UNSPOLRED BY ABUNDANCE AND COMFORT, THE DEVELOPING NATIONS NOW HAVE AN ENVYABLE OPPORTUNITY TO DEVELOP AGRICULTURAL MECHANIZATION SYSTEMS, NOT ONLY CONSERVATIVELY, BUT MORE PRODUCTIVELY AND ECONOMICALLY THAN GENERALLY RECOGNIZED. THIS IS THE FIRST OF SEVERAL ARTICLES PLANNED OVER THE NEXT FEW YEARS TO GUIDE THE REORIENTATION OF MECHANIZATION. THOSE TO FOLLOW ARE:

PART II - ADAPTATION - NOT INVENTION - OF MACHINES.
PART III - OUR GREATEST TOOL - "THE TRIAL DEMONSTRATION".
PART IV - TRAINING.

NO LONGER SHOULD THE WESTERN WORLD'S OBJECTIVES AND PATTERNS OF AGRICULTURAL MECHANIZATION BE ADOPTED PER SE BY THE DEVELOPING COUNTRIES. THEIR MASS PRODUCTION TECHNIQUES TO REDUCE LABOUR AND COSTS AND MAXIMIZE CONVENIENCE ARE SIMPLY NOT APPLICABLE. IN PLACE MUST GO SELECTIVELY MECHANIZED SYSTEMS THAT MAXIMIZE CROP PRODUCTION AND LABOUR UTILIZATION PER UNIT AREA PER YEAR. THIS PAPER WILL PRESENT THE JUSTIFICATION AND THE GUIDELINES FOR THE CHANGE.

DESPITE MEASURABLE PROGRESS IN MANY INSTANCES THE DEVELOPING COUNTRIES' MOST PRESSING PROBLEMS REMAIN: TOO MANY PEOPLE, AND TOO LITTLE FOOD AND/OR POOR DISTRIBUTION. WHAT HAS MECHANIZATION TO DO WITH THESE PROBLEMS? A LOT! IT IS NOW RECOGNIZED IN LIMITED CIRCLES THAT MACHINES, SELECTIVELY AND WISELY USED, IN CONJUNCTION WITH MULTIPLE CROPPING WILL CONTRIBUTE MARKEDLY TO:

- INCREASED YIELDS AND PRODUCTION OF FOOD CROPS;
- INCREASED UTILIZATION OF LABOUR (MAN HOURS PER YEAR, UNIFORM INPUT, REDUCTION OF PEAKS AND PRODUCTIVITY).

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However, our policies, attitudes and action programmes are simply inadequate to meet these needs. Specifically we need facts on the relationship of machine systems to yield, labour utilization and multiple cropping. We need to eliminate the unessentials in talks, plans and programmes and concentrate on getting tangible measurable facts. Only then can the validity of machine systems, economically and otherwise, be determined.

The Mechanization Dilemma

Mechanization is the one segment of a total agricultural programme in the developing nations that has never been well thought out. It has been haphazard, hurried and so many times misdirected, both in its objectives and interdisciplinarian approach. Examples are numerous: a piece of steel added to an indigenous plough; a puddler made of steel; harness for bullocks; universal frame with wheels for animal drawn improved equipment; steel mouldboard plough; low-power tractors of varietal configurations; and the list goes on and on. Most importantly, much of the work has been on single machines and operations. True, these efforts have made contributions. They were, however, really insignificant in meeting the more pressing need for systems that produce more food and put more people to work productively. In so many instances their value to agriculture has been measured in terms of draught, time, convenience, etc. So often, too, designs have been cobbled up to meet the single objective, however noble, of "something cheap for the poor farmer". And so many times the emphasis was on mechanizing existing single operations.

Much has been written and spoken of the pros and cons of mechanization in the developing countries. Several recent papers adequately cover the world's knowledge and situation. Notable are papers by C. Voas (1), E. von Hulst (11) and A. Koens (13). Unquestionably these and other works contribute greatly to our knowledge of mechanization. Still, facts are woefully inadequate.

