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IDENTIFYING PRIORITIES FOR RESEARCH AND DEVELOPMENT IN RICE MECHANIZATION SYSTEMS

by

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IDENTIFYING PRIORITIES FOR RESEARCH AND DEVELOPMENT IN RICE MECHANIZATION SYSTEMS

Randolph Barker and Bart Duff *

Introduction

One of the most controversial aspects of the modern rice technology concerns the area of mechanization. At one extreme are those who tend to equate mechanization with modernization; at the other are those who feel that mechanization will reduce employment and result in a more highly skewed income distribution in the rural area. The IRRI program in agricultural engineering and machinery design is based upon the premise that neither one of these extreme views is correct. Mechanical technology can be developed and extended which will complement the new biological technology and enhance crop production without reducing employment opportunities. Such a strategy of mechanization is frequently referred to as "intermediate mechanization" or developing "appropriate technology". However, to implement such a strategy requires the development of a set of criteria for assessing the priorities that should be given to alternative engineering projects.

The purpose of this paper is to outline an analytical framework through which we can establish areas of high priority for research and assign priorities to specific projects. The analytical procedure we

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intend to use might be called a systems analysis in its broadest context, in that we intend to study the entire crop production and marketing system. Initially, however, we will not attempt to construct a highly formal systems model. We will model certain components of the production and post-production systems if we find that greater sophistication is needed to establish clearly the priorities for research.

The paper begins with a discussion of the role of mechanization in rice production systems under traditional and modern technology. We emphasize the link between the introduction of modern biological technology and the demand for mechanical improvements in the production and processing systems. To illustrate this link, examples based on IRRI engineering designs are discussed. Finally, we set forth the criteria for establishing project priorities and evaluate several operations and current IRRI projects on the basis of these criteria. These are employed in mapping out future priorities for engineering design and development activities.

Mechanization in Rice Production and Processing Systems

Under traditional procedures for growing rice in monsoon Asia, the choices open to farmers have been very limited. The time of planting and harvesting is dictated by the weather. Lack of water control in the lowland rainfed paddies and in upland rice fields results in wide variability in year-to-year yields. Crops in the

irrigated areas may also suffer unforseeable and unpreventable damage from typhoons, flood and drought. Small farmers operating under these conditions find it difficult to adopt modern farming practices. The traditional subsistence systems that prevail through much of Asia cannot easily make use of modern inputs to increase farm yields.

The development of those modern varieties that are non-photoperiod sensitive, and have a shorter growth duration, coupled in many instances with improved irrigation and water control, are helping to create a new environment for rice culture in both the physical and economic sense. To realize the full potential of these new varieties, more and better decisions must be made with respect to the proper development and use of complementary inputs and related cultural practices.

If we consider the total rice production system, there are three broad areas where rice production relates to mechanization: (1) water management, (2) crop production, and (3) post-harvest processing. Although all three areas form a part of a total production system (Fig. 1), they are sufficiently independent from one another to be discussed separately.

Water management and land consolidation

The production of lowland rice calls for the construction of paddies to bund water and, in the case of irrigated rice, the construction of canals, turn-outs, and farm ditches to deliver water. Following the introduction of modern varieties, the area under irri-

gation has expanded rapidly (Table 1). However, much of this area still has extremely poor water control. There is considerable debate among those concerned with irrigation development as to the appropriate degree of land forming and consolidation needed to insure adequate irrigation, drainage, and water distribution throughout the system. In some systems, the task of constructing tertiary canals and farm ditches is left completely to the farmers with the result that water is used very inefficiently. In other cases, a very intensive land consolidation scheme is being tested similar to Taiwan or Japan. Nothing is left to the farmers and the development cost is so high as to be economically unsound. Some intermediate steps need to be developed which will make use of appropriate mechanical technology and the existing pool of local human resources. Institutional innovations such as irrigation associations coupled with appropriate irrigation equipment such as pumps and land leveling devices are examples. This issue is being studied by the Water Management Section.

Crop production

The spread of modern rice technology changes the marginal productivity and the demand for various complementary inputs that go into the production process. A brief examination of the alternative means of performing various tasks and hence, choices to be made by farmers in rice production will help to illustrate the point.

The proper method of land preparation requires choosing between animal power, mechanical power (tractors) and chemical energy (as in minimum tillage).

Traditional transplanting must be compared with direct seeding methods.

The optimum level, timing, and placement of fertilizer and insecticides must be determined.

A choice must be made as to the best method of weed control, and the best method of harvesting and threshing rice. There are social as well as economic issues to be considered. For example, many farm laborers depend upon returns from harvesting and threshing rice as a major source of livelihood.

Even the standard procedure for puddling rice becomes subject to question when one considers the possibility of growing rice in combination with other crops.

Not only changing technology, but changes in prices and costs of purchased inputs affect the appropriate method of producing rice. As a farm or a nation develops, the appropriate choice of technique will vary over time.

