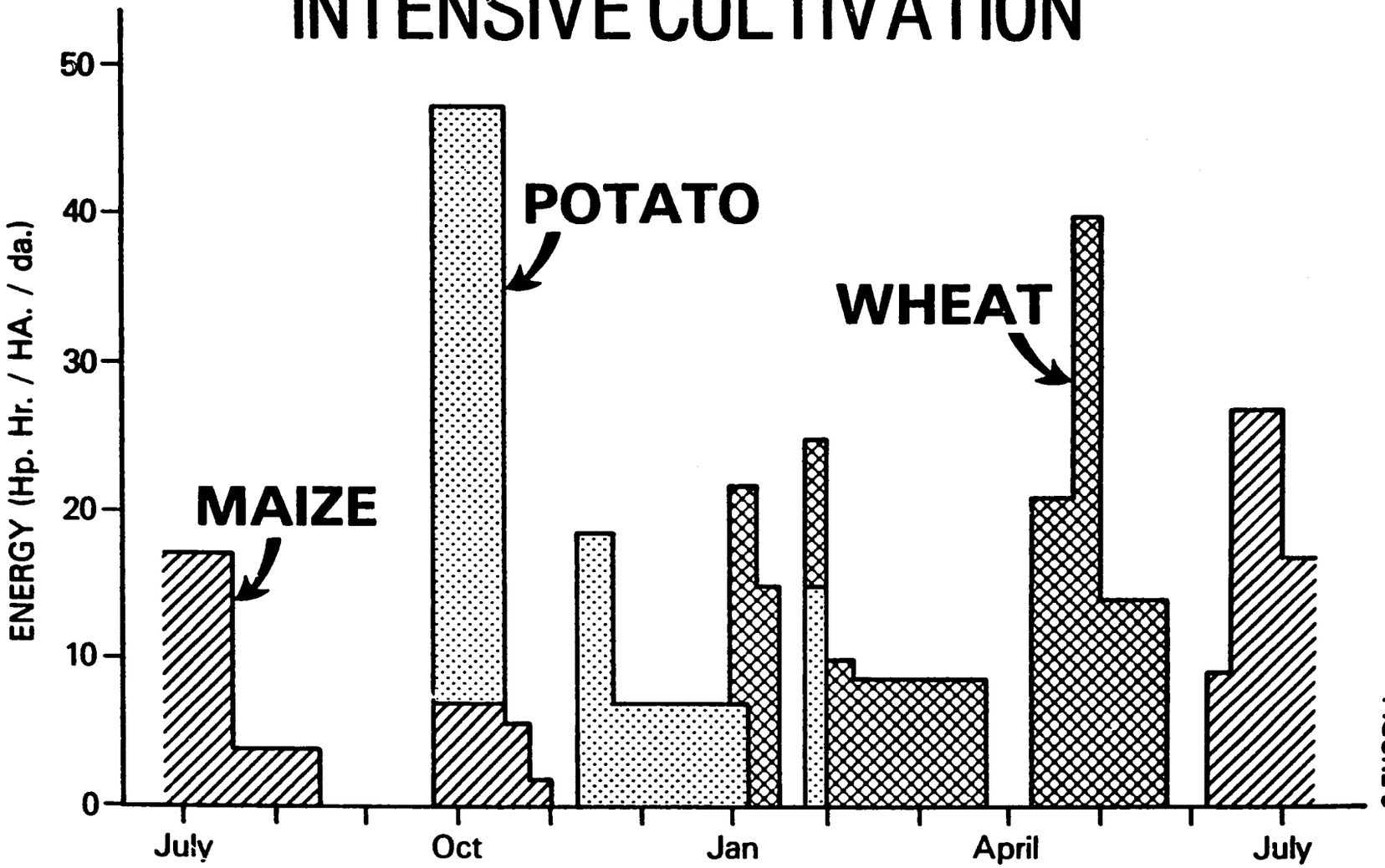
The cultivation of HYV's introduces new operations such as fertilization and more weed control which add to the work load. There are also possibilities of multiple and rotational cropping systems being developed using new combinations of variety and maturity dates. Some of these combinations will not be practical unless the power supply is supplemented. In LDC's where new land is not available, increasing crop production may require double cropping of more land. This maximization of production leads to extreme peaks in work load, note particularly the month of October which is the corn harvesting - potato planting season (Figure 5). Even in this cropping system there will be more than two months when there is practically no field work to be done.

HYV Workloads

By cultivating a HYV of wheat the farmer raises his potential harvest from 1,000 pounds to 4,000 pounds of grain per acre. He also increases the amount of straw that must be handled (Figure 6). For

FIGURE 5

SEASONAL WORK DEMAND FOR INTENSIVE CULTIVATION



AG. INPUTS DIV. USAID, New Delhi

Sept. 1969

SOURCE: ENG'G REPORT

UPAU – 1968

many farmers it has been the combined straw and grain handling that has overloaded the traditional systems and prompted consideration of combines. The increase in workload for other HYV's may take other forms as for example a crop spraying operation to control disease or insects. The plant breeders continue to improve the crop characteristics by breeding disease or insect resistant crops or by breeding more efficient varieties with even lower straw to grain ratios. But in the interim, if the farmer is to use the available varieties, there must be a means of doing these essential tasks.

The HYV's are also responsive to improved management. The yield of maize is 40% higher when planted with an improved seed and fertilizer planter (Figure 7). This increase results in part from more timely planting, in part from better seed placement, and in part from better placement of fertilizer with respect to the seed. It is not necessary to use a sophisticated planter to realize some of the potential of HYV's of maize, but the yield that can be expected is proportionate to the management control that the farmer can apply.

Irrigation and Economics of Scale

Concurrent with the increased cultivation of HYV's farmers have increased irrigation. Many farmers are quite able to mobilize the resources for investment in improved wells, pumps and the means of water distribution. The development of irrigation has been facilitated by industrial development which has improved availability and reduced the cost of irrigation equipment. Irrigation is used predominately with HYV crops which respond dramatically from adequate and timely irrigation.

Some observers of the trend of investment in diesel and electric driven irrigation pumps have expressed concern about farmers' judgements. Obviously the farmer becomes more dependent upon supporting infrastructure and must master a relatively complex technology as he invests in a pump set. However the fact that farmers recognize the advantage of the diesel or electric driven units and are willing and able to invest in such equipment demonstrates a considerable degree of management sophistication. The comparative investment and performance of irrigation systems is a classic case of economy of scale (Table 8). It is significant that this principle applies across the range of farm sizes typical of LDC agriculture.