It is not surprising to find that government administrators and leaders in both developing and developed countries have vacillated somewhat in establishing firm continuing policies in mechanization for the non-industrialized nations. There is always an uneasiness among such leaders about promoting machines, largely because of the growing population and unemployment. As a consequence a middle ground is hedged - some tractors, improved hand and animal powered tools, and local industries. Still, there is something amiss in this rationale. Relatively undiscovered and unpromoted is the fact that machines wisely selected and used will not only satisfy the latter recognized needs, but more importantly will contribute to higher crop yields and labour utilization. Outside technical Consultants have not been sharply tuned to these values either, both in their knowledge and obligated leadership.

It is time to stop arguing the pros and cons of mechanization and in place plan and implement action programmes. Stout and Downing said "National mechanization policies are desperately needed in every country" (2). True, providing they lead to action programmes based on facts. We need to get those facts by controlled experiments.

A New Approach

It would be well to first understand the past pattern of progress in agriculture and mechanization. A study by the author of a total of 23 regions, countries, districts and farms covering a time span of more than six years indicates that higher levels of general mechanization have come after crop yields are up. Note Figure 1 attached. The horsepower per cultivated hectare in this chart is used as an indicator of the degree of mechanization. This indicator includes all three power sources, that is human + animal + mechanical. As von Hulst summarized (11), most engineers now recognise three main levels of mechanization; hand tool, animal draught and mechanical power.
FIGURE 1

CHART OF AGRICULTURAL PROGRESS

AVERAGE AGGREGATE YIELD OF MAIZE CROPS
TONS PER HECTARE (LOGARITHMIC)

Egypt
U.S.A.
Israel
Ludhiana
Africa
Asia
India

WHY NOT THIS?
.3 hp/ton

A-B Developing Countries
.1 hp/ton

HORSE POWER
### REFERENCE NUMBERS

<table>
<thead>
<tr>
<th>Name &amp; Classification</th>
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<td>Iran:</td>
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<tr>
<td>Farm Coop. of Rudpishe</td>
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<tr>
<td>Gorgan &amp; Gonbad Province</td>
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<tr>
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<tr>
<td>Farmers Zafri &amp; Keyha, Gorgan</td>
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<tr>
<td>Khuzestan Province</td>
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</tbody>
</table>

### 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.

Data taken from FAO Production Year Books and local collections.
The chart teaches that agricultural areas in the past have generally developed initially along line A-B, and later along C-D. Apparently, along A-B crop yields, and returns, are greater by using other inputs such as fertilizer. The rate of increase is 0.1 horsepower per ton of crop yield per hectare. At around 2.5 tons per hectare mechanization seems to compete economically with other inputs and thus is increased rapidly along line C-D (0.7 hp increase per ton yield). Along line A-B the power is invariably increased by adding tractors and tillers, and not without good reason. Along line C-D, however, tractors, as well as animal power, are accompanied by more precision type of equipment such as a grain drill.

Note that India, as a country, during the period from 1964/65 to 1970/71 moved generally along line A-B (Points 20 to 21) whereas Ludhiana District in India has achieved the approximate 2.5 ton turning point and is now advancing swiftly along C-D (points 50 to 51 to 52).

W.H.M. Morris of Purdue University with experience in Ivory Coast spoke strongly at the 1974 CIGR meeting of the need for increased production to precede mechanization. However, much depends on the area and its peculiar situation. Von Huiist (15) rightly points out that advancement along line A-B is particularly true for areas of high population density. In contrast, he says that new areas being opened up benefit from tractor prepared seed beds and plantings and therefore cannot wait for increased yields to occur first. Also, in dry areas soil and water conservation practices made possible by mechanization are more important to increased yields and production, than say fertilizer and fertilizer responsive varieties.

These realizations bring up two points. The chart is really intended as an aid to better understanding how an area has progressed, and secondly may be used to plan and record its future progress. The status of a nation with respect to crop productivity and energy capacity for field operations at any given time and relative to other agricultural areas is more easily comprehended by using this chart. Note that during the five-year period Japan increased its farm power from 2.3 hp per ha to 4 and the USA from 1.02 to 1.55 hp per ha. On the other hand, Africa, Asia and India have made relatively modest increases in this regard. The chart points out rather dramatically the ever widening gap between the developed and less developed countries.