What is particularly significant about the new rice varieties in relation to mechanization is not only their yield increasing potential *per se*, but also their shorter growing season and non-photoperiod sensitivity which make possible a considerable shift in the cropping pattern. The introduction of modern varieties results in an increased demand for machinery to: (a) improve the timing of operations, (b) lift power constraints, and (c) make more efficient use of purchased inputs such as fertilizer and insecticides. In many instances, existing mechanical

technology can be adopted or modified to meet these needs. In other instances, a new design may be required. The appropriate combination of mechanical and biological technology must be developed.

There are many potential areas for engineering research and development. A first step in determining priorities is to examine the major rice farming systems in Asia with specific reference to farm size, water control, and labor use. Most of the rice growing farms in Asia are small, but a very large number are extremely small. Forty-four percent of the farms are 1 hectare or less in size but this accounts for only about 10 percent of the total cultivated area (Table 2).[1/] Approximately one-third of the rice farms are irrigated, and modern varieties are grown extensively in the irrigated areas. Modern varieties are at present grown on only a small percentage of the rainfed farms which account for nearly half of the total area, and to an even lesser extent in upland and deep water areas. But where the potential exists in the rainfed and upland areas for growing more than one crop, the short season modern varieties may play an important role in increasing production in the near future.

Eight rice farming systems based upon degree of water control are sketched out in Table 3. The level of infrastructure investment (irrigation, roads, etc.), cash inputs, and labor use are designated for the typical farm in each category (H = high, M = moderate, L = low). The IRRI engineering program is focused on small farms using a moderate

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[1/] In countries such as Bangladesh and Java in Indonesia, the number of farms of less than one hectare is a much higher percentage than the overall average indicated by the figures in Table 2.

amount of cash inputs and labor (100 man-days per hectare). This includes most of the irrigated area where modern varieties are now grown extensively, and that portion of the rainfed and upland areas where the potential for intensification of cropping systems seem to exist (systems 1 - 4).

The remaining four systems include the relatively small but well-irrigated farms in East Asia-Japan, Taiwan, and Korea where wage rates are rising and labor-saving technology is being rapidly dopted, and at the other extreme, the less commercialized rainfed, upland, and deep water areas where not only capital but labor inputs are low.

The first four systems account for more than 60 percent of the farm operating units and 45 percent of the farm area. However, there is considerable variation in the number of farmers and area represented from one farming system to another. While there are pressures to serve the very small farmers who represent 40 percent of the total, it would be difficult to design machinery for this group that would have a major impact on production. It is perhaps fair to say that IRRI machinery designs to date have been more appropriate for farming system 1, although considerable thought has been given to the extension of services of equipment owned by farmers in this group to those in system 2 through contract operations or possible joint ownership.[1/]

Rice farms in Asia typically hire a high percentage of the labor used in rice production. With the exception of East Asia, hired labor

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[1/] The low level of cash income of farmers found in this system makes generation of the necessary capital extremely difficult for small farmers wishing to own and operate machines independently. There are, however, selective opportunities to design and introduce small, low-cost devices making intensive use of labor which offer significant potential for improving resource productivity and output on these small farms.

usually makes up more than 60 percent of the total. The hired labor force includes a growing number of landless laborers who depend on this work for a major source of their income. Thus, mechanization of those tasks which use a large amount of hired labor should probably receive low priority. Major tasks in irrigated rice production together with their labor requirements (H = high, M = moderate, L = low) using traditional practices are listed below:

	Labor requirement[1/]	
	Total labor	Hired labor
Land preparation	H	L
Transplanting	H	H
Fertilization	L	L
Plant protection	L	L
Weed	H	H-M
Water management	M	L
Harvesting	H	H
Threshing	H	H

From this listing, it can be seen that transplanting, harvesting, threshing, and in some cases weeding require large amounts of hired labor.

One of the areas of research and machinery design in agricultural engineering has been land preparation. The evidence does suggest that there is a considerable demand for tractor services for land preparation,

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1/ There is considerable variability among countries in the degree of intensity with which labor is employed in tasks in the rice production sequence. There will also be differences by country and within countries in the division hired and family labor use for individual tasks. The above represent an aggregate estimate of a "typical" rice farm in the irrigated regions of Asia.

but the social benefits have been a matter of considerable debate. Research conducted by the Agricultural Engineering Department has already demonstrated that there is no direct yield advantage for tractor as compared with animal power in land preparation. The table indicates that potential labor displacement through mechanization is for family rather than hired labor. As long as the farm operator is free to make the decision regarding adoption, the labor displacement issue is not as acute, but the social benefits may still be negative in particular if tractor purchases are heavily subsidized.

A main rational for tractor mechanization is the importance of timing and the effect that this has on yield and area planted. Presumably, the introduction of tractors would shorten the time required for completing land preparation and make it possible to: (a) grow more crops, (b) insure a high yield from one or two crops in areas where water is limited or (c) release land from feed to food production. The question that needs to be answered is how much time can be reduced and date of planting advanced, and what effect this would have on production and yield.

Figure 2 diagrams the relationship between the method and timing of land preparation and final yield or output. Advancing the date of seeding or transplanting depends upon the availability of water as well as power. A more detailed investigation along the lines of this model should make it possible to define those situations in which farm power is a major constraint to increased output.