FIGURE 6

HARVEST WORK LOAD

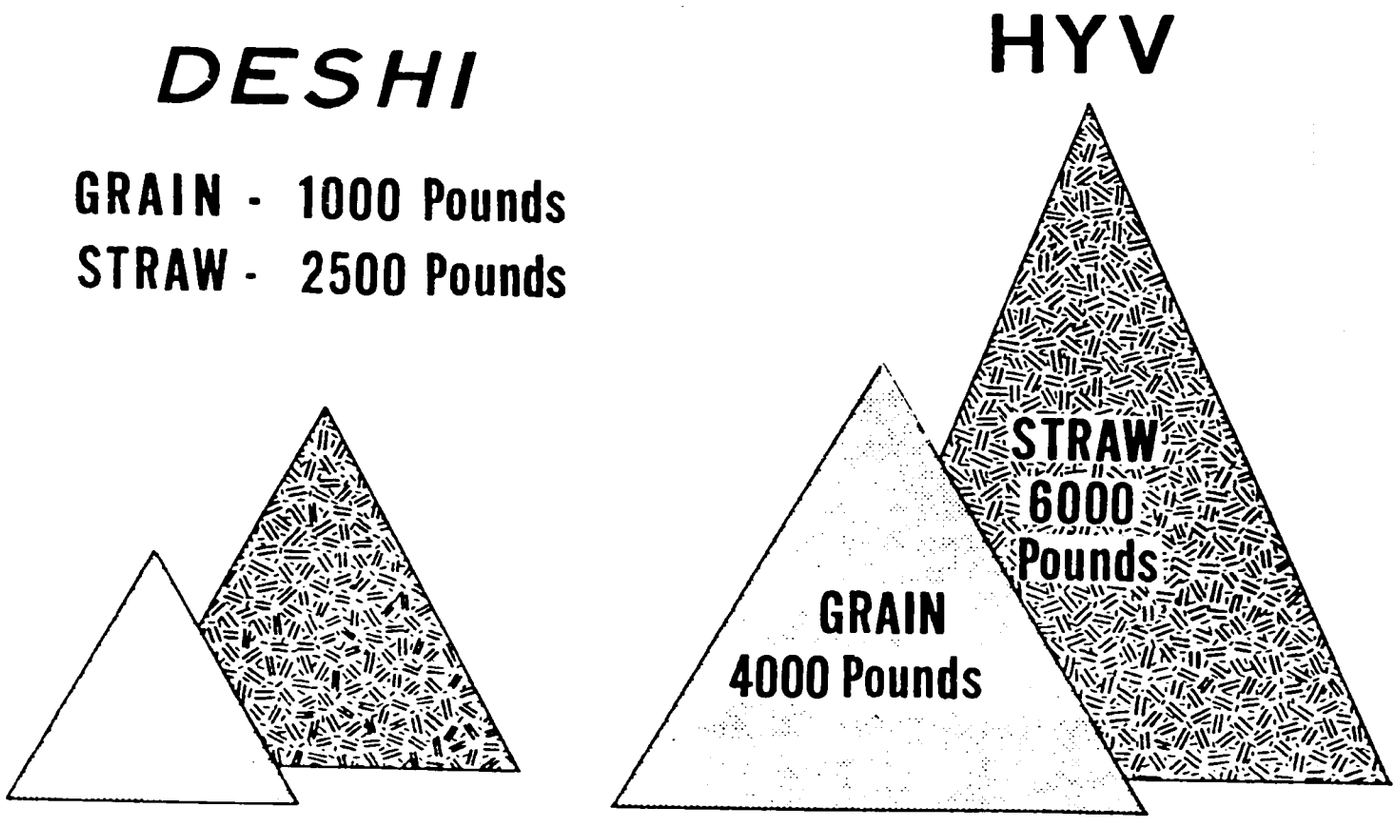
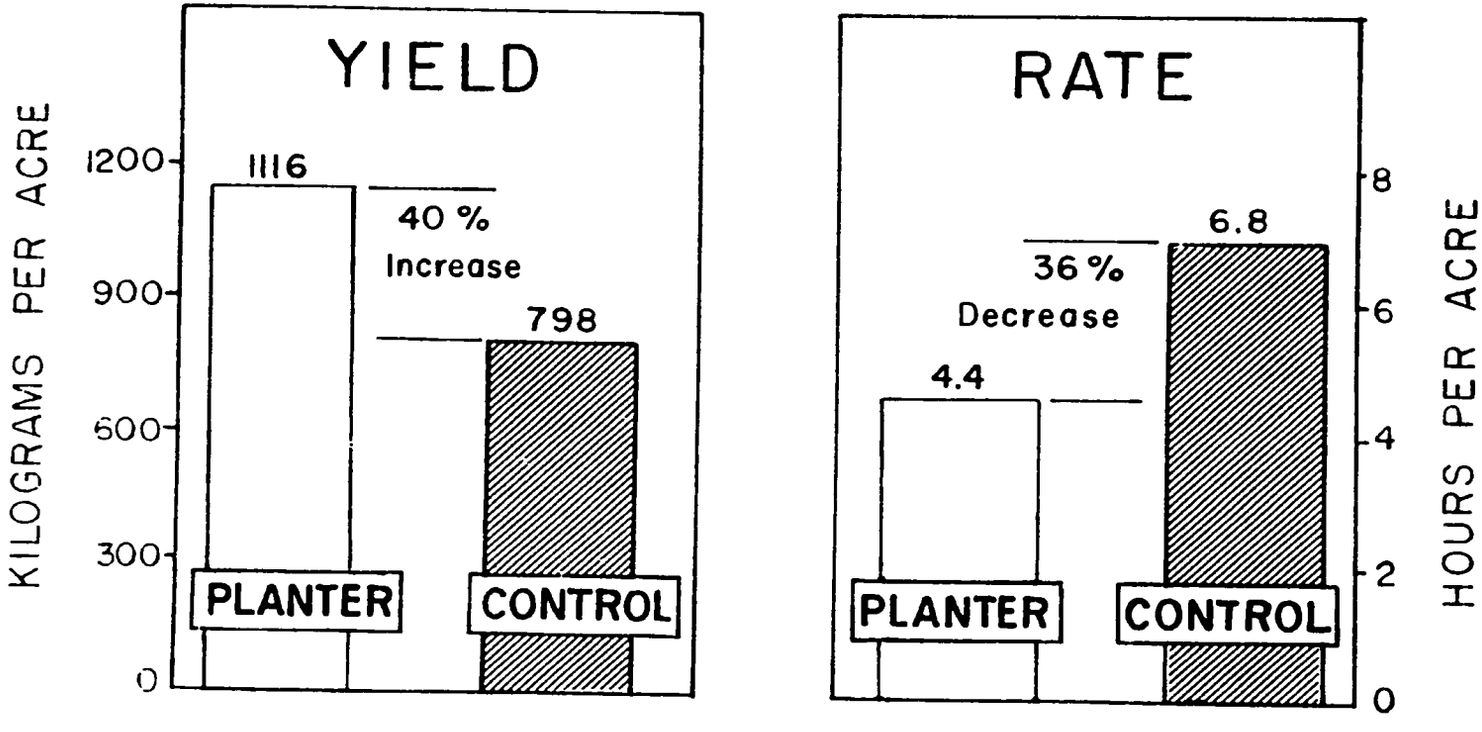