Suffice to say at this time that each agricultural area is uniquely different (to be covered later herein) and must use its own "Chart of Progress". For example, an area might well justify progress along line A-B providing their mechanization is properly orientated as suggested later. The problem of the developing countries is really one of determining the kinds and types of machines that are vitally needed, or more appropriately, adopting the "selective mechanization" approach. It is for each area to maximize crop production and optimize energy input in its own way, and to record and compare its advances using the chart—a reorientation of mechanization, if you please, in the total scheme of agricultural development.

**Energy and Green Crops**

The fossil energy that will be required for more highly mechanized systems and for the fertilizer input as well, is of major concern. A critical inspection of the energy input with respect to achieving the world's food goals is, therefore, compelling. A study by Pimentel et al. (3) of the energy requirements in the USA for producing corn in 1954 and in 1970 is summarized in Table 1. Note that in 1970 the field operations account for around 42% and the off-field operations about 17% of the total fossil energy input (solar energy excluded). The increase in the use of fertilizer, etc., and of such off-field operations as drying during the 25 year period from 1945 to 1970 reflects the adoption of fossil energy intensive technologies that have characterized the progress of developed nations. The increase in energy input is also apparent in Figure 1. The horsepower in that figure represents the capacity for carrying out, largely, the field and off-field operations.
Table 1
Percentage Distribution of Fossil Energy Inputs for Producing Corn in USA
(adapted from Pimental et al. (3))

<table>
<thead>
<tr>
<th>Type of input</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1945</td>
</tr>
<tr>
<td>Labour</td>
<td>1.4-</td>
</tr>
<tr>
<td>Field operation (machinery + fuel)</td>
<td>78.0</td>
</tr>
<tr>
<td>Fertilizer</td>
<td>8.1-</td>
</tr>
<tr>
<td>Seed</td>
<td>3.7-</td>
</tr>
<tr>
<td>Pesticides</td>
<td>0</td>
</tr>
<tr>
<td>Irrigation</td>
<td>2.1-</td>
</tr>
<tr>
<td>Off-field operations</td>
<td>6.7</td>
</tr>
</tbody>
</table>

While conservation of energy applied to agriculture may well be important in the developed countries at this time, it definitely should not be a top priority objective in those countries that are in the developing stages and have great potentials for producing food for the world. India is one such country.

In the first place, the developing nations' existing power source for food production is not always predominantly tractor. Table 2 illustrates this point.

Table 2.
Distribution of Agricultural Power

<table>
<thead>
<tr>
<th>Region</th>
<th>Total HP per ha.</th>
<th>Percentage of available power per ha.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Human</td>
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<tr>
<td>Asia (exc. China)</td>
<td>.22</td>
<td>26</td>
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<tr>
<td>Africa</td>
<td>.10</td>
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<td>.25</td>
<td>9</td>
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<tr>
<td></td>
<td></td>
<td>24 *</td>
</tr>
<tr>
<td>India</td>
<td>.23</td>
<td>26</td>
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<tr>
<td>Ludhiana Distr., India</td>
<td>.82</td>
<td>4</td>
</tr>
<tr>
<td>West Godavari Distr., India</td>
<td>.40</td>
<td>20</td>
</tr>
</tbody>
</table>

Asia is very much tied to an animal powered agriculture for some time to come even under the most optimistic tractor production and/or import programme. One must be careful, however, in looking at large areas. Ludhiana District in India, for example, obtains around 74% of its power from tractors compared to 12% for India as a whole. West Godavari District derives 40% of its agricultural power from animals.

Secondly, the biological system remains as the world's most effective converter of the sun's free and limitless energy. Of the total energy input in producing and processing corn in the USA under a highly mechanized system, around 90% comes from the solar source (3). Of the remainder, around 10% comes from fossil fuel and an
insignificant amount, perhaps 0.2% comes from labour, (see Figure 2-A). Under more intensive labour and animal power farming, however, labour would be greater and fossil fuel energies less. Nevertheless, these quantities are minor in relation to the solar input. (Figure 2-A).

Thirdly, the product of the biological factory, food and fiber, is also energy. It is used to fuel the man and animal power. In this sense, it is reusable.

