International specialized media for agricultural mechanization in Asian developing countries.

AMA

AGRICULTURAL MECHANIZATION IN ASIA

VOL.X,NO.3, SUMMER 1979

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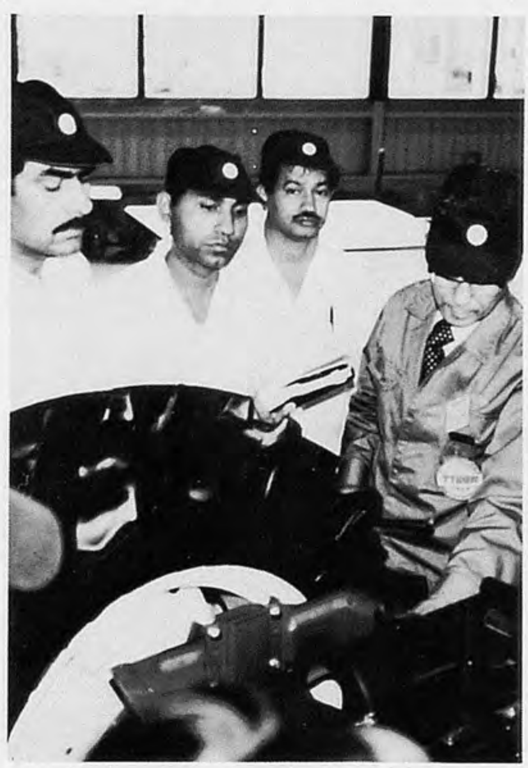

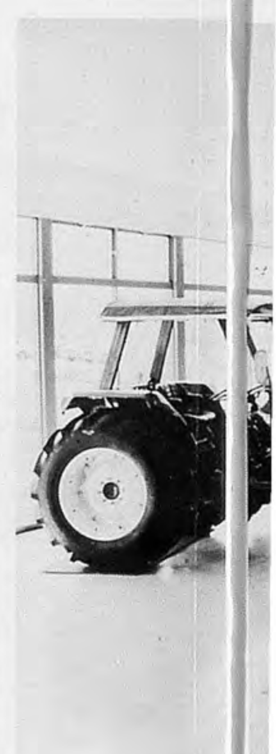

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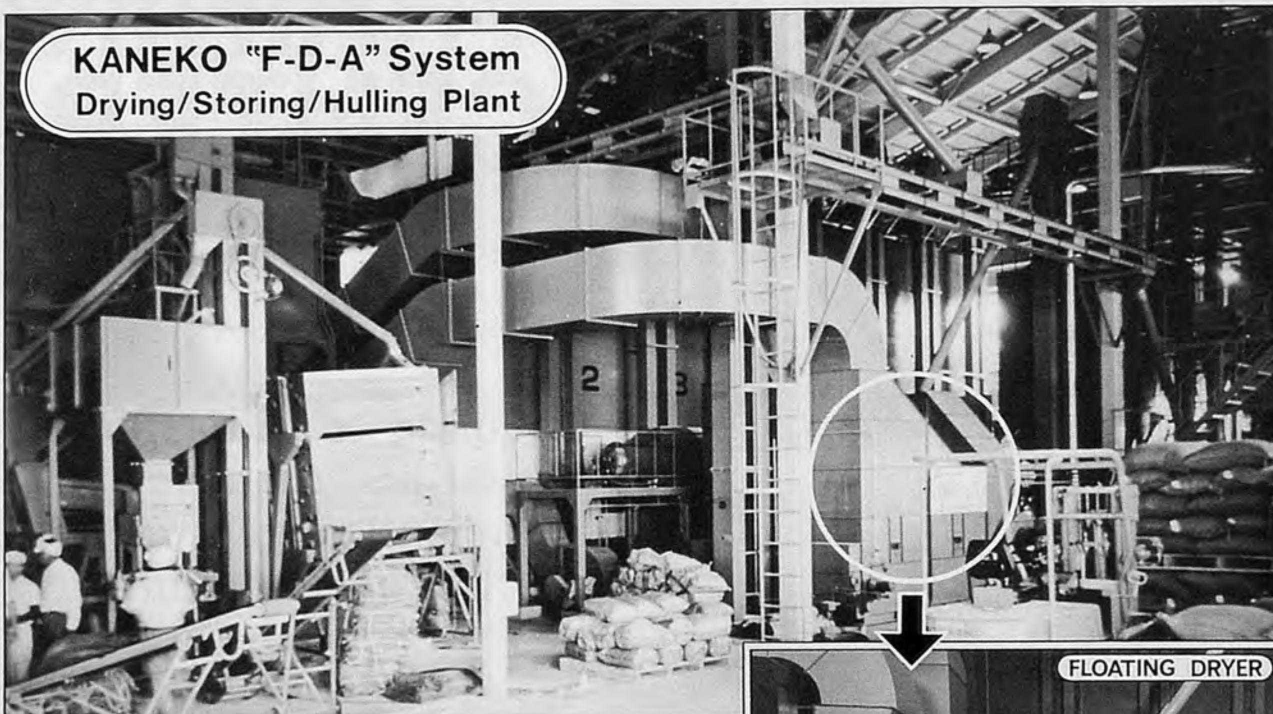

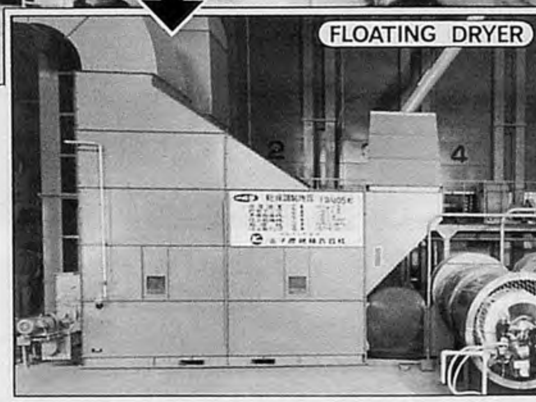

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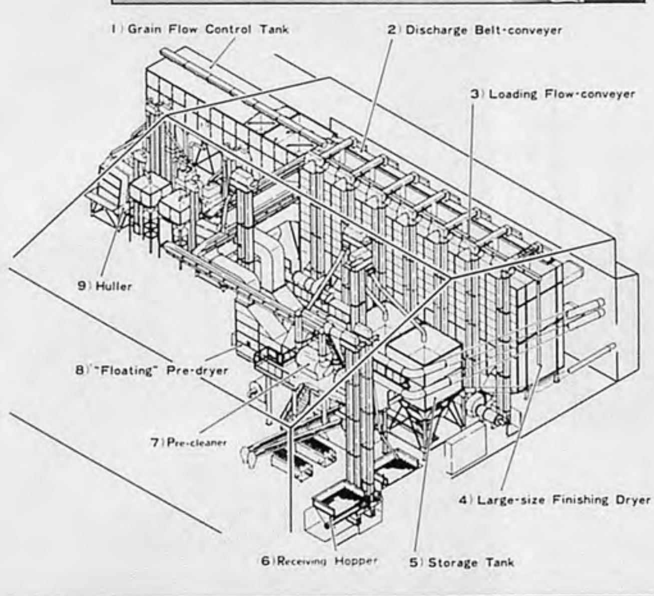