FIGURE 7

SEED - CUM FERTILIZER PLANTER

MAIZE

AVERAGE OF 18 TRIALS - 1965



AG. INPUTS DIV. USAID, New Delhi

Sept. 1969

SOURCE : EVALUATION REPORT

AAI. — 1966

TABLE 8.

Performance Data

LOW-LIFT IRRIGATION PUMPS

POWER SOURCE	LIFT (FT.)	Discharge RATE (GPM)	INVESTMENT (RS.)	Command AREA (ACRES)	Investment PER ACRE (RS.)	Water** COST (RS/10 A.in)
MANUAL	5	38.4	360/-	2.5	145/-	120/-
BULLOCK	15	50.8	3000/-	3.3	910/-	118/-
ENGINE	25	230.00	10500/-	15	700/-	45/-
	40	200.00	10500/-	10	1050/-	60/-

INCLUDES WELL

** INCLUDES COST OF MAN & ANIMAL. POWER

AG. INPUTS DIV. USAID, NEW DELHI, SEPT. 1969

Options in Technologies

Classically there are three options for farm power: i.e., manpower, animal power and engine power. These may be interchanged to a considerable extent. There are major implications for social structure in the transformation from dependence on one to another of these power sources. In this discussion reference to a power source implies a system of tools and infrastructure services which become significantly more elaborate as the transition is made from manpower to animal power or from animal power to tractor power. There has been some tendency to refer to engine power as advanced technology and refer to manpower as traditional technology with the implication that animal power is an intermediate technology. This simplification is inappropriate.

Another simplification that is misleading is the implication that one power technology will completely and rapidly displace another. Emperical evidence does not support this belief. If agricultural tractors simply displace rural labor one should expect rural wage rates to be lowest in the areas of greatest tractor population. Yet the reverse is commonly the case. In this regard attention is again drawn to Table 1 and Figure 1. Using Giles suggestion that one horsepower is required to produce 5.5 tons of grain per hectare it will be necessary for India to raise available farm power from 0.2 to 0.3 Hp/Ha in the process of obtaining a 50% increase in production. India with 137 million cultivated acres would require an additional 13.7 million horsepower. Using the common equivalence for horsepower this would be 137 million laborers, 13.7 million pair of work animals, 1.37 million small tractors, or 550,000 larger tractors. It is apparent that none of these sources alone can provide the needed power but that each of these sources could contribute and should be used where it is best suited.

General Considerations in Farm Power Technology

To recapitulate the points already established. First, the LDC farms are not entirely undeveloped, nor are the farms and industry unfamiliar with farm equipment. Second, there is a wide diversity of farming enterprises therefore appropriate technology will be a composite of many kinds of power sources and tools. Third, the potential to use tools and to invest in more tools is quite significant. Fourth, we do not have a solid basis on which to either design for immediate needs

or to predict future needs. Fifth, the task of providing the right tools at the right places is sufficiently difficult and complex as to require the full participation of every available resource. In other words there are many opportunities for technological innovation in tools and equipment for developing agriculture.

There continues to be an almost irresistable, progressive characteristic about technological innovation that is mutually reinforcing across various kinds of technology. The farmer experiments with a little fertilizer or seed first because it doesn't cost much and it has been given a lot of publicity. However, when he gains some confidence with the results of new seed and fertilizer he becomes interested in an irrigation pump and the seed-fertilizer technology provides the means of generating resources to pay for the pump. Once the farmer has the pump it is possible to change his crop rotation and perhaps use quite different varieties. Throughout this evolutionary process the farmer becomes better able to relate to the market place and increase his investment in education and social infrastructure thus establishing new levels of progress for himself and his children. In this process the farmer's own experience and the rhetoric of the politician combine as a strong force raising expectations and changing cultural or social values.

Alternative Power Levels

The farming intensity of most LDC's requires animate and/or inanimate power in addition to human power. The small farmer has essentially four options for obtaining this power; (1) hired power, (2) animal power, (3) small tractor suited to individual holdings, or (4) large tractor used in cooperation with a neighbor. Study of the performance characteristics of these options provides the basis for selection of power units for the distribution of farm sizes and other factors.

Hired Power. The farm enterprise of less than 5 acres cannot financially justify the ownership of a power unit. There are some such farmers who do own animals or tractors because ownership is practical as they hire the power and equipment out to their neighbors. Generally these farms will utilize manpower extensively, particularly the smaller enterprises which may be further constrained by having numerous very small plots unsuited to any form of animal or mechanical power. There are two sub-classes that are heavily dependent on human labor: the urban vegetable grower and the steeply terraced farm.

These farmers may utilize the tools and equipment designed for the larger farms in some form of joint organization. The organizational problem is simpler for smaller tools because the group can be smaller. But we have very little more than a general principle favoring smaller tools as a basis of design for this group of farm enterprises.

Animal Power. Animal power appears to be the most economical source of power for the 5-10 acre farmer primarily because this unit enables the farmer to carry out his operation entirely independently. The productivity of animal power can be increased appreciably by improved designs of tools and equipment. It may be possible to increase the command area of an animal unit to a 15 acre farm. This farm group is a strongly independent group in many societies and are expected to place some premium on retaining that independence. As long as farmers hold this desire for independence and can maintain their economic strength, the group will continue to be a key segment of agriculture and will be the stronghold of animal power.