Consequently, it doesn't make sense to support the sole objective of arbitrarily reducing the fossil fuel input to agriculture. Instead we should concentrate on capturing more of the sun's energy by maintaining maximum vegetative growth—and production—throughout the year. And in doing this we should be as conservative of fossil energies as possible. However, if it takes more fossil energy for maximum vegetative growth, so be it. Conservation can be in less essential uses such as processing food for convenience.

For the sole purpose of exciting one's imagination to the opportunities of energy-crop studies, look at Figure 2-B. One crop (maize) is compared with two crops (maize-wheat) per hectare per year in India (5). The energy figures, in hp hours of output per ha per year, are estimated and are for field operations only, excluding the amount to manufacture the machinery. Twelve hp hours of energy is saved for every ton of food grains produced by the two crop system. The indicated savings come in the land levelling and major seedbed preparation operations.

While 12 hp hours of energy is small compared with the total of 635, the possible returns and benefits certainly are not; around two times more grain, greater and more productive use of labour, and some animal power utilization. Of course twice as much solar energy is used but it is free.

It is also worth noting that system 2 has an improved balance of labour, draught animals and motorized mechanization. C.M. Downing has pointed out the importance of countries with limited foreign exchange to utilize local energy and other resources in developing optimum systems. He said "it is not a matter of arbitrarily reducing fossil fuel input but deciding what to limit (fuel, fertilizer, machines, etc.)"(14).

The calculations for Figure 2-B are estimates based on a hypothetical farm (5). They are presented only to indicate the need for studies in the operations-cropping system area, as this paper will emphasize later. No claim is made to their validity.

Note that in Figure 1, Egypt has achieved comparatively high yields at a low horsepower capacity level. It is true that a large percentage of their cultivated land is irrigated. Nevertheless, there are opportunities in un-irrigated or partially irrigated situation, for higher crop productivity at modest horsepower levels.

Lastly, let it be understood now that power alone will not do the job in mechanization. The tool that converts the power into something beneficial to biological plants—a change in the soil structure, removal of weeds, achieving good seed-soil contact etc.—is vital. Let it be said at this time that more productive systems that maximize the solar and minimize the fossil energy inputs can be developed.

Selective Agricultural Mechanization and Crop Yields

Considering the afore stated background, what is needed to reorientate mechanization? First and foremost, we must recognize that in some instances a positive relationship exists between the machine input and an increase in yields.

Only some machines when used in some farming situations and under some management expertise contribute significantly to increased yields. This is "selective mechanization" in terms of machines, farming situations and managers. Studies in the use of a grain drill in India illustrate this point (4). For a total of 66 trials, the average increase was 12.5 percent, significant to the 5 percent level.
FIGURE 2
ENERGY AND ITS USE

A - Percentage Distribution by Type - Maize, USA, 1970
Ref. No. 3

90% Solar
10% Fossil
0.2% Human

Fossil & Human Inputs Are Essential to Utilize Free Solar Energy

B - Utilization for Field Operations by System
Ref. No. 5

Energy Output of Power Units (t/d) per Hectare

System 1
(65 hp hrs per ton grain)

System 2
(53 hp hrs per ton grain)
(2 x Solar Energy)

Animal
Human
Mechanical (tractor)

Plants - Cropping System - Maize, Sunflower
See Figure 3. The results varied from District to District and, of course, among farmers. Some farmers who managed well their bullock drawn 3-row drill, got as high as 70 percent increase over their conventional country plough method. At the time of these trials, a Punjabi farmer could pay for his drill through the yield increase achieved by using it to seed only 6 hectares - quite an economical investment.

It is important to note that the above cited trials compared modern wheat seeding principles such as precise and uniform metering and placement of seed, side placement of fertilizer and good seed-soil contact, with the conventional farmer practice of using a wooden plough. The power source is immaterial. Although a bullock drawn unit was used, equivalent results are achievable with a tractor powered unit providing the drilling principles, management, and operational skills are identical.

In India in 1965, eighteen field trials were conducted to compare, among other things, the yield of maize resulting from the use of a modern one row bullock-pulled maize planter over the country plough method (6). The resulting average yields presented in Figure 3 were 40% higher for the planter, but not significantly so in this particular set of trials.