Post-production technology

The quality as well as the quantity of rice is a function of both the production and processing practices used. Choice of variety, cultural practices in production, methods of harvesting, threshing, handling, cleaning, drying, storage and milling all ultimately affect the characteristics and volume of rice reaching the consumer. In general, however, decisions affecting post-production operations are separable from those of production.

There is a wide range of labor and capital combinations employed in post-production techniques. The selection of a particular technology is heavily conditioned by prevailing institutional arrangements, access to markets and the nature and level of economic incentives facing farmers and millers. As was mentioned previously, operations in the post-production sequence tend to be the most sensitive in terms of potential labor displacement because of the widespread practice of paying labor a portion of the crop following the threshing operation.

There have been many unsuccessful attempts to improve the performance of post-production systems through the introduction of improved machinery and management. The evidence indicates that many of these attempts were planned and implemented with little understanding of the problems or their possible causes. There has also been a heavy preoccupation with the large-scale commercial processing sector rather than small village level milling and farm operations. With more than one-half of all rice retained in the rural areas passing through these small-scale systems and non-farm markets acting as the residual claimants, it is imperative that more attention be given to the technical needs of this sector if marketable supplies are to be increased.

will accentuate the need for more efficient facilities, particularly at the farm and village level where traditional techniques continue to constitute the bulk of post-production capacity.

In summary, technical improvements in post-production techniques leading to increases in quality and quantity appear possible in three distinct areas: (1) through a reduction in losses caused by untimely and inefficient harvesting, threshing, drying and storage operations; (2) by upgrading the technical efficiency of existing small-scale village processing facilities to improve recovery rates; (3) by improving head rice recovery and nutritional quality through integration of individual elements of farm and mill level systems.

Empirical Examples from IRRI Research

In this section, we draw upon examples from research conducted at IRRI to illustrate the potential solutions to problems which are associated with the use of improved rice varieties and other modern inputs.

Direct seeding of rainfed rice

Lowland rice production which relies entirely upon rainfall accounts for approximately 50 percent of total rice production area in the Asian region (Table 1). Under prevailing rainfed production

systems, it has usually been possible to grow only one crop per year and only during the latter half of the wet season when rainfall is declining. Using short season varieties in conjunction with improved cultural techniques, it is possible to grow two crops. These two systems are illustrated in Fig. 4. Under the improved system, it is necessary to prepare the land for the first crop in a dry or unpuddled condition and direct-seed the crop instead of transplant.

Land preparations under these conditions requires more timeliness and higher energy inputs -- in general possible only using mechanization. Note also that the first crop is harvested at the peak of the rainy season. To ensure that the crop is removed efficiently so that a subsequent crop can be sown, it is necessary that techniques be available to harvest, thresh, dry and preserve paddy under high moisture conditions.[1/]

This improved rice production system is an example of how successful use of improved genetic materials and management techniques must be closely coupled with improvements in the technology to carry out farm level field- and post-production operations.

Fertilizer and insecticide placement

The recent rise in the cost of fertilizer and other chemicals has emphasized the need to improve the efficiency in their use through better timing and placement of applications. Experiments conducted by

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1/ The improved double cropping system outlined requires major changes in land preparation, seeding weeding, threshing and drying techniques. A number of promising designs are being tested in cooperation with the Department of Rice Production Training and Applied Research.

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The recent rise in the cost of fertilizer and other chemicals has emphasized the need to improve the efficiency in their use through better timing and placement of applications. Experiments conducted by

the departments of Agronomy and Entomology demonstrate that precision placement of both fertilizers and insecticides can significantly reduce application rates. By placing fertilizer 8 to 10 cm below the surface in flooded soils, there is a decrease of 50 to 70 percent in application rates over conventional techniques of surface broadcasting with no significant decrease in yields.

Root zone application of systemic insecticide reduces the number of applications from four to one per season with more rapid and effective protection than possible with either foliar sprays or granular application in the irrigation water.

However, if this technology is to be adopted by farmers, a way must be found to place the fertilizer properly with little cost and effort. What appears on the surface to be a very small problem is in fact rather complex. Chemicals can be applied in liquid or granular form. Application at depths shallower than 8 to 10 cm will cost less but will reduce the efficiency gained through placement. At each step of the way in the equipment design there has to be a continuing dialogue between engineers and biological scientists. Promising designs will have to be appraised by economists and tested by farmers. A successful piece of equipment if widely adopted could have a major impact on production efficiency.

Grain drying

Research in the Engineering Department indicates that there is both a qualitative and quantitative benefit to be derived from use of improved drying technology. In a series of post-production pilot trials, the combination of a simple batch drier with traditional methods of harvesting, threshing and handling, produced a 2.6 percent increase in overall milling recovery and a 10 percent increase in head rice. Employing other combinations of improved post-production technology, it was possible to increase overall rice recovery by as much as 10 percent over traditional methods. Optimal timing of harvesting and threshing are often meaningless without the addition of drying facilities in the system.

We pointed out earlier that successful use of an improved double-cropped rice production system in rainfed areas will be partially contingent upon the availability of drying facilities during the wet season harvest. The same is true in irrigated areas where double or triple cropping becomes possible.