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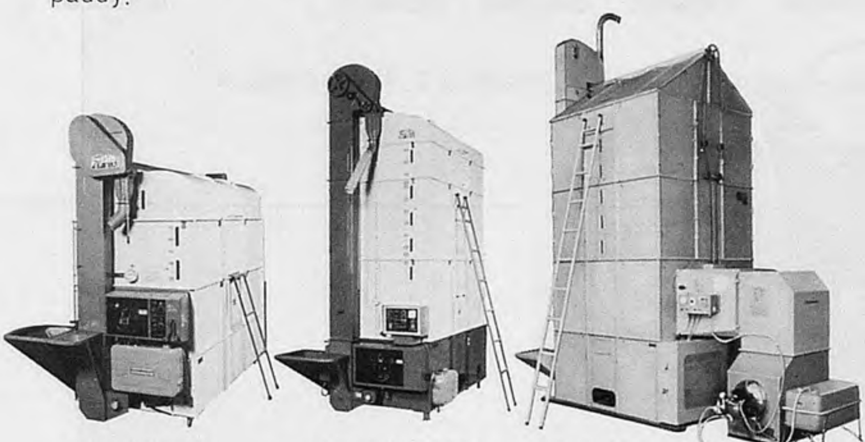

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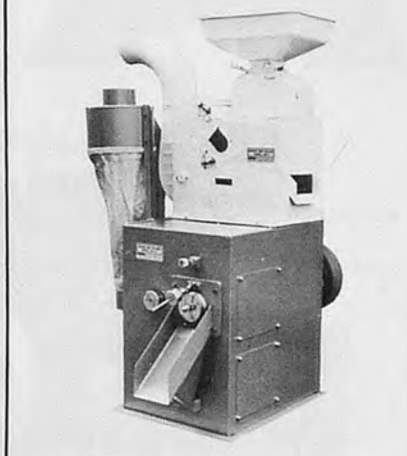

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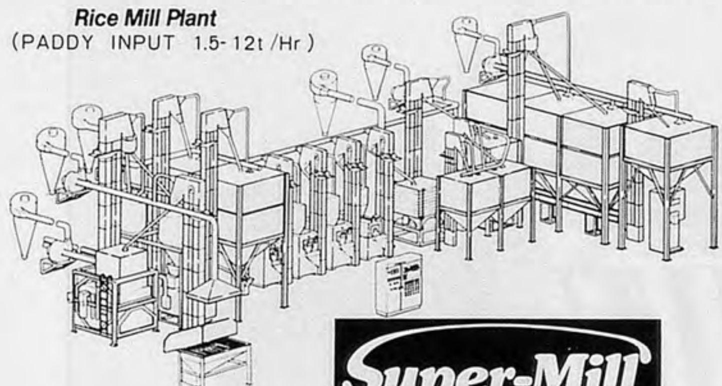

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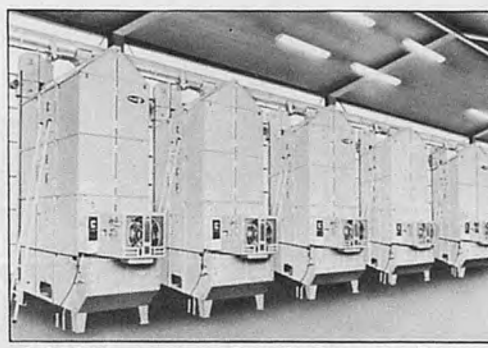

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Editorial

Watned: Ideas on New Energy Source

When the 1973 energy crunch shocked both the developed and developing countries and caused untold economic dislocations, very few believed that it will recur this early and, as before, hit hard the oil importing countries. The soaring of oil prices in recent weeks continues unabated. Already, it is hurting industrial activities and is likely to slow down world economic growth before long. Agricultural activities are equally hit hard what with important oil-based farm inputs gradually becoming scarce and costly. Crude oil and gasoline that power farm machineries might sooner than expected be rationed or immobilize the machines.

What all this spectre means is that before it is too late, ways and means of harnessing new energy source must continue to be found. The need for continuing research in this regard is both real and urgent and so is the need to disseminate the results so that farm machineries will not grind to a halt. The Brazilians, for instance, have for sometime now been mixing alcohol (from sugarcane and cassava) with gasoline with considerable success in reducing oil demand. The U.S.A., on the other hand, plans to meet some 20 per cent of that country's energy requirement with renewable resources such as solar power at the turn of the century. Investigations elsewhere are being made to harness wind power and sea waves.

In view of the seriousness of the current oil price and short supply, the AMA will henceforth give top priority to publishing articles that pertain to the use of renewable resources for energy, particularly those that have direct bearing on agricultural mechanization.

Chief Editor
Yoshisuke Kishida

July, 1979
Tokyo

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Energy for Worldwide Agriculture

by
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Professor

C. A. Myers
Specialist

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Abstract

This comprehensive manual is designed to put energy use in agriculture in perspective. Energy resources are tabulated and the principles and efficiency of various conversion processes are discussed along with their applications in the food system. Energy flow in the food system and energy requirements for each operation in production, processing and delivery are also presented. The following paper is a summary of the FAO book.

Introduction

Energy is the basic driving force in man's development. Energy is the capacity to do work, that is, to exert a force on a body moving it some distance. Scientists describe the rate at which work is performed as power. The history of civilization is largely a story of man's progress in harnessing energy, i.e., to convert energy to a more useful form.