The crucial problem is that we know far too little about establishing a self-sustaining animal implement industry. There have been numerous prototypes of equipment introduced in development projects, a number of moderately successful demonstrations, and a number of pilot production workshops. Most of these projects have faltered and many have failed. The reasons seem to lie in the domain of the industrial and commercial aspects. The small, rural workshops are practically starved of raw material and find it extremely difficult to organize a low-cost marketing structure to an adequate commercial territory. An interesting aspect is the method of encouraging the village blacksmith into an improved implement industry. If the blacksmith is not involved he fights the intervention, which seems to have been the case in many instances and would explain the stagnation that seems to have paralized previous efforts in this type of development.

Small Tractors. The case for small tractors is largely hypothetical however the collection of evidence is increasing. The impact of small tractors on Japanese agriculture is indeed of major proportions. The dynamic interest in small tractors in Philippines, Malaysia and Sri Lanka is also impressive. There are economic advantages in substituting one small tractor for the two or more animal power units of the 15-50 acre farms. These are dynamic farmers in the LDC's with the highest per acre yields and an impressive record of timely acceptance of HYV technology. The 15-50 acre farmers are not rich. These farmer's decisions are pragmatically reached and technically sound. The small tractors will be enthusiastically received by these farmers only if the tractors pass functional and economic tests.

Perhaps the most crucial test is how does the farmer visualize the trade-off between the farm enterprise returns from independent farm power as compared with the farm enterprise returns from use of less costly, hired power. Malayasia and Japan provide strong evidence that there is a significant range of farm enterprises who apparently gain from the availability of small tractors. In these cases the choice of large, hired tractors existed, yet the small tractor was adopted.

Large Tractors. The 35-45 Hp tractor is a versatile and economical power unit and with its matching tools has an amazing range of utility. Large farmers, above 50 acres, may be a relatively small percentage of the market but their numbers are still sufficient to be an economic market unit in most LDC's. The major tractor manufacturing companies have recognized these facts and established viable manufacturing and distribution enterprises in a number of countries. The performance of these tractors has been good and has demonstrated the potential of modern technology establishing some new horizons for both agriculture and industry. This is clearly an appropriate technology for a number of LDC farmers. In a number of countries these farmers are both well off socially and quite capable of continued improvement without assistance. However there are a number of dryland agriculture regions that may have 50 acre farms or larger and due to limited rainfall require the 35 Hp tractor yet remain in a low income range.

Constraints on Agricultural Technology Innovation

We now turn our attention to the boundry conditions of the agricultural enterprise in the LDC rural sector - particularly these conditions that act to constrain the use of tools and equipment. Three items are frequently mentioned as critical; limited capital for investment, limited infrastructure and the high cost of energy. In terms of gross averages these factors, and others are constraints. Yet due to the heterogeneous conditions there are significant areas where these factors do not completely restrict development and technological innovation. In order to delineate the opportunities for development and the boundaries of appropriate technology, the constraining factors must be described in some detail.

Capital Investment Rate

Tools and equipment are investments that must be amortized over several years, probably six to ten, and the factories which produce these items and the service infrastructure are even "lumpier"investments with a life of 20-30 years. Farmers face quite different problems in financing the cost of tools as compared with the cost of fertilizer. Hiring of machinery services is one way of minimizing the farmers financial burden, and such services have been established in a number of countries as public sector service programs. However private sector operations are very few and are generally financial disasters. There are problems of contracting, business management, supervision, collection, etc; none of which are inherent to the LDC, but all aggravated by the conditions of an LDC. Few governments are interested in subsidizing agriculture through a hiring service, therefore these operations are gradually being phased out.

Unfortunately if the investment in technology requires individual savings the prospects for very small farmers appear very bleak. Recall Barraclough's category of sub-family farms where the produce of the farm was not adequate for family support, a category enclosing 55.8% of farming enterprises in Columbia. This picture is brightened somewhat to the extent that some of these families are able to find work off their own farm for supplemental income.

As one examines the cases of successively larger farm enterprises the prospects for savings mobilization improves markedly. However the calculation of surplus income is not particularly straight-forward as the larger farms tend to support larger numbers of the extended family as well as a larger labor force. The farms in the family farm category now consume 70% or more of their production. If the HYV technology increases their production by 30%, the market surplus of the farm

increases by nearly 100%. There is no doubt that these families have many needs which can be met by this new income, but some set-aside for savings or investment is also quite manageable. In fact as family labor represents a major labor source for the 5-25 acre farmers the short-term mobilization of savings can be quite significant. It is this class of farmers that are today managing to invest in irrigation pumps at the rate of $100 to 150 per acre using private resources and privately arranged credit. This investment is possible by utilizing family and farm labor in some of the construction work and by allocating most if not all of the increased farm revenue to investment. These practices are themselves quite rational and demonstrate a sound management perspective.

It is projected that tractor power could be available at $100 per horsepower plus $50 per horsepower for implements or $150 per horsepower to invest in the new power source. With tractors capable of commanding 1-4 acres per horsepower the investment per acre in tractors is much more modest than the investment in irrigation. Thus we arrive at the conclusion that capital investment rate is not necessarily a critical constraint on technological innovation in farm power.

Infrastructure Dependence

The introduction of technology or the raising of the sophistication of the technology is only possible as the farmer can depend upon infrastructure services. It is a relatively simple matter for the farmer to sell a bag of surplus grain and buy a simple plow and then each year to sell a little more grain and buy a new plow share. To get an irrigation pump requires a larger sale and either connection to electric service or a means of periodically getting diesel fuel. And a tractor may have greater needs for fuel and repair parts thus further raising the dependence on the market place.

The market infrastructure is being developed as a fundamental element of development planning. Rural roads and rural education are placed high on every LDC list of things to do. With the heavy investments in military service it is becoming quite easy to find retired army personnel even in remote villages who have more than adequate training and ability in simple mechanical service.

There is available today the experience of a number of years of development which can serve as something of a trend from which to predict the expansion and improvement of infrastructure. Official plans can also be scrutinized in predicting further availability of services. There

certainly will be locations that cannot service some technologies, but the simple fact that large numbers of tractors are being successfully serviced indicates that a considerable infrastructure is now adequate to support a quite sophisticated technology.