Two additional examples of yield-intensive mechanization will be cited. Unlike the two previous examples, the machine(s) do not stand alone. Rather they are some of the necessary inputs to a more complex and improved farming system that does result in increased yields.

The first example is a system for growing maize in India, being experimented with by Y.C. Arya (9). The reader is invited to read his article published separately herewith. The complete system involves bedding on a grade so channels serve both for irrigation and surface drainage (water control), and precision seeding and side placement for the fertilizer simultaneously on a firmed bed. Most importantly in Arya's data was a trial on a farm on heavy poorly drained soil. This new system was compared with the conventional seedbed preparation and using all recommended agronomic practices in both cases. The new system gave 8.28 tons of maize grain yield per hectare against 4.25 tons for the conventional. This is a nearly 100% increase.

The second system involves minimizing soil compaction. Depressed yields resulting from soil compaction is recognized world-wide. Tractors may cause it. In the developing countries centuries of animal traffic together with shallow tillage may cause it.

W.T. Dumas et al. have experimented with a system for producing cotton at Auburn, Alabama, USA, that minimizes compaction (10). Their system established permanent root beds on which no wheel traffic passed, and permanent tracts to accommodate especially designed wide-spaced four-wheel tractors. The yields of the most important treatments appear in Figure 4. The average of two years' data shows increases of 20.5% over the control, regardless of depth of tillage. The control was a conventional tricycle tractor with rear wheels spaced 80" plus a tricycle high clearance sprayer with rear wheels spaced 80". Because the experimental system is only practical with tractors and not with human or animal power, one must attribute the increase solely to tractor mechanization.

Selective Mechanization, Labour Utilization and Multiple-Cropping

The second thing we must realize is that machines can increase the labour input. For example, Faidley and Esmay found that in Bangladesh power mechanization increased the demand for hired labour (12). Also, we need to realize the potential of and in fact the need of machines to increase production per unit area per year through
FIGURE 3

TWO YIELD-INTENSIVE MACHINES

1. DRILL - 60 Trials India
   WHEAT (with Fertilizer Placement) Source: Ref. No 4

   \[ \text{Wheat} \text{ tons per hectare} \]

   \[ \text{12.5\%} \]

2. PLANTER - 18 Trials India
   MAIZE (with Fertilizer Placement) Source: Ref. No 6

   \[ \text{Maize} \text{ tons per hectare} \]

   \[ \text{40\%} \]
FIGURE 4

TWO YIELD-INTENSIVE MECHANIZED SYSTEMS

1. GRATED BED FOR MAIZE (1 trial). Source: Ref. No. 9.
   LUDHIANA, INDIA.

   8.28
   8.25

   Tons per Hectare

   100%

   Graded Bed + Precision Seeding + Fertilizing + Recommended Agronomic Practices
   Conventional Seed-Bed Preparation + Recommended Agronomic Practices

2. MINIMUM SOIL COMPACTION (AV. of 242) Source: Ref. 10
   AUBURN, U.S.A.

   20.5%

   20.5%

   18" Deep Tillage
   8-10" Deep Tillage

   Tractor wheels spaced 120" in traffic lanes
   Control

   Tractor wheels spaced 120" in traffic lanes
   Control

   3000
   2000
   1000

   Seed Cotton - Pounds/Row
In essence then, selective mechanization, increased labor utilization, multiple-cropping and increased production are very much intertwined.

There is evidence that a properly planned and managed combination of multiple-cropping and selective machines will increase the total labor input per hectare and per year. Furthermore, the labor distribution throughout the seasons and the year is much improved. These values were borne out in a hypothetical study of a 12 hectare farm in Ludhiana District, India (5). See Figure 5. For field operations only, this model multicrop farm required a labor input of nearly 0.6 of a man year per cultivated hectare. As a comparison, the district, as a whole, has available only about 0.5 year per hectare. Despite this large labor input in our model, a high and satisfying degree of mechanization was used.

Most importantly the selected machines leveled off the peak labor demand periods and should keep people gainfully employed throughout the year (Figure 5). Multiple-cropping and the diversification from field to field seemed the best means of filling in the valleys of the labor distribution chart. Keep in mind that the off-field operations will contribute measurably to an even higher labor input as well as more uniform distribution throughout the year.