More energy is needed for two reasons: 1) the world population is growing at an exponential rate; and 2) energy use per capita is steadily increasing. However, because petroleum and certain other energy forms (natural gas, coal, etc.) are limited, the energy base to continue man's development must shift to renewable or practically infinite energy forms such as solar or nuclear energy.

Much of the world's food is produced, transported and processed by hand and/or animal effort. Humans and animals, although limited in individual energy capacity, represent a large energy resource because of their sheer numbers. For example, the 4 billion humans on earth, exerting 75 watts for 8 hours a day, 250 days per year could produce 600×10^9 killowatt-hours per year (2×10^{18} joules). Applying the same logic, if even 10 percent of the world's 1.5 billion head of potential draft animals (horses, mules, asses, cattle, buffaloes, camels) were used at an average output of 500 watts, the result would be 112×10^9 kilowatt-hours (4×10^{17} joules). However, the value of man's work (when compared to work from petroleum-fueled machines) is insufficient to produce a reasonable standard of living. Even when man's energy capacity is supplemented by draft animals (75 + 500 watts), the result is often a bare subsistence standard of living.

Some advocate a moratorium on mechanization and a return to a more labor-intensive food production system. Worldwide unemployment or under-employment make labor-intensive methods even more attractive in the developing countries. However, a shift to more labor-intensive agriculture is unlikely in the U.S. due to agriculture's dispersion some distance from population centers, labor immobility, and the established farm tenure system. A more rational policy is to develop additional energy resources and the technology to apply them.

Energy Flow in Agriculture

Shifting cultivation requires much labor and yields are low but this primitive agricultural practice is still widely used today. An estimated 36 million square km of land (about 30% of the world's exploitable soils) are presently farmed this way, producing food for

* Presented at the Solar Energy Society of Canada Conference on Renewable Alternatives, August 20-24, 1978, London, Ontario

**A new book, Energy for Worldwide Agriculture by B.A. Stout in collaboration with C.A. Myers, A.Hurand and L.W. Faidley, is available from FAO. To obtain a copy please write to: Dr. Harmut von Hulst, Chief, Agricultural Engineering Services, Agricultural Services Division, FAO, Rome, Italy 00100 about 250 million people (4).

The only commercial energy input in traditional farming is that needed to produce tools and animal implements. In the transition from traditional to modern farming, the commercial energy usage increases sharply. Tillage requires commercial energy to produce and operate farm machinery. Improved varieties, a key element in modern farming, require commerical energy for their production and distribution. To help realize yield potentials, soil fertility is improved using commercial fertilizers, pesticides and irrigation.

The transition to more modern production methods varies from one area of the world to another, particularly the cost of land and labor relative to each other and to agricultural prices (8). Therefore, where land is inexpensive compared with labor, labor-saving mechanization is introduced to increase worker production. Conversely, where land is costly and labor inexpensive, biological and chemical inputs, such as plant breeding, chemical plant protection and inorganic fertilizers are stressed to increase yields. In some cases, labor-saving mechanization and fertilization are combined to achieve high productivity of both labor and land.

The commercial energy input per ha and per agricultural worker parallels closely the cereal output per ha and per worker in all regions (**Table 1**). The largest energy input of 556 x 10^9 joules per worker in North America corresponds with the largest cereal output of 67,882 kg per worker. The rank of the other developed countries in use of energy per worker corresponds with their rank in output per worker.

If past trends continue, commercial energy used worldwide in agriculture will almost double from 1972 to 1985. This substantial increase would only slightly raise agriculture's share of the world energy use from 3.5% in 1972 to 4.1% in 1985. These projections indicate energy use in agriculture would increase by 177% in the developing countries (LDC's), as compared with only 56% in the developed countries.

Energy Embodied in Fertilizer

The growing world population, particularly in the last 25 years, could never have been fed without increased reliance on inorganic chemical fertilizers. Fertilizers fall in two categories: organic and inorganic. Organic fertilizers are primarily crop residues and manure. Inorganic fertilizers are man-made compounds that center around three essential elements: nitrogen, potassium and phosphorus. Worldwide use of inorganic fertilizers is 80 to 90 million mt and represents a substantial monetary investment. World demand is expected to increase by 6 or 7% per year through 1980 to 1981. In LDC's an 11% per year increase is projected (9).

World consumption of nitrogen fertilizer is projected to rise from 36.2 million mt of nutrient from 1972 (28% in LDC's) to about 84 million mt between 1985/86 (37% in LDC's). About 83% of the 1972 world production of nitrogen fertilizer was in developed countries. The LDC's produced about 48% of their own consumption.

World consumption of phosphate fertilizer is projected to increase from 22.5 million mt in 1972 (14% in LTD's) to about 40 million mt in 1985 (28% in LDC's). Phosphate fertilizers require 126 to 200 x 10^8 joules per mt of P_2O_5 in their manufacture (6). Compare this with 517 to 654 x 10^8 joules per mt required to produce nitrogenous fertilizers.

In 1974, world potash production exceeded consumption. From 1960 to 1973 production increased 147% compared to a 125% increase in consumption (9). However, demand is likely to surpass production by 1980 if current capacity is not increased.

More efficient use of chemical fertilizers is possible in both developed and developing countries, e.g., timely sowing to coincide with nutrient demands of crops, better water management and proper soil placement. Better conversion of solar energy by plants should also help increase yields with less fertilizer. And, hopefully, biological fixation of atmospheric nitrogen through a symbiotic relationship with certain bacteria (presently found only in legumes) can be genetically transferred to cereal and other crops.

Table 1 Commercial Energy Use and Cereal Output Per Agricultural Worker and Per Area Of Land, 1972

	Energy/ha	Energy/Agr. Worker	Energy/ha	Output/Agr. Worker
	10^9 joules		kg	
Developed Countries	24.8	107.8	3,100	10,508
North America	20.2	555.8	3,457	67,882
Western Europe	27.9	82.4	3,163	5,772
Oceania	10.8	246.8	976	20,746
Other Developed Countries	19.4	19.1	2,631	2,215
Developing Countries	2.2	2.2	1,255	877
Africa	0.8	0.8	829	538
Latin America	4.2	8.6	1,440	1,856
Near East	3.8	4.4	1,335	1,386
Far East	1.7	1.4	1,328	781
Centrally Planned Economies	5.9	6.8	1,744	1,518
Asia	2.4	1.7	1,815	911
Eastern Europe and the USSR	9.3	28.5	1,682	4,109
World	7.9	9.9	1,821	1,671

Source: (5)

Energy Embodied in Farm Machinery

Rapid tractorization of agriculture in the developed countries over the last 50 years, combined with more recent growth of mechanical power technology in LDC's, have led to a substantial rise in commercial energy usage for mechanical power. The number of four-wheel and crawler tractors at work in agriculture is projected to rise from 161 million in 1972 (9% in LDC's) to 20.6 million by 1985 (13% in LDC's).