Energy

By simple definition it is necessary to expend energy to produce food and it is possible to increase production by increasing energy expenditure. Unfortunately LDC agriculture is a relatively inefficient converter of the sun's energy, primarily because of the low investment of animate and inanimate energy. While there is common agreement that the food production should be raised there seems to be some expectation that this can be done without raising the energy expenditure particularly the energy derived from fossile fuels. Singh and Chancellor studied quite intensively the production, energy and unit cost aspects of successive increments of technology and reached the conclusion that energy expenditure is a sound investment.1/

Some perspectives on energy expenditure would be helpful. U.S. agriculture utilizes approximately 5% of U.S. energy and much of this food production is for export. Secondly, food costs have been rising more rapidly than the increase in cost of the energy consumed in their production. Third, LDC economies are importing both fuels and foods and could probably reduce total foreign exchange cost by importing more rather than less fuel if it were used to produce food. Fourth, at the density of human population in many LDC's any increase in draft animal population will significantly reduce human food production. Fifth, the under-utilized human labor force suggests that human energy is not the production constraint. While this set of circumstances builds formidably to the conclusion that more fossile energy should be invested in food production, these facts do not provide an answer to how much energy should be expended. The importance of energy research has only recently been recognized and it may be several years before a research basis for policy is available. In the interim, however, the intuitive case supports more rather than less energy expenditure in agriculture.

Animal use will extend only so far as there are waste and by-product feeds available for their support. To the extent that animals harvest a

1/ Gajendra Singh and William Chancellor, "Energy Inputs and Agricultural Production Under Various Regions of Mechanization in Northern India" Transactions of ASAE, 1975.

renewable resource and conserve fossile fuel they provide a positive contribution to a nation's energy supply. But if animal population is increased beyond the point of such subsistence, they reduce the supply of human food. From this basis of analysis the animal energy resource can be only marginally expanded. We thus are inevitably forced to the conclusion that fossile fuels are required for the major portion of expansion of food supply.

This does not mean that the agricultural scientist or administrators should be content with present food production systems. There is a very important need for major investment in more energy efficient product methods; i.e. minimum tillage, biological nitrogen fixation, etc. Given the present state-of-the-art for such technologies it is quite likely that investments in known technologies will be fully amortized before they become obsolete by more energy efficient agricultural production systems.

In the final analysis the use of energy is not a finite constraint for agriculture, but energy expenditure is indeed a serious concern. There is no known way of avoiding increased energy expenditure. There is of course hope that more energy efficient systems can be developed, but until these are identified we are faced with a very difficult resource management problem. As the U.S. has found, the matter of domestic energy policy and management has no easy answers. The right answers in terms of appropriate technology for LDC's are probably even more difficult.

Identifying Appropriate Technology

Merrill concluded his analysis of the role of mechanization by noting three alternative approaches to mechanization policies; these were, selective mechanization, fractional mechanization and appropriate mechanical technologies.[1/] He concluded that the appropriate technology approach was more realistic for LDC's. He defined appropriate mechanical technologies as follows:

"A third approach is to promote appropriate mechanical technologies. This approach views the mechanization of agriculture as a continuous and inevitable process in economic development but one whose speed and direction can be altered by public policies and programs. The criteria used to define what is 'appropriate' depend on a nation's goals. If a nation's development program emphasizes equity, employment and production, then particular agricultural implements would be considered appropriate if:

1. their use is profitable for a relatively large proportion of the nation's farmers,

2. they can, to a large extent, be produced locally,

3. they make the maximum possible use of domestically available resources such as energy, materials, and labor skills, and

4. they provide more effective and timely operations which enable farmers to increase output either through increased yields or more intensive use of their land resources.

Obviously, what is 'appropriate' for one country may not be appropriate for another, or even for the same country at a later stage of development. Less obvious, but perhaps more important, is the implication that appropriate mechanical technologies, or at least the most appropriate ones, may not yet be available to many countries."

A number of the tests of appropriateness suggested in the literature include aspects in addition to the functional and economic realm, the so-called socio-cultural factors. For many of these factors the testing judgement is subject to interpretation, often by individuals with quite different value systems. It is particularly difficult to

1/ pp. 31 and 32, William C. Merrill, "The Impact of Agricultural Mechanization on Employment and Food Production," USAID, TA/AGR, September, 1975.

assign trade-off values in terms of socio-cultural benefits in comparison with functional and economic benefit. In spite of the difficulties of analysis, the socio-cultural factors are given some consideration in technology selection up to the limits of available analytical technique.

Compatible With the Diversity of Farming Enterprises

To be able to take advantage of his unique combination of land, family labor and management ability the farmer must be able to get the right tools and these may be similar to or quite different from his neighbors. On the other hand, an infinite selection of tools and equipment is impractical. However, too much attention has been focused on standardization of designs and too little on diversity. Centralized decisions about tools and equipment may effectively constrain many farmers in their ability to maximize returns from the features of their enterprise. Unfortunately, the limited descriptive data on LDC farms makes it quite easy for policy planners and administrators to assume a greater uniformity in LDC agriculture than in fact exists.

It is important in this regard to keep in mind the perspective of numbers involved in LDC agriculture. When the average farm is on the order of five acres there may be 125 farms per square mile or 40,000 farms within a 10 mile radius. Within a territory of this size the replacement sales of a machine designed for only 10% of the farmers would be approximately 400 per year. This would be a quite respectable retail volume for most classes of farm tools. In fact a manufacturing plant which was intended to serve a 100 mile radius would have a market territory of 4 million farms and could have a sales volume of 4,000 units per year just meeting the needs of 10% of the total farm operations. A more practical working operation for a small-scale industry might be for a market territory of 10 mile radius and a market share of 25% of the farm operations for a tool of ten year life. This small-scale operation would have market volume of 1,000 units per year. Obviously the industrial economics will readily accommodate design diversity in meeting the specialized needs of the farm population.

Capable of Industrial Support

The error committed in assuming that an LDC has no industrial infrastructure is perhaps as serious as the error committed in assuming that the latest products of the developed world can be imported and effectively utilized. It is possible to find imported tractors successfully used, while it is also possible to find imported tractors that have been in repair shops for excessive periods due to poor care and inadequate

maintenance. In marked contrast to the usual stereotypes about LDC industry is the dynamic irrigation pump industry with its small, local workshops.