Drying is much more than a technical problem, however. The proper organization and management of drying systems, particularly at the village and individual farm level is crucial to their successful adoption and use. There also needs to be considerably more research to determine the correct mix of economic incentives to induce farmers to use drying facilities.

Drying is a critical operation, but it is only one element in an overall system. Its profitability is tied closely with improvements in other post-production operations, infrastructural development and varietal research.

Criteria for Establishing Research and Development Priorities

We have outlined the major relationships between use of the improved rice technology and mechanization. A number of specific examples were cited to illustrate the nature and importance of these relationships.

As a first approximation we have presented in Table 4 a set of criteria to specify project and task priorities grouped under five broad headings. The first assesses the private profitability of an innovation to farmers and the conditions necessary for its successful introduction and use. Of primary concern is the impact the innovation has on farm income. If technology is not profitable to the individual adopter, other factors become unimportant. In many cases, the degree of profitability is difficult if not impossible to measure quantitatively because of the inherent value a farmer may place on improvements in personal welfare.[1/] Reduction in drudgery and provision of a more attractive

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[1/] Distortions in relative factor and product prices caused by subsidies on credit, input and output prices and wage legislation may create inconsistencies in priorities based on private versus social objectives. From an overall development perspective, the design, development and use of appropriate mechanization technologies should be closely coupled with complementary government policies which minimize such distortions. Without such policies, decisions affecting research and development activities embody the dilemma of choosing between private profitability, which may enhance the welfare of the adopter but have negative effects elsewhere, and social profitability which improves overall welfare, but could result in a low level of adoption.

working environment are examples of these qualitative factors.

The second set of factors measures the impact of a particular innovation on non-farm activities such as increased industrial incomes, generation of employment in manufacturing and distribution activities and changes in capital investments required to produce farm equipment.

A third group of criteria examines the effect on overall societal objectives such as aggregate food supply, the distribution of benefits and complementarity with other technological changes.

The fourth section examines the impact of change on social costs, i.e. the public investment necessary for successful introduction and use of a particular technology. Training education, roads and investment incentive programs are examples of the costs.

The fifth set of criteria focus on the relative and absolute advantage that IRRI may have in carrying out research and development activities on a particular project. The time necessary to develop and introduce a machine, its development costs and existence of competing institutions or agencies make up this set of factors.

We have asked the engineers and economists at the Institute to rate each project/task using each criteria on a scale of 1 to 5 with 5 having the highest value. By weighing the criteria to reflect their relative importance, it is possible to develop an overall ordinal rating for projects, for selection of rice production and post-production tasks which should receive priority attention, and for measuring IRRI's comparative advantage in conducting R & D in a particular area.

The actual formulation of parameters, conceptualization of designs and fabrication of prototypes will continue to be a function of the engineering development staff.[1/] The criteria we have outlined will serve to sharpen the focus of the mechanization program, permit measurement of the potential benefits and costs of individual projects and forge a closer working relationship among complementary discipline/program areas.

[1/] While the criteria provide a procedure to allocate research and development resources, such a structure should embody sufficient flexibility to permit innovative, pioneering work, of a type embodying a high risk component, although within the overall mandate of the IRRI program.

Table 1. Estimated percent of rice crop area and production by specific land type in South and Southeast Asia, early 1970's.

	Crop Area		Production	
	mid-60's	early 70's	mid-60's	early-70's
Irrigated				
Single crop	10	19	15	24
Double crop	10	14	25	24
Rainfed	50	47	42	40
Upland	20	10	10	5
Deep water	10	10	8	7
	100	100	100	100

Table 2. Number of farm operational holdings by size, Asian countries, ('000 of farms, ha.)

Country	.5	.5-1.0	1.1-2.0	2.1-3.0	3.1-5.0	5.1-10.0	10.0-20.0	over 20.0	Total	Year
India a/ b/	9102	10783	11191	6165	7466	2958	1795	514	49874	1961
Indonesia c/	5332	3245	2223	693	431	221	69	22	12236	1963
Bangladesh a/ c/	1492	1677	1615	698	442	188	27	d/	6139	1960
Pakistan a/	742	856	806	581	759	729	388	d/	4860	1960
Thailand c/ e/	na	595	945	na	884	616	163	11	3214	1963
Philippines f/	89	161	642	459	404	290	100	21	2166	1960
Nepal g/	630	300	313	na	341	492	d/	d/	2076	1965
South Vietnam c/	692	355	411	182	143	70	19	d/	1872	1960
Sri Lanka c/ h/	411	350	222	132	na	38	8	6	1167	1962
West Malaysia c/ k/	46	158	99	72	57	13	4	1	450	1960
Total	18536	18480	18467	8982	10927	5614	2573	575	84054	
% of total units	22.0	22.0	22.0	10.7	12.9	6.6	3.1	0.7	100.0	
% of total area	2.5	7.6	12.1	10.8	19.1	18.4	15.5	14.0	100.0	