It would be disastrous if higher costs for farm machinery slow down its application where it is essential for increased food and agricultural production in LDC's. Thus, it is imperative to improve farm machinery efficiency. Design and manufacture of farm machinery better suited to the conditions of LDC's as well as local manufacture of improved equipment for use with draft animals could be of major importance in many areas.

Energy Use In Irrigation

The energy requirement to produce irrigation equipment is about the same as for farm machinery: 86.7×10^6 joules per kg of equipment. Both increased efficiency in irrigation use and higher cropping intensities can be achieved by: 1) improving water distribution channels and providing field drainage; 2) improving field layouts; 3) land grading and leveling; and 4) improving cropping practices with better implements and water application methods.

Energy Use in Pesticides

Substantial commercial energy is required to produce pesticides. Raw materials for modern pesticides come mostly from the petrochemical industry. Manufacturing, packaging, transport, distribution and application require further energy inputs. The total energy required to provide a kg of pesticide is estimated at 101×10^6 joules (10). Thus, pesticides are the most energy-intensive agricultural input. Although continued growth in pesticide use is unavoidable, concern about possible detrimental effects to the biosphere from chemical application has stimulated the search for ways of economizing their use.

Energy Use in Agriculture

United States

Fig. 1 shows the energy flow in the U.S. food chain to produce 1 kilo-calorie of human food (20). Of the plant energy potentially available about 31% is in non-food crops and exports. Thus, with 16 kilocalories of potential food, feed and fiber, only 11 kilocalories remain for domestic food and feed. Of the original 16 kilocalories, only 1/16 or about 6% is actually eaten by the U.S. population.

The U.S. food system uses 5.5% of the industrial energy, 4.4% of the transportation energy, 3.4% of residential energy and 3.2% of the commercial energy. Thus, the total food system uses about 16.5% of the energy consumed in the U.S. (7). Production agriculture uses only 3 to 3.5% of the nation's

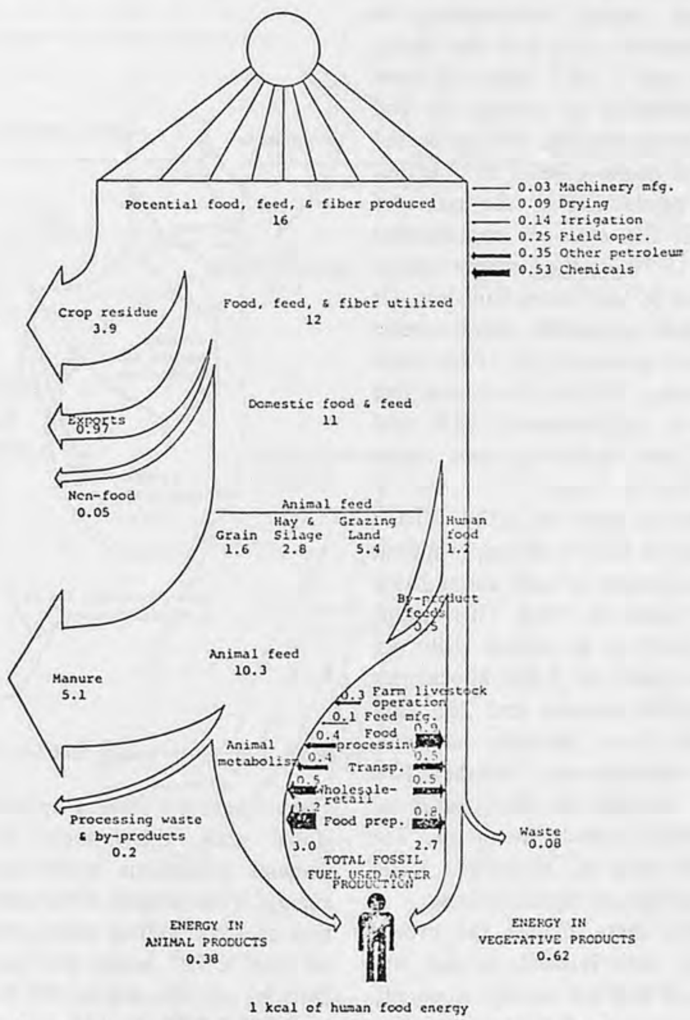

Fig. 1 Energy flow in the U.S. food chain to produce one kilocalorie of human food (12)

energy. Therefore, of the total fossil fuel input for food production in the U.S., only about 25% is expended at the farm level. Three times as much fuel energy is used to process, transport, market and prepare food after it leaves the farm.

In 1970, 50% of the energy used in the food system was liquid petroleum fuel – primarily diesel fuel, gasoline and LP gas. Natural gas supplied 30% and electricity 14%. The remainder came primarily from residential fuel oil and coal (21).

United Kingdom

In 1968, agricultural production in the United Kingdom required 378.4 x 10^{15} joules of energy (**Fig. 2**). This amounted to 4.6% of the primary energy consumption in that country (11). For this investment 130 x 10^{15} joules of food was delivered or enough to feed half the population. With an overall total of nearly 1,300 x 10^{15} joules, food production to the point of sale in the store or supermarket took 15.7% of the primary energy utilized by the United Kingdom. Of the total, agriculture plus domestic fisheries accounted for 31.6%; food processing, 36.6%; food and fish imports, approximately 21%; and food sales, including some transport, 10.7%.

With an input of 1,300 x 10^{15} joules, the U.K. food supply system had an output of only about 261 x 10^{15} joules in 1968. This output was based on an average daily per capita intake of 2,560 kilocalories from food sources and 265 kilocalories from alcoholic beverages plus confectionary. Another 10% must be added for food and drink consumed outside the home. The overall total is, therefore, 3,107 kilocalories per person per day.

With these figures the overall energy ratio is 0.20, so that five units of fuel are needed to supply each dietary unit of energy. This does not include energy used beyond the grocery store. Copied on a global scale, this system would demand prodigious quantities of energy. If the present world population of 4,000 million each consumed 23.6 x 10^9 joules per year of fuels to eat, the annual bill would be 2,247 x 10^6 mt of oil equivalent or 40% of the global fuel consumption in 1972.