There are however serious weaknesses of infrastructure which are traceable to neglect of organizing and financing the distribution network. One finds generally adequate interest in the large factory, but the small retail or service point are quite poorly developed. Where such facilities exist one finds them set-up by local entrepreneurs often with little if any constructive franchise agreement. An appropriate technology should be as attractive for mobilizing resources for investment in the infrastructure facilities as the technology is attractive for major production investment or for farmer purchase. The experience in technological intervention indicates that the weakest level of entrepreneural interest in the market level.

Capable of Progressive Investment

Tools and equipment are considered to be "lumpy" investments and therefore a particular device may be comparatively more appropriate for the LDC if it is less costly. One means of reducing the lumpiness is to phase into the technology such as to move from traditional animal-drawn equipment to small tractors through an intermediate step of improved animal-drawn implements and then a substitution of tractor power for animal power. Another means is by a credit program that enables the farmer to pay the costs over the years of use. A combination of phased adaptation and credit purchase is commonly endorsed in principle, but only partially considered in the planning process.

There is relatively little known about the complexity which the farmer can "master" as an increment of technology or the lumpiness of debt which is appropriate. Because these factors are interrelated with educational levels, other aspects of development, etc. there are no simple formulas for calculating a threshold of appropriateness. The problem of "lumpiness" also applies to the industrialist role in establishing technology, to the educational demands on skills development and to other aspects. This factor more than any other implies, in fact demands, that appropriate technology is a "moving target" in a developing economy.

Positive Socio-Cultural Implication

The fact that the socio-cultural characteristics of the LDC are distinctive is quite commonly acknowledged, but the interaction of these characteristics with technological innovation are less well documented.

For example, the LDC is sometimes described as tradition bound or conservative, yet there has been a substantial change to cultivation of the HYV's. It is not expected that the LDC's would have the "Protestant work ethic", in fact many LDC people associate considerable status with leisure rather than work, but little study has been given to the effect of these values on technology choice.

Family Support. The extended family institution provides a flexible labor force as well as a social security system. This family system is an efficient means for mobilizing practically every able-bodied person at peak seasons and distributes the sustanence of life for year around support. This system should continue to function in pro-rating work and sharing of income even as some technological intervention caused a displacement of the traditional labor force. Some work may continue to be women's work (rice planting) but a reduction in field labor will immediately enable at least the young men to get better education. With the very high regard for education, the young men would be released from farming for school before the permanent labor force would be released.

Role of Labor Category. It is important to note that the labor status is of significantly lesser social standing in an LDC than that of management and leisure. For the farmer this means that a tool which reduces the demand for field labor while increasing production may enable the farmer to spend more time as a manager - getting better seed, more fertilizer, or selling directly at a better market. Also the laborer who by the use of tools can increase his productivity and income will not be forced to send his wife to work in the fields. The information about these choices is very scanty but it appears that the social structure has some sound protection for the permanent labor class in a process of technology change.

The social protection for the daily or occasional labor class is much less on the short term, but is quite promising to the extent that a growing economy will create jobs. In fact if agricultural marketings double as they would from approximately a 30% increase in production, the impacts on jobs in produce marketing and consumer industries may be large. Many of these industries are labor intensive and may require nearly a doubling of the labor force to double the volume of produce handled. There are of course some serious social stresses involved in the transition from membership in the rural, casual labor-force to membership in the market town or urban, commercial labor-force.

Community Enterprise. Among LDC's there are quite wide variations in attitudes toward community enterprise. Where community farming

activities are common practice such as in Africa, there are opportunities to organize work so that larger equipment can be used by joint ownership or hired use. However in many LDC's there are weak social and legal conventions of community enterprise upon which to build tractor hiring and other commercial services. A tractor owner may have some confidence that a relative will pay for plowing at the end of the season when the crop is harvested but all others must pay in cash or the service is not available. Where illiteracy is common a signed contract is of relative little value particularly when most needed as a means of resolving misunderstandings.

Obviously these factors are in transition in the course of development. Education and participation in the market place dramatically change the attitudes and participation in socio-economic activity. The problem of establishing the causal and enabling thresholds has not been studied and therefore we are at a disadvantage in saying whether or when community use of equipment is a possibility. It appears however, that the most common situations favor individual ownership and use of farm equipment. In some cases individual ownership and hired use by 3 to 5 neighbors would be feasible. But the system for use by 10 or more neighboring farmers seems socially impossible except in few instances.

An A.I.D. Perspective of the Total Picture

The above considerations are a complex set of factors out of which may be identified a set of importance for the purpose of A.I.D. program planning. Both pragmatism and compromise are required to address the complexity of this "real world".

Mid-Size Grain Farm as Target Enterprise

A major task for A.I.D. is the definition of the target farm enterprise which will satisfy the Congressional Mandate of increasing agricultural production and assisting the rural poor. This is a tough question. If one takes an arbitrary definition that to be landless is to be poor, then the target group should be the rural landless and those whose holdings are small. With this definition the target group would be perhaps 40% of the population whose total land holdings would not be 15% of total cultivated land area. There is no question that this group has a serious economic problem. If A.I.D. is to simultaneously contribute to food production it is imperative that another means be used to identify that target group.

The U.S. family farm enterprise has been a keystone of U.S. agricultural growth. These enterprises of mid-size comprise 50-60% of the farm land. Before identification of the mid-size group in LDC's as an A.I.D. target we must answer the question, what is the wealth of this group. Here we are at a disadvantage for there is very little rural family income data. Many of the "lower 40" might actually be in this group. This group would not be the wealthy, nor would they readily move into that category if assisted in development. That is, the family farms would not only retain their permanent labor and increase the joint family size supported by any increase in income, but also invest part of the earnings in increased productivity and more consumer expenditure. The multiplier effect for the economy is much better for this group than any other target group.

It is interesting to note that the family farm category requires an intermediate size of technology which has been largely neglected in earlier conceptualization of development. More recently, after taking a critical look at the assumption that farm sizes would get smaller due to population pressure, rather than larger due to economic forces, attention was shifted to the "average size farm". In many countries the average land holding is significantly less than the average size farm because of the large numbers of small land holdings which are rented out. A technology that would work for this "average land holding" does not work well for the family farm enterprise. In fact there has been quite considerable attention focused on simple technology for these small "average farms" during the last ten years or more without significant benefit. It is apparent that the family farm or mid-range of farm sizes

has been badly neglected in development and merits attention as a target unit.