a/ Size categories are: <.4, .4-1.01, 1.01-2.02, 2.02-3.04, 3.04-5.06, 5.06-10.12, 10.12-20.23, over 20.23
b/ Source: Directorate of Economics and Statistics, "Indian Agriculture in Brief," 11th ed.
c/ Source" FAO report on the 1960 World Census of Agriculture.
d/ Included in previous size class.
e/ Size categories are: <.96, .96-2.4, 2.4-4.8, 4.8-9.6, 9.6-22.4, over 22.4
f/ Source: Bureau of Census and Statistics, 1960 Census of Agriculture
g/ Source: Nepal Ministry of Economic Planning, "Physical Input-Output Characteristics of Cereal Grain Production for Selected Agricultural Areas in Nepal."
Size categories are: <.5, .5-1.0, 1.1-2.0, 2.1-4.0, over 4.0
h/ Size categories are: <.4, .4-1.0, 1.1-2.0, 2.1-4.0, 4.1-10.0, 10.1-20.0, over 20.0
k/ Size categories are: <.4, .4-1.2, 1.3-2.-, 2.1-3.0, 3.1-6.0, 6.1-10.0, 10.1-20.0, over 20.0

Table 3. Rice farming systems in South, Southeast and East Asia based on water control showing different levels of input intensity.

	Farming Systems[a]							
	IRRI Focus				Other			
	1 Irrigated small	2 very small	3 Rainfed multiple crop	4 Upland multiple crop	5 Irrigated[b] East Asia	6 Rainfed single crop	7 Upland single crop	8 Deep water
Infrastructure	M	M	L	L	H	L	L	L
Cash Input	M	M	M	M	H	L	L	L
Labor	M	H	M	M	M	L	L	L
Estimated % of Farms	15	40	6	1	12	17	4	5
Estimated % of Area	23	9	10	2	6	32	8	10

[a] For the typical farm in each system the level of infrastructure development (irrigation, roads, etc.), cash inputs, and labor use is designated as L = low, M = moderate, H = high.

[b] Japan, Taiwan, and Korea.

Table 4. Ranking Priorities for Research and Development in Agricultural Mechanization Systems

Criteria[1/]

I. Private Benefits (farm level)[2/]
   A. Increase farm income[3/]
      1. increase output/ha/year[4/]
      2. reduce costs/ha
      3. improve quality[5/]
   B. Reduce arduous nature of work
   C. Reduce risk[6/]
   D. Potential for adoption[7/]

II. Private Effects (non-farm)[8/]
   A. Increase industrial income
   B. Increase capitalization requirements[9/]
   C. Increase employment[10/]

III. Social Benefits[11/]
   A. Increase aggregate production
      1. physical production
      2. quality of output
   B. Equitable income distribution[12/]
   C. Impact on hired farm labor
      1. increases total labor use[13/]
      2. better distribution over time[14/]
   D. Enhances development of manufacturing[15/]
   E. Has complementary effects on use of other technologies[16/]

IV. Social Costs
   A. Institutional/organizational development[17/]
   B. Infrastructural development[18/]
   C. Development of manufacturing capabilities[19/]

V. Research and Development Costs
   A. Resource costs
   B. Time to develop[20/]
   C. Ease of extension
   D. IRRI's comparative advantage[21/]

1/ In ranking projects, a scale of 1 to 5 is employed with 1 being the lowest in terms of desirability and 5 being the highest.

2/ Private benefits are returns as perceived by the individual farmer or adopter of the innovation. Higher returns to individual farmers are not necessarily consistent with improved overall welfare for society as a whole.

3/ Increased income derived from higher production or value of crops sold and improved opportunities for off-farm or subsidiary farming occupations.

4/ Increased output may be achieved through higher yields, reduced losses, increased cropping intensity or increased land under cultivation.

5/ For example, improved quality may result from more timely and efficient harvesting, threshing and storage practices.

6/ Reductions in risk refer to lowering the variability and dependence on natural phenomena such as rainfall through devices such as pumps.

7/ Refers to the extent of the market and the overall attractiveness of the innovation to individual farmers.

8/ Primarily benefits accruing to the manufacturing and distribution sector.

9/ The additional capital investment necessary to fabricate and distribute a particular machine.

10/ Refers to the additional employment opportunities generated in the production, distribution and servicing of a machine.

11/ Social benefits are distinct from private benefits. They represent improvements in welfare and income that accrue to society as a whole through lower food prices, improved grain quality and more assured supplies.

12/ A measure of distribution of benefits resulting from the introduction and use of a particular innovation.

13/ How much total employment changes on an annual basis.

14/ Change in the seasonal labor use profile.

15/ The degree to which introduction of a machine strengthens inter-sectoral linkages and stimulates manufacturing activities.

16/ The degree to which use of a mechanical innovation lead to other beneficial changes in productive systems such as improved water use efficiency and processing systems producing higher recovery rates.

17/ The level of organization or institutional support necessary to successfully implement or use a mechanization system.

18/ The cost to develop infrastructural facilities such as roads, electrical grids or irrigation systems to ensure successful operation and use of an innovation.

19/ The need to develop special training or educational skills to develop local manufacturing capabilities.