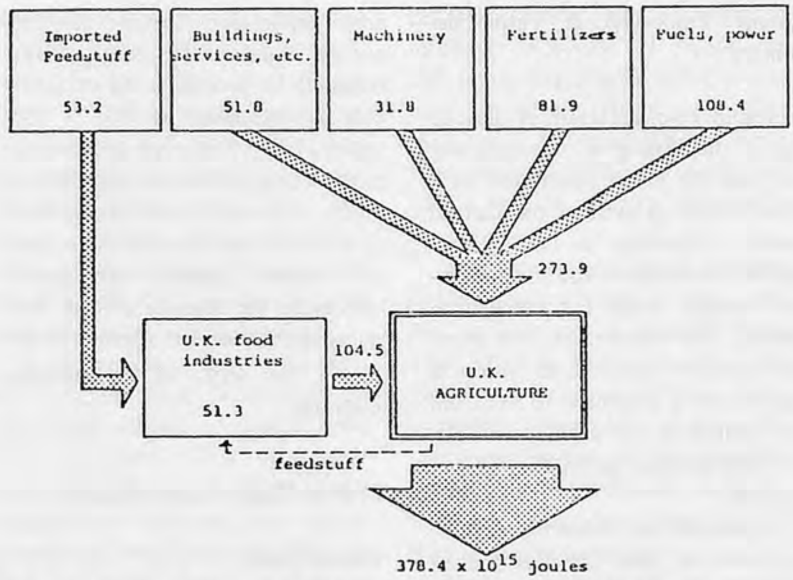

Fig. 2 Energy input to agriculture in the United Kingdom, 1968–Units = 10^{15} joules (11)

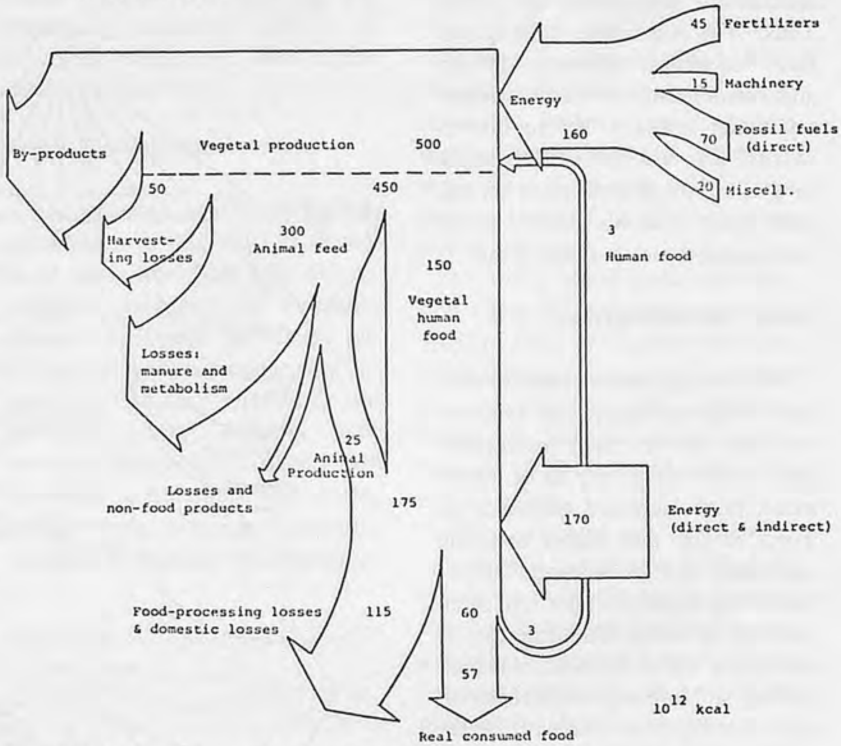

Fig. 3 Agricultural energy flow for France (1)

France

In France, about two-thirds of the harvested food is used to feed animals. This percentage is less than the amount used for animal feed in the U.S., and more than in the

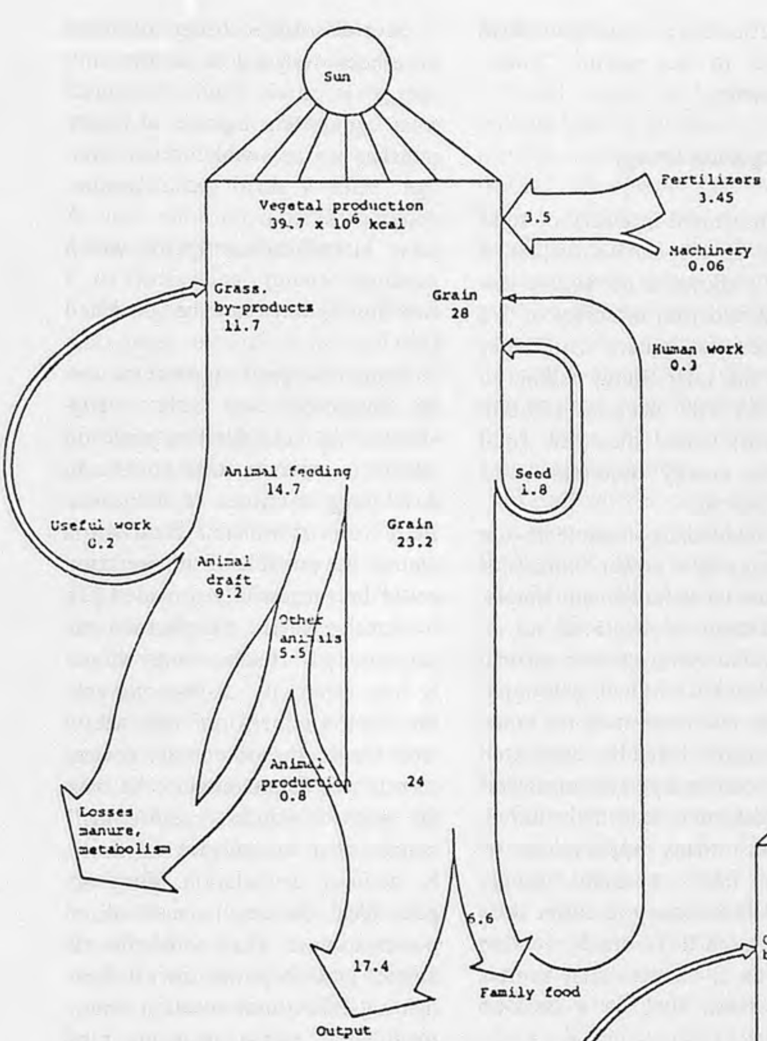

Fig. 4 Energy flow for traditional farm in Senegal (2)

LDC's.