Irrigated and Non-Irrigated Agriculture

From the point of view of increasing agricultural production the improvement of irrigated agriculture has been the best route. However, this improvement of yields for irrigated agriculture has enabled a relatively few farmers to gain considerable economic advantage in comparison with the neighboring, unirrigated farmers. In fact, the irrigated farmers were relatively better off at the outset of the "Green Revolution" and this technology has improved their status. Inasmuch as the potentially irrigated land is at most some 20% of agricultural land, an agriculture program that is exclusively focused on the irrigated technology will be of limited social impact.

The rainfed agriculture problems of the LDC's are much more difficult. The quantitative lack of rainfall is only a partial expression of the constraint. The unpredictability of rainfall makes it time consuming to test technology and demonstrate or prove technology to the satisfaction of the farmer. To illustrate, it may be characteristic of a locality to have two successive years in a ten year period with rainfall more than 30% below the long-term average. The farmer would probably not be interested in a new practice until he had seen the performance in an adverse weather cycle, but the research worker may not even be willing to demonstrate the practice for the farmer until he had tested the practice under two such cycles. If the typical frequency of these two bad years was once in ten years it could be a thirty year process from the time of the first experiment to the point where farmers were actually convinced that the practice was reliable for adoption.

Of course there are many farmers who have both rainfed and irrigable land therefore farming systems under various levels of water availability must be developed. The International Centers for Agricultural Research are approaching this problem in their emphasis on the farming systems application of the HYV technology. The experience of these centers in developing improved technology that is suited to the semi-irrigated farms provides impressive evidence of the difficulty ahead in developing the agricultural technology of improved yield and broader social benefit.

The Rural Development Interface

The development of a strong, rural market for farm machinery could mobilize the savings of the small town entrepreneur for investment in a machinery production unit. Thus there is a synergistic relationship between the farmer and entrepreneur in the rural market town insofar as

they both visualize the utility of the technology. There is a similar mutual interest of agriculture and education which is stimulated by technology intervention. On the political level the popularity of large numbers of small tractors mobilizes a very high level of support for a rural roads program. The dynacism of mechanical technology, particularly small tractors, is significantly higher than agronomic technology because of the larger number and more dependent links with industry and other elements of the community.

The potential benefits of mechanical technology as an "engine of change" have significance for the governmental operations as well. By investing in farm machinery rather than consumer goods the farmer is increasing his production capacity and is in effect creating growth potential. Inasmuch as the establishment of an indigenous machinery industry is a simpler task than building a consumer goods industry the industrial development requirements are indeed simplified. There is also some reason to believe that in many societies there is a stronger motivation to save for purposes of machinery investment than for some of the consumer goods, thus the industrial benefit of agricultural production technology would be proportionately higher than a consumer goods innovation. An established farm equipment industry could also provide the government with a tax instrument which would have some incidence tending to fall on commercial producers with ability to pay.

Seasonality and Risks of Agriculture

The seasons and weather affects on agricultural production are obvious but the interdependence of this variability and the commercial activities involving agriculture is quite often overlooked. The seasonal marketing patterns of agriculture result in cyclical patterns for agribusiness that tend to raise the costs, perhaps even doubling the distribution and warehouse cost over that of a hypothetical steady rate of sales. When the effects of weather are super-imposed upon the normal season cycle there is the prospect of a seasonal peak being unusually high in certain years when all weather signs are favorable. The problem for the supplier is that by the time the weather signs are established for a season it is too late to adjust either production or distribution.

These cycles of events are quite well understood and accepted by the farming community but they have proven to be a serious problem for the entrepreneur. The obvious impact is to push up the cost and risk of doing business for the rural market. When money is short and opportunities are relatively plentiful the business community find ample opportunity without agricultural service investments. Too often the fact that farmers are poor has encouraged government to attempt to hold down prices to farmers

thereby making the rural market even less attractive.

Proposals of crop insurance are frequently voiced in order to stabilize farm incomes by minimizing the extreme weather effects. With a stablized income the farmer's buying tendencies would also stabilize thereby making the agricultural market somewhat more attractive. Another device might be a flexible credit program that would reduce the costs of inventory carry-over in the difficult years while not protecting bad management in good business years. Another alternative is a credit program with flexible terms of repayment for farmers according to crop harvests. None of the program objectives can be achieved without complex administrative means which makes the policy and administrative implications a major consideration.

Agro-Industrial Overhead Costs.

The marketing margin for the agro-industries is comparatively high in comparison with other industries for three major reasons: i.e., widely dispersed markets, poorly education clientele, and minimal alternative infrastructure. It is common practice for U.S. markups of 35% to cover the distributional costs for farm machinery, but there is a tendency in the LDC's to think of this category of cost as being "profit" which must be cut down. The excessive loss and breakage which one typically finds in an underdeveloped transport system is an additional cost of considerable importance. The unreliability of delivery adds further to the inventory management of the marketing system as well as detracts from the reliability of the technology.

An important duty of a product salesman is to provide the customer with information about the product. In the developed countries the salesman's job is relatively easy as the customer is quite well educated and most of the sales time is spent on minor features which distinguish one brand from a competitors. In the LDC the product is new and the basic techniques of use must be conveyed in considerable detail. Obviously, the sales person cannot do this if he realizes no income from the service. It is theoretically possible to include new technology in a public education program, but to educate the general public is not the most efficient way of reaching the early adopters. Generally the extension and education services are badly under staffed and have a variety of administrative functions that have been assigned to them. There is relatively little known about how long it takes farmers to master new technology and until this information is available it may be quite difficult to establish sound parameters of time and cost for the technology skills function.

The Problem of Industrial Structure

Farm machinery is a good product line for a dispersed, small-scale, rural industry, but there are vital links which must be set up between the basic small-scale production unit and other industrial enterprises. Generally these linkages are neglected and their failure has inhibited development of a small-scale farm equipment industry.