20/ In ranking projects using this criteria, one refers to a period of 1 to 2 years, two to 3 to 4 years, three to 5 to 6 years, four to 7 to 8 years, and five to 8 years or longer.

21/ Measures the relative advantage IRRI has in carrying out development work on a particular project. The existence of another organization with special interests or skills to handle a particular project would lead to a lower ranking.

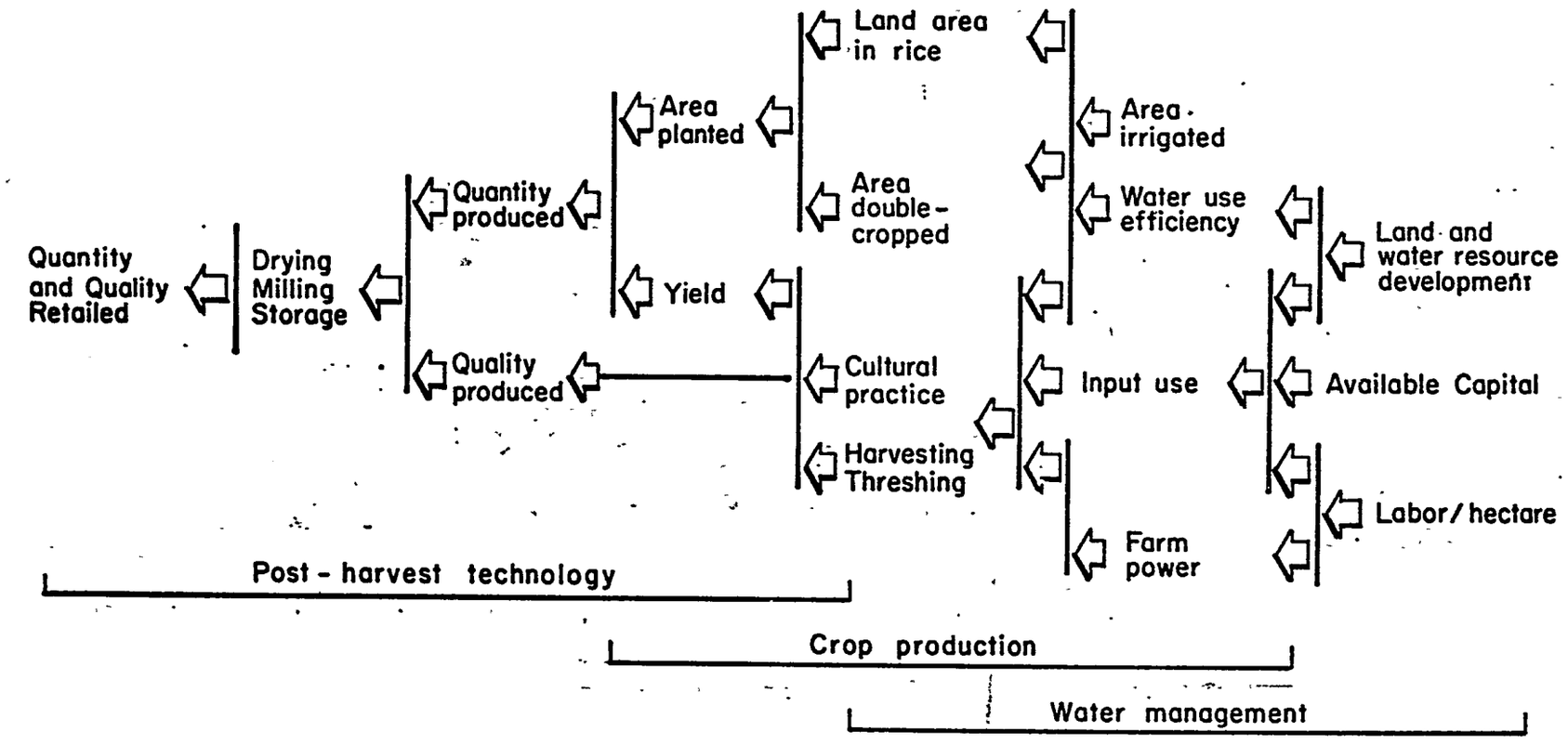

Fig. I Mechanical Technology in a Rice Production System.