For each kilocalorie of energy invested in production agriculture in France, 2.8 kilocalories of food and feed are produced (Fig. 3). Of the 160 × 10^{12} kilocalories of input energy required for production only 70 × 10^{12} kilocalories are direct fossil fuel.

From the 300 × 10^{12} kilocalories used for animal feed, 25 × 10^{12} kilocalories of animal production results – a 1 to 12 conversion ratio. After accounting for losses and by-products from post-production, 60 × 10^{12} kilocalories of actual food are consumed. Thus, about 1 kilocalorie of food is consumed for every 5 kilocalories invested in production and post-production input energy. Agriculture in France, therefore, requires about half the input energy of U.S. agriculture and produces one-sixth as much food, feed and fiber.

Senegal

Although data are fragmentary (14), energy flow has been tabulated for a typical traditional farming system and an improved system using an animal toolbar. Consider as an example two farms in the Sine-Saloum area:

– 11 ha of land – 3 ha in peanuts, 3 ha in millet, 2 ha in rice and 3 ha in fallow used for pasture;

– several animals including chickens and goats with a

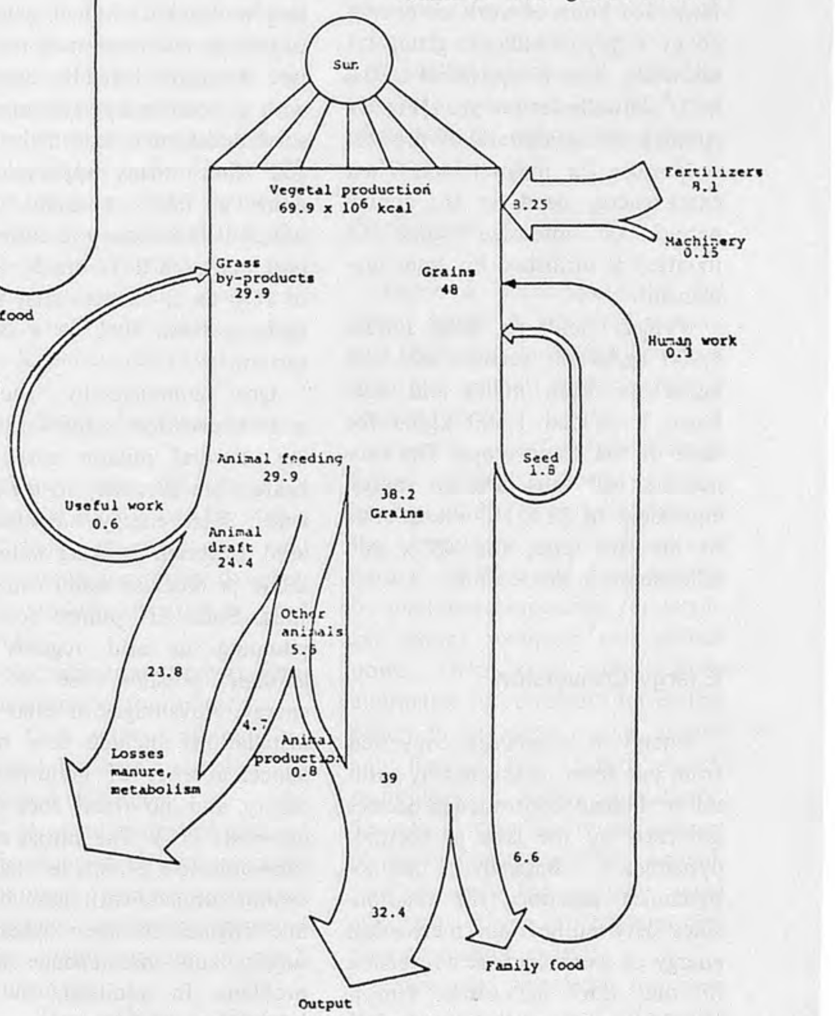

Fig. 5 Energy flow for a single-family farm in Senegal. Eleven-hectare improved farm using animal draft power (2)

total weight of 250 kg;

– one family with an equivalent of six adults.

In the traditional system (farm a) an animal weighing 300 kg is used to pull simple implements (maximum weight of 30 kg) and in the improved system (farm b) a pair of bullocks weighing 800 kg pull a multi-purpose toolbar (total weight 75 kg). The same amount of seed was used for each farm. Fertilizer inputs were 150 kg per ha in the two farms. No chemicals for pest or weed control were used.

Farm a requires 539 hours of animal work assuming each animal's output is 0.48 kilowatts. The work performed per year by the animal would be about 0.2×10^6 kilocalories (**Fig. 4**). On the second farm, 661 hours of work are provided by a pair of bullocks giving 1.1 kilowatts. This is equivalent to 0.6×10^6 kilocalories per year (**Fig. 5**). Animals eat agricultural by-producs or pasture for maintenance. Their extra energy need for the annual period of intensive work (4 months) is furnished by grain supplement.

Typical yields for farm a were 1,000 kg/ha for peanuts and 800 kg/ha for both millet and rice. Farm b yielded 1,500 kg/ha for each of the three crops. The production will thus have an energy equivalent of 28×10^6 kilocalories in the first case, and 48×10^6 kilocalories in the second.

Energy Conversion

Energy is constantly converted from one form to another by natural or human controlled processes governed by the laws of thermodynamics. Basically, thermodynamics describes the relationships between heat and mechanical energy or work, and the conversion of one into the other. Unfortunately, energy cannot be converted from one form to another with 100% efficiency; some is always converted to less useful "lower-grade" energy.

Capturing Solar Energy

The maximum intensity of solar radiation at the earth's surface is about 1.2 kilowatts per square meter. At a radiation intensity of 5×10^5 joules per square centimeter per year the solar energy falling on about 59×10^5 hectares (59,000 square km) would meet the total worldwide energy requirement (3×10^{20} joules).