Most notable is an intensive cropping system developed by Dr. Richard Bradfield at IRRI (7). His objectives were to produce a diversity of food for a balanced diet and to increase production and income. Five crops per year with remarkably high yields and income was accomplished with a six horsepower rototiller and attachments. The labor input would be unquestionably higher, more uniform, and certainly more effective and appealing by using the power tiller, although this value was not measured.

Apparently missing in this project is a critical analysis and adaptation of equipment to improve the operations - precision, timeliness, practicality, effectiveness and ease of performance should be the objectives of the missing segment.

It is highly questionable whether the farmer is able or willing to put forth the managerial and concentrated effort required to produce five crops per year. Much will depend on the equipment used and its ease of operation. Nevertheless, the project points the way and represents in part the kind of "operational system" project mechanization experts should be actively engaged in as a top priority.

The next step following Bradfield's experiments should be to get the project off of the experiment station and in a "trial demonstration" on the farm. There, such performance factors as labor input and economics, as well as yield and production under the operational and managerial skill of the farmer, can be meaningfully determined.

I.A.R.I. at New Delhi, India has done some admirable work on relay cropping (8). A four crop, single year rotation gave a consistent yield for four years of 13 to 14 tons/ha. The problem here, again, is one of developing a farm level operational system. It is one thing to interplant small station plots, but quite another to make the system operationally acceptable on a farm. Reported also in reference (9) on multiple-cropping in India are the cost benefits and employment potentials. Both resultant values are extraordinarily good.

The combination of selective machines and multiple-cropping appears to be an unbeatable and necessary combination to achieve the top priority objectives - maximum production, and more and uniform labor input. The real trick is to adapt machines that will make multiple-cropping enticing and exciting to labor. If we don't, labor will still migrate to the cities. Downing (14) rightly put it "The amenities of mechanization are far more important in a modern society than they are given credit for".
FIG. 5
Monthly Distribution of Labor-Months
For 12 Ha. Farm

SELECTIVE MECHANIZATION
2.85% Crop Intensity
11,000 M. Hrs Total

Source: Ref. 5

BULLOCK POWER
100% Crop Intensity
10,500 M. Hrs Total
The Machine Element in a System

One cannot always validate a claim that the use of a machine in the production, harvesting and processing of field crops is a sole contributor to a demonstrated yield increase or to an effective increase resulting from a reduction of losses. The reason is that the machine usually is only one of many exceedingly complex interacting inputs within a system.

This complexity and interdependence of influencing elements within a system can be illustrated in the case of a planting system for maize in rotation with wheat being tried out in Egypt by Ahmed Bahgat and G.W. McLean. The seed bed is prepared by chisel ploughing, cultipacking, harrowing, and planing. Irrigation furrows are formed by the use of a country plough. Two rows are planted by a specially designed planter working astride this channel. Fertilizer is simultaneously placed between the seed and irrigation water (below the seed and to the side). The conventional system involves seed bed preparation with a country plough and no planing to a grade. The furrows are formed by the country plough, basal application of the fertilizer broadcast by hand, and the seed planted by hand. The system is illustrated in Figure 6.

More than a 50% yield increase resulting from using this system is anticipated. None of this increase can be attributed directly to any one or all of the machines. The placement of the fertilizer will unquestionably affect the yields, as will the uniformity of the irrigation from one end of the row to the other, made possible by planing and furrowing. But are these specifications achievable without machines? No! Humans simply cannot and will not compete with some machines in the kind of precision and repetitiveness required. A few, perhaps, but the developing countries' food and labour problems require a workable system on a large area basis.

Another important point pertains to multiple-cropping. The time available to harvest one crop, prepare the seed bed, and plant the next, is very short if the yields are to be maximized. In many instances machines and power will be necessary. It is simply impossible for large agricultural areas to assemble and manage the necessary hand labour. On isolated, special farms, Yes! Of course irrigation is usually a requisite. But, world-wide the cropping intensity of irrigated land is slightly over 100%.

The important point is that some machines are absolutely necessary to make the system work, especially under irrigated situations. If this be so, why should one attempt to segregate out the contribution of those components that are essential? Admittedly, the system can be made to work by using only hand operations on relatively small plots on agricultural experiment station farms. But it is not a rational plan for farm usage in the future. The problem is one of supplying those machines that are needed to make the system practical at the farm level.