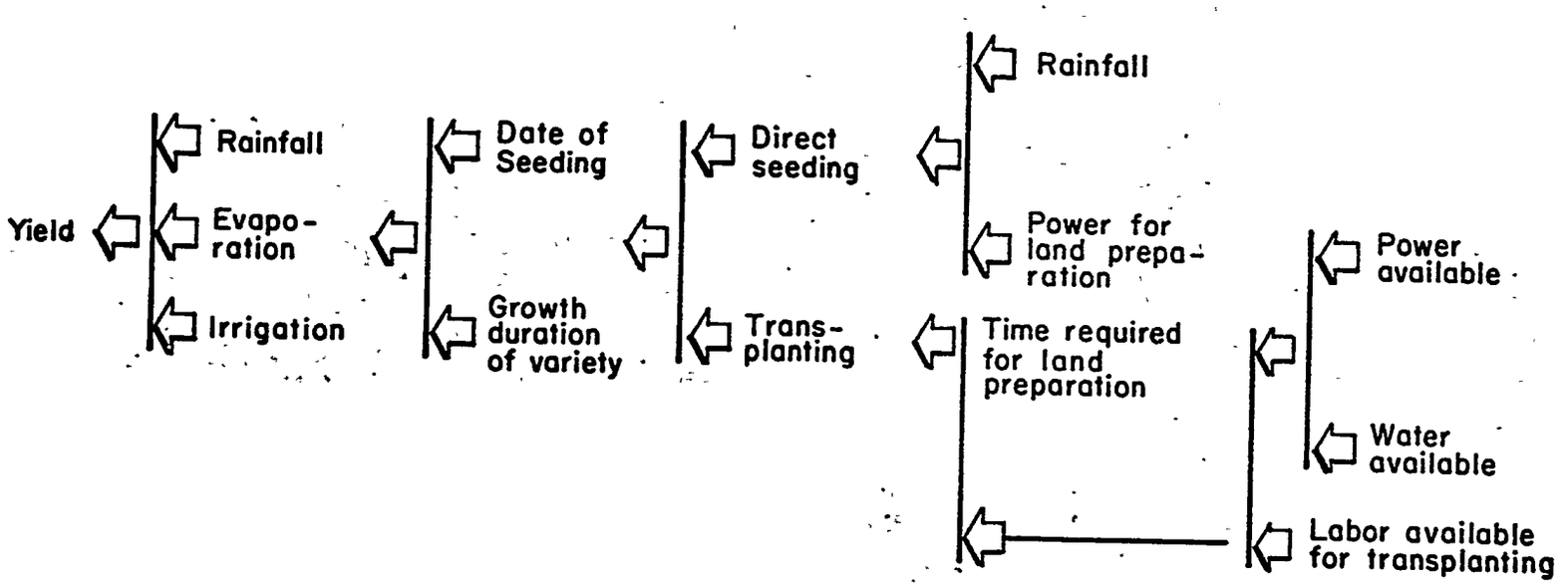

Fig. 2 Measuring the benefits of timing in land preparation through systems analysis.