It is technically feasible to use solar energy as a power source but costs must be reduced, and simple, more efficient applications are required. Solar energy seems particularly well suited to small-scale applications in countries near the equator. A major difficulty associated with all solar energy systems is that solar radiation is extremely unreliable. Since many applications require a fairly constant energy source it is necessary to either store heat collected in favorable weather or rely on a conventional source, such as fossil fuel, in a back-up system.

One commercially successful solar application is for water heating. Several million solar water heaters are currently in use worldwide. Solar energy has also been used to obtain drinking water from saline or brackish water using solar stills. Solar lift pumps for water pumping in arid regions offer another possible use of solar energy. Advantages of solar power installations include low maintenance, absence of pollution, simplicity and no fossil fuel operating costs (16). The initial cost of solar-powered pumps is high and cannot compete with diesel or gasoline engines in areas where fuel supply and maintenance are no problem. In addition, the sun's energy is useful for low temperature crop drying (18).

Several small focusing collectors have been designed to use the sun's energy to cook food. A typical solar cooker is composed of highly polished surfaces which reflect sunlight onto a small area. Another cooking device is the solar oven. A solar intensification factor which produces energy equivalent to a fuel-fired oven can be obtained (13).

Many refrigeration systems can be considered for solar refrigeration. As yet, the best scale on which to operate solar coolers in developing countries is unknown. Better use of available food stuffs would be possible if refrigeration could be successfully provided (3).

Another device, the photovoltaic cell, can convert solar energy directly into electricity. It does not rely on heat to perform the useful work as do the other solar devices mentioned. Photovoltaic cells have no waste products, require little maintenance and operate indefinitely without degradation. They appear ideal for small decentralized power sources. They could, for example, provide power for off-shore lighting, telecommunication equipment, and refrigerators in rural health dispensaries. At this time they are too expensive for most applications but the price is rapidly decreasing.

Harnessing Wind Power

The total worldwide wind potential is estimated at 2×10^{10} kilowatts (19). However, wind energy is very dilute, i.e., the energy density is low. Thus, a large wind machine is needed to capture a small amount of energy. The major factors responsible for power output of a wind machine are area and wind speed. Depending on the rotor, windmills can provide power for pumping water, powering generators and generating electricity.

A major drawback of wind-generated electricity is the lack of constant power supply when needed. Before wind-generated electricity can be used for domestic purposes, a storage system or some adjustments in energy use patterns are necessary.

Utilizing Organic Residues

Plant biomass is another potential energy resource. It is possible to extract energy from wood, wood by-products, food processing refuse, crop residues, non-harvested plants, animal excreta, sewage, ocean kelp, etc. However, it is impractical to convert all of these materials into useful energy using a single process. Energy conversion can lead directly to heat production or to intermediate fuels (solid, liquid, or gas).

Combustion is the most common example of energy conversion. Usually the heat produced by combustion is used for heating for domestic purposes or industrial applications.

Another process, pyrolysis, was developed mainly for municipal waste, whose moisture content ranges between 30 and 70%.

Through anaerobic or alcoholic fermentation, organic residues can be converted into liquid or gaseous fuels. The amount of gas (methane) produced is highly variable, depending on temperature, organic material composition, dilution and digestor design (12). Most digestors have been built in the LDC's to extract energy from animal manure; much of the manure's fertilizer value is retained.

Transformation of sugars, largely encountered in agricultural plants, into alcohol by fermentation is a common process used in the food and beverage industry. Ethyl alcohol is a good liquid fuel and can be used in spark-ignition engines either alone or in a mixture with gasoline without much change in power output.

Hydropower

Small rivers and streams can provide limited supplemental power to drive machinery or generate electricity. Hydropower systems are reliable, flexible and require only simple equipment and little maintenance. Each water power system must be adapted to the site configuration. The quantity of water flowing in the streams changes with the seasons and hydraulic conditions must be considered when designing the system.

Water wheels date back many centuries and are still widely used throughout the world. They are suited for small power requirements (1 to 10 kilowatts), especially in places lacking elaborate power generating facilities. Water wheels are attractive where fluctuations in flow rate are large, but speed regulation is not practical.

Water turbines are needed to achieve a higher power range (20 kilowatts to a megawatt or more). They can be connected to the general electric distribution network, but are especially valuable in isolated areas and small towns where a local network exists.

Electrical Energy for Rural Areas

A primary aim of rural electrification is to improve the standard of living in rural areas and prevent population influx to urban areas by industrialization of rural areas (15).

Rural electrification projects typically pass through four phases:

- Only a few scattered, isolated business need and can afford electricity;
- A small collective demand develops and is met by a local network from autogenerators (isolated generators powered by diesel engines or small turbines);
- The collective demand reaches a point where a grid system is justified; and
- Low demand centers near networks are connected at low marginal cost.

Coal and petroleum products are commonly used to generate electricity. But rising oil prices have seriously affected costs of electricity from diesel-powered autogenerators (increases of roughly 50 to 100%). Nuclear power for electricity generation remains questionable. Capital costs have escalated and radioactive waste disposal questions are unanswered.

The rural electrification problem is complex, especially for countries with limited capital. Areas to be supplied are often remote from the sea, separated from one another by great distances, have inadequate transportation and communication systems, are sparsely populated, lack skilled manpower, maintain low-level economic activity and often have an unfavorable climate.

Conclusion

There is some potential for saving energy in the food systems of LDC's, but developed countries offer the greatest opportunity for conservation.

There is cause for concern about future supplies and prices of petroleum products. By no means should the importance of petroleum and natural gas in world food systems be minimized especially for fertilizer, water pumping and mobile power. There is no really suitable alternative to petroleum for mobile power in the next decade or two and beyond that, future energy technology is highly speculative. Therefore, wise use by all nations of the world is essential. Agriculture deserves top priority when allocation of scarce petroleum supplies becomes a reality.

Ultimately petroleum resources will be exhausted and alternative energy resources must be developed. Emphasis should be on development and effective use of renewable energy sources such as solar energy and biomass. The future of mankind rests on our ability to shift to a new energy base.