The most serious problem for the small-scale businessman is the effort required in competing for scarce raw materials. The bulk of a farm machine can be fabricated from common grades of iron and steel, but good performance requires that a few parts be fabricated from special grades. The manufacturer has essentially three kinds of material needs: i.e., bulk raw material, special raw material, selected components. Special raw materials might be arranged through cooperative buying, but the small entrepreneurs do not seem to recognize the potential of this form of association. The selected components will require a linkage with large-scale industry which generally does not recognize the potential of the rural market for hardware components.

Although today there are many farmers who purchase equipment directly from small-scale producers, a useful service could probably be provided by an intermediary between the farmer and the producer. This could be the blacksmith although most attention to upgrading the village smith has been directed to improved iron working technique. The blacksmith serves a useful service role in the community for traditional tools and could continue a service role if brought into the technology adaptation process by the mastery of new sales and service skills.

SUMMARY

An appropriate agricultural machinery technology should include three major categories of hardware with a diversity of options in each category. The major categories are hand tools, improved animal tools and small tractors. The design options would adapt the equipment for the diversity of farming operations of the LDC's. This equipment would be designed, produced, distributed and serviced for the family farm enterprises of the LDC and should achieve measurable positive benefits in terms of both production and employment. Although it is possible to make a narrow economic and technical case for larger tractors as appropriate technology this case is weakened by the consideration of the socio-political impacts of the large tractor technology. The problems experienced by LDC's in land reform has been taken as indication that adequate political will does not exist to restructure drastically the pattern of farming enterprises. Thus the appropriate technology should be designed to raise the productivity with the broadest segment of smaller farmers using a technology that is heavily dependent on labor. This strategy contains a trade-off of production and employment factors and represents a judgement that at this stage is not well supported with field data. Some caution and continuous evaluation is suggested during the pursuit of the strategy to ensure that the benefits do in actuality conform to the expectations in an acceptable degree.

Family Farm as the Target Group. The family farm enterprises of the LDC, like their U.S. counterpart are the most efficient users of available land. This strategy would provide these farmers with the tools and equipment to further raise production and the well-being of the farm family and their society. These farmers are not well off economically, in fact generally significantly poorer than the urban labor class. In past development programs there has been a pre-occupation with production for the commercial market which resulted in the neglect of the family farm. More recently the emphasis on the "rural poor" focused upon the landless and therefore also neglected the family farm group. The family farm merits attention because it is a poor group with production potential. The family farm is not a narrow typology and the strategy has the flexibility to support the full gamut of mechanical technology required to develop the potential of this segment of the LDC economy.

A Positive Social Impact. An increase in total food supply and an increase in income of a sizeable segment of the farm population will

have broad social benefits. This strategy attempts to improve equity by positively excluding a sizeable segment at the top end of the economic spectrum. However the available production parameters indicate that there are limits on the labor absorptive capacity of a production increasing technology and it is not proposed that this technology will correct all social ills although there is expected to be a net gain in well-being.

Productivity Benefits. This technology will not produce maximum production per unit of input as this is only one of the benefits sought from the intervention. However the internal motivation of the family farm enterprise is comparatively high, perhaps higher than can be attributed to economic factors alone. Thus, the return for improving the production technology is multiplied by the factor of good management. A large portion of the production will be consumed by the farmer and by his labor force thus making measurement difficult. At the same time a lack of fertilizer, for example, may in fact limit production more seriously than will be assisted by the better tools. Realistically it is the combination of better farming methods rather than any one that produce crop yields and it will be necessary to expand all of the inputs in some coordinated manner in achieving the productivity gain.

Broad Based Economic Impact. The industrial facilities for producing, distributing, servicing and repairing of this appropriate technology can be wholly indigenous or nearly so. This broadens the economic benefit in the society and also conforms with fiscal management objectives of many LDC's. The simplicity of the technology and its capability for immediate utilization can make it an attractive investment for local entrepreneurs. It is generally felt that previous emphasis on sophisticated technology was too lumpy to stimulate wide interest and hence resources were accumulating or being consumed unproductively. The proposed technology offers the opportunity to test that hypothesis. The caveates must be hastily added. There is an extensive set of policy and administrative adjustments that must be simultaneously instituted if the full benefits of this technology are to be realized.

Broad-Based Political Impact. The objective is to provide a modest positive economic and/or social benefit to a broad segment of the population. The target group of farm families are minimally involved, or at the immediate fringes of, the present political processes. Strengthening of their economic status, notably their relative economic status, is expected to improve their political capability. At the same time there is no threat of a political revolution, nor is it necessary as a precondition

for utilizing the technology. Thus the participating political base should broaden as the impacts of the technology are felt. This broadening will not simply be in numbers of farmers, but in numbers of industrial or urban participants as well. Some may be concerned as the political interests of agriculture are strengthened and begin to reshape the agro-industries. Yet the agro-industries interests may themselves become the political bridge that links the existing conservative rural majority and the sometimes hyper-modern urban industrial class.

Compatible With Existing Technology. The appropriate technology concept readily assimilates existing traditional and modern technologies. It is not proposed to replace any existing technology with a technology proposed to be "right". It is proposed that existing technology will be supplemental and complimented in the course of improvement. Displacement will occur in the context of evolutionary improvement as resources are mobilized. The establishment of the new technologies will improve the productivity of the existing technologies by common reliance on the same infrastructure and other features of the economy and social structure.

Requires Minimal Facilitating Programs. The LDC's have made significant gains in fertilizer, irrigation, etc. for HYV agriculture and in industry and infrastructure of a modern economy. These are the essential building blocks of the new technology. These blocks need to be expanded and perhaps modified to permit continued agricultural expansion, but drastic modifications are not required. There may be major problems in expanding these various elements, but the expansion of the agricultural economy should be a major resource enabling more rapid expansion.

The crucial factor is to percieve the influential nature of a set of interlinked policy and administration policies focused at the family farm as a dynamic economic enterprise. The family farm has the capability of a high multiplier effect in utilizing development resources to yield both a production increase and an improvement in social well being. Policy reformulation and some restructuring of the administrative set-up are necessary to achieve the target objective of the family enterprise. However the more important benefit will be the economic stimulation and reinvestment of resources when the family farmer reinvests in his enterprise and expands the productive capability. The industrial response to the farmers demand for capital goods becomes an integral element of the expansion of the total economy. Much of this expansion can be underwritten by farmers and rural businessmen as they recognize the potential returns of this kind of dynamic new business enterprise. An appropriate agriculture technology thus becomes an effective engine of economic and social development.