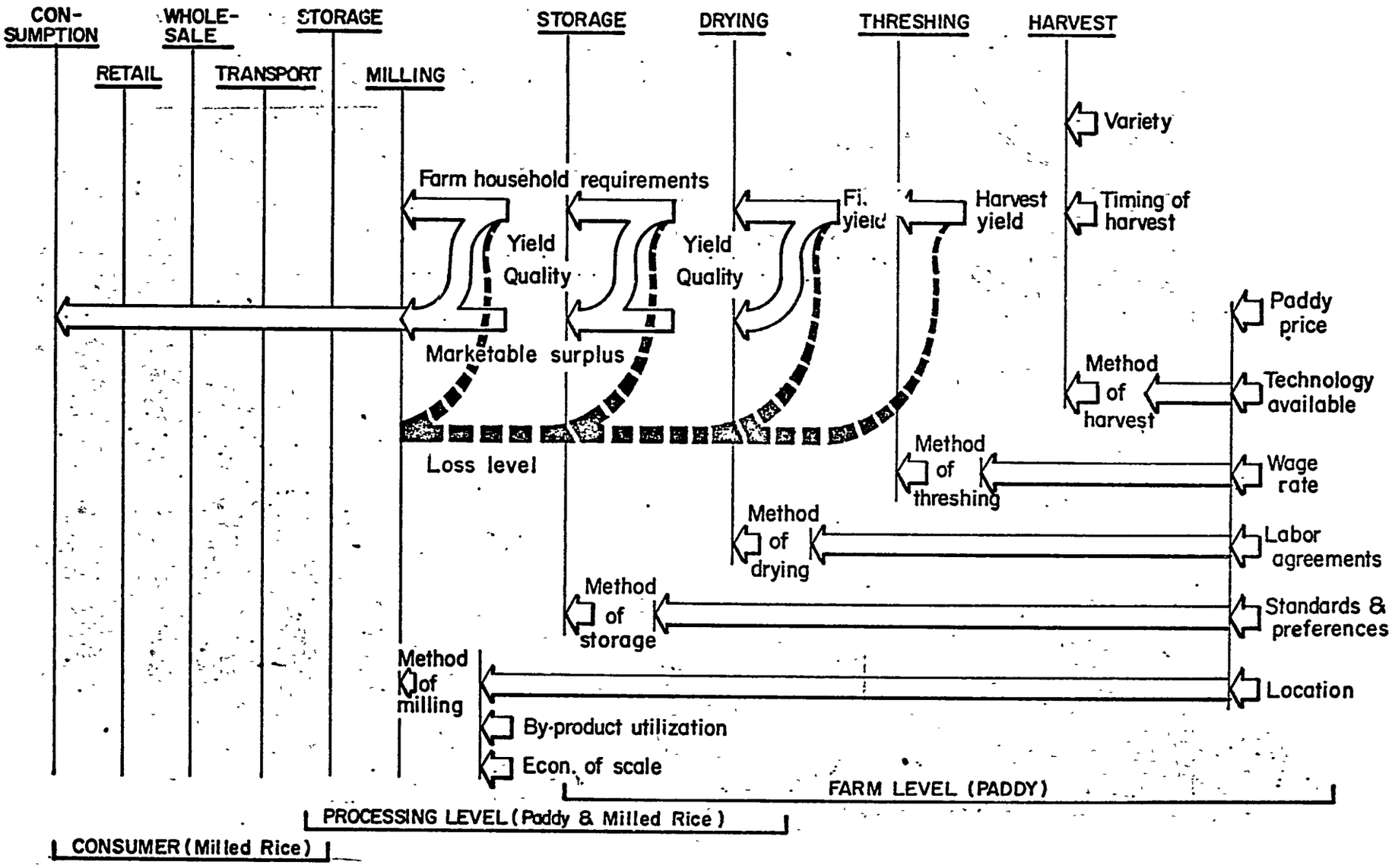

Fig. 3 Farm and Processing Level Post-Production Systems.

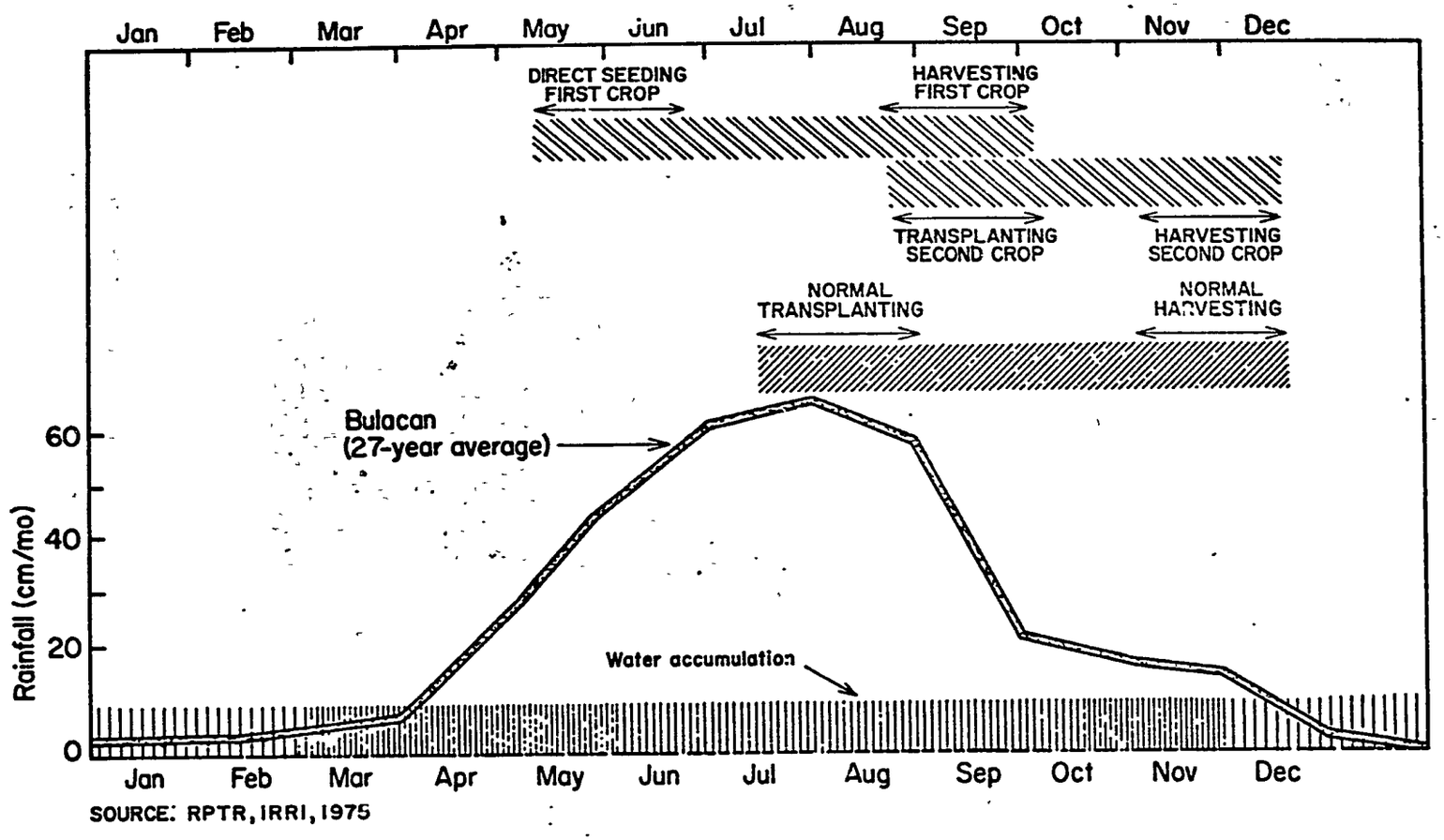

Figure 4. Actual and Potential Rice Production Systems Under Rainfed Conditions in Central Luzon, Philippines.