The Action Programme

We have pointed out that the scientific facts with respect to mechanization are woefully inadequate. We also said that the scientific facts needed as a top priority are those pertaining to a system. To acquire such requires hard work over many years involving "field plot experiments" at experiment station level, and "field trial demonstrations" at the farm level. These will be covered in subsequent papers. Following are some general policies and attitudes pertaining thereto.

Multiple-Discipline Approach a Must

If we are to have an integrated system, it follows that we must have an inter-disciplinarian effort to "develop" the system. There is no alternative to this principle. Involved in the initial development work of the maize system described and illustrated in the previous section should be the following specialists in
**Figure 6**

**PLANTING SYSTEM FOR MAIZE - EGYPT**

**EXPERIMENTAL SYSTEM**

(Left)

1. Chisel plowing 15 cm. or more deep.

2. Cultipacking and harrowing combination.

3. Land planing (not shown).

4. Forming irrigation furrow with wooden plow. 220 cm. yoke.

5. Planting two rows astraddle furrow.

**CONVENTIONAL PLANTING**

(Below)

Children drop maize seed in a hole on side of performed furrows.
addition to the Agricultural Engineer:

Irrigation and Soil Scientists on furrow lengths, sizes, absorption rates and fertilizer placement;

Agronomists and Plant Breeders on varieties, planting rates, seed spacing and depths, and cultural practices;

Plant Protectionists on treatment of the seed and the use of chemical pest control measures.

The Agricultural Engineer is usually involved in all of the original development studies by the above specialists because they must, (a) integrate the system, (b) make it operative on a practical farm basis, and (c) develop or adapt the machines necessary to make (b) possible.

Where is the Economist in the above? He is very much involved later after pre-operational systems have been devised and evaluated. In the early stages of development economics can be very inhibiting and restrictive. The opposite is required in the early stages. Secondly, a valid economic analysis cannot be made until the benefits of a system are established, in particular the resulting yields and the labour inputs. After these values are known and one is ready to try the system, operationally, on larger plots usually at the farm level, an economic analysis is then important. Also, in later stages the Economist should be heavily involved in policies pertaining to adoption, manufacture and distribution, as they are now doing. Make no mistake, the policy as proposed herein is one of accepting and implementing the idea of developing, by a multiple-discipline attack, new and imaginative systems that are yield, production and labour intensive.

Mechanization Institutes

There are many centres throughout the world whose function is to develop and test agricultural equipment. As is well documented, many of these are concerned, as a top priority, with only one part of a system, as for example, a puddler. Although such objectives are important, the developing countries need a few exceptional centres that are geared, as a top priority, to the development of new systems designed to increase yields, production and labour utilization. It is suggested that a few be established at existing research and development centres where the required specialists are presently at work. To make such a centre acceptable, three points seem important. First, there must be room to recognize the accomplishments of each Specialist. Second, the name must carry the connotation of being as it really is, inter-disciplinarian. "Operational Systems Institute" is suggested. Thirdly, we must recognize that it takes time to develop a machine as a part of a system. Basically the development of a machine is similar to the development of say a new variety. Elements and characteristics are put together to achieve desired effects. Each promising result must be adequately field tested and evaluated.

A complementary requirement to development centres, conventional as well as operational systems institutes, is a coordinating agency. In this regard the international FAO Rice Mechanization Studies in collaboration with Coordinator Prof. A. Moens of and with Wageningen University, Holland is noteworthy. In operation since 1971, it is concerned with exchange of information on designs, field tests, systems analysis etc. Its duties might well be expanded to promote with greater strength the top priority objectives called for herein (16).

Local Planning is the Foundation

Up to this point the discussion has been directed to policies and attitudes at the national level, and well they should. Within a nation, however, is the diversity of agriculture. Crops, soil, rainfall, labour availability, drainage, irrigation,
management competence, and the will to accomplish change, varies widely, even from one farm to another. Therefore, improved cropping systems must be evaluated and applicable to a manageable area - preferably a farm.*

This principle is no different than one governing the use of the other major inputs. For example, recommended fertilizer rates and grades are made on a wide area basis. However, in the final analysis, an individual farmer, usually with the aid of the Extension Specialist, must adjust his applications to his crops and fields based upon crop response. As in the case of fertilizer, mechanization must also be selective with respect to the local area. The graded bed system for maize is particularly effective on heavy, poorly drained soil.

Ludhiana District, India has 0.61 hp per hectare of mechanical power (74% of its total available power), whereas the average for India as a whole is only 0.028 (12%). The tractor has been developed, however as a successful universal power unit applicable to very wide usage. This is not necessarily so with some machines. The two row maize planter, for example, shown in Figure 6 may work only with the system shown. At this stage in "reorientation" it is sufficient to recognize that systems must be workable at the individual farm level and not necessarily applicable to the entire nation. National leadership must recognize this principle in planning mechanization programmes.

Lastly, local farmers will make mechanization work if they have the incentives. Leaders must remove the clutter of insignificant factors, such as poor roads, small farms, low mechanical aptitudes, from their planning. They should concentrate instead on offering the farmer a number of mechanised systems, and components thereof, that will make a significant impact. Aranda Beredia of Spain, speaking at the 1974 CIGR meeting, put it aptly, "Mechanization can introduce itself if the right alternatives are offered". It is for the local people to pinpoint the alternatives.

Summary and Recommendations

This paper has suggested that the world, particularly the under-developed countries, must reorient their agricultural mechanization programmes to help:

- increase yields and production of food crops, and
- increase the utilization of labour (man-hours per year, uniform input, reduction of peaks and productivity).

Why? Because the most pressing and urgent problems are too many people and too little food. Some machines will increase yields. Some machines are necessary to make multiple-cropping systems work.

It follows that machines are one of the main influencing elements in a system designed to increase crop production and the labour utilization. All of the major inputs - fertilizer, seed, pesticides, water and machines - inter-react and are very interdependent. If one can segregate out the contribution of each, fine! Still, more importantly the top priority goal must be the development of systems that produce more food and put more people to work productively.

It then follows that the problem of developing such systems must be attacked by concerned specialists working together. The economics of the new systems must be postponed until pertinent resulting values such as yields are determined significantly and the system operational. Then, and then only, can economic calculations have real meaning. Prior to that time, such calculations might be inhibiting.

Our most challenging opportunity is to establish at least a few Institutes to develop new systems by a truly workable multiple-discipline approach. In line with its objectives and professional content such an Institute might appropriately be called "Operational Systems Institute".

Fossil energies are a relatively small percentage, up to 10 percent of the total energy required to produce a field crop. The free limitless solar energy input, however, is 90 percent or more. The world must always find ways to provide the fossil energy necessary to maximize the green crops per unit area per year. This is our only method of utilizing the amount of solar energy so necessary to maximize the production of food crops. We have no alternative but to follow this path.

National leaders must be cognizant of the fact that mechanization programmes must start with, and be implemented at, the local level. In the final analysis, machines and the systems they make practical will be accepted and used by individual farmers. National programmes can best coordinate, promote and make possible the local ones.

The top priority principles, then, for establishing rational, effective national policies and attitudes are restated in itemized form as follows:

1. Judicious use of yield-increasing and multiple-cropping machines. Some machines will, in fact, increase yields. Some machines, necessary to and in combination with multiple-cropping, will increase production per unit area per year, and will increase the utilization of labour in terms of man hours per year, yearly distribution and productivity. Therefore, mechanization must be recognized as an essential component of systems that produce more food and put more people to work productively.

2. Action programmes to develop and evaluate systems at the field-plot (Experiment Station) and field-trial demonstration (farm) levels are desperately needed. The development of new systems must be by a team of specialists whose efforts are coordinated by a strong, competent Administrative Leader.

3. A few nations or regions should establish "Operational Systems Institutes", interdisciplinarian in their approach and action. Establish an international coordinating agency for these centres such as the FAO-Wageningen University Studies.

4. Direct the amount of fossil energies necessary to maximize green crops per unit areas per year.

5. National planning for the manufacture/importation, distribution, demonstration and service of farm machines must start at the local level, such as a District.

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