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Energetics of Crop Production in Fuji

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Abstract

The world energy crisis of the 1970's has focused attention on the development of appropriate technology and the conservation of resources in agriculture. In the less developed nations such as Fiji, which depend entirely on imported fossil fuels for most of their energy needs, the study of energy use in agriculture is particularly vital. In the village and small holder semi-subsistence farming systems, which are the dominant systems of agriculture practised in Fiji, the energetics of crop production can be used as an important measure of farm operating efficiency. One such measure is the efficiency ratio, which is the edible yield of crops expressed in kilojoules (kJ) and divided by the kJ of energy expended by man, draught animals and fossil fuels to attain that yield. The higher the efficiency ratio of a crop the more efficient that crop is in the energetic efficiency with which it uses resources to produce food under a cropping system of a given technology. The energetics of crop production indicate, among other things, how efficiently the food needs of a family can be derived from the farm. The efficiency ratios of the major staple crops of the Fijians such as cassava, sweet potatoes, taro and yams and that of the Indians such as rice and pulses, are discussed in terms of production technologies and the ease of food production. Finally these measures are used to indicate the pathways for agricultural development in Fiji.

Introduction

Studies of agricultural development often neglect the constraints that can be imposed by the limits of energy use in agriculture. This problem has been particularly obvious in the 1970's when the rapid increase in the world price of oil put severe restrictions on the use of fuel in agriculture and industry. This situation has been of major concern in the less developed nations, most of which depend on imported fossil fuels for their energy requirements. In an effort to reduce import bills for fuels, governments of such countries are now attempting to develop low technology agricultural systems which gives optimum pay-offs from the available resources.

In semi-subsistence agriculture energy relations in crop production are particularly useful in indicating pathways for agricultural development as well as for community nutrition. This is because the two basic goals of the semi-subsistence farmers are: (a) to produce enough food to meet the subsistence requirements of the family members, and (b) to produce sufficient cash with the remaining resources to be able to enjoy a satisfactory standard of living.

This paper outlines the concept of the energetics of crop production based on actual farm data derived from Sigatoka Valley, Fiji. The energetics concept is then used to describe the case of food production on Fijian and Indian farms and how farm operating efficiency in semi-subsistence situations can be compared. Finally some policy conclusions are drawn from these measures.

Description of the Farming Systems

Farming in Fiji is mainly carried out by two distinct ethnic groups, Fijians and Indians. In the Sigatoka Valley, in the main island of Viti Levu, smallholder agriculture in Fijian villages and Indian settlements is the dominant system of land use. The data used in the following analysis was derived from a major farm management survey of sample farms in the Sigatoka Valley between November, 1970 and October 1972. During these two years enumeration of the farm inputs and outputs were made at weekly inter vals and have been detailed elsewhere (Chandra, 1977a; 1977b). The analysis that follows is based on sample sizes of 26 and 24 for Fijian farms and 38 and 35 for Indian farms in year 1 and year 2, respectively.

A large number of crops are grown on these farms as illustrated in a later section. Farm size are small, averaging 2.64 ha for Fijians and 3.54 ha for Indians. The cropping index, which is the cropped area expressed as a percentage of the area available for cropping (Ruthenberg, 1971) varies between 50 – 100 percent for Fijian farms and 75 – 125 percent for Indian farms. The farms have low levels of capital investment. Horses and bullock are the important sources of power on these farms with few Indian farmers owning tractors. Other common capital items are knives, forks, hoes, ploughs, harrows and wooden sledges.

Family labour is almost always used for farm work. The mean size of a Fijian family was 5.6 persons while for Indians it was 7.0 persons. Both groups have very young populations averaging two to three persons of school age. Gross output, defined as the total value of all subsistence and commercial crops using the farm gate price, was \$733 $year^{-1}$ for Fijian farms and \$1,446 $year^{-1}$ for Indian farms.

The Concept of Energetics

Two measures that describe the concept of energetics are defined below.

Efficiency Ratio

A measure of the energetic efficiency of crop production is the efficiency ratio (E), which is the edible yield of crops expressed in kJ and divided by the kJ of energy expended by man, draught animals and fossil fuels to attain that yield (Black, 1971). The definition does not include the photoshynthetic energy utilized by the crop plants. The higher the E of a crop the more efficient that crop is in the energetic efficiency with which it uses resources to produce food under a cropping system of a given technology.

Energy Purchasing Power

Energy purchasing power (EPP) is another concept used in the analysis of the energetics of crop production. The EPP of a crop is the kJ of food energy that can be purchased for one cent (¢) value of that crop. The EPP values indicate how cheaply the energy requirements of a family can be met from various crops.

Computational Procedure

The efficiency ratio, E, of crop i is given by:

$$E_i = \frac{\text{kJ produced by edible portion of crop i}}{\text{kJ expendable energy used in crop i}}$$

If A = total yield of crop i in kg

B = nonedible portion of the yield of crop i in kg

Then, A – B = C=edible yield of crop i in kg

Total kJ of crop i = C x kJ kg^{-1} of crop i = Y_i

To calculate kJ of expendable energy used in crop i, let

D = Number of manhours used in crop i

E = kJ per one hour of human work (628 kJ)

F = Number of oxen hours used in crop i

G = kJ per one hour of oxen work (1674 kJ)

H = Number of horse hours used in crop i

I = kJ per one hour of horse work (2512 kJ)

J = Number of tractor hours used in crop i

K = kJ per one hour of tractor work (167,440 kJ)

and Σ (D×E) + (F×G) + (H×I) + (J×K) = Z_i

$$\text{Then, } E_i = \frac{Y_i}{Z_i}$$

The energy purchasing power, EPP, of crop i is given by

$$EPP_i = \frac{Y_i}{\text{Value of crop i (in cents)}}$$

The data on the kJ kg^{-1} of the edible portion of food crops were derived from the Fiji School of Medicine Food Composition Tables for use in the South Pacific (n.d.). This publication has been compiled from various published sources such as the Food and Agriculture Organisation (1957) and World Health Organisation (1972). Data on the daily kJ and protein requirements of humans used in the calculation of the food intake of the Fijians and Indians, discussed in a following section, were also derived from the above source. The conversion factors used for the calculation of energy expended per hour of work by man, oxen, horses and in tractor fuel consumption were derived from Black (1971). These are 628, 1674, 2512 and 167,440 kJ hr^{-1} respectively.

The data on the daily food intake of the Fijians and Indians were collected from the Naduri village and the Naceva settlement over a one-month period during the field survey. Adjustments were made on the data based on previous consumption habits to account for the seasonal variations in crop availability. It was assumed that the nine sample farms at Naduri and five at Naceva were sufficient to define adequately the major differences in food consumption between the two races. The food crop dietary preferences of Fijians and Indians are very different and for energetic comparisons to be meaningful it was necessary to define the subsistence food bundle of each race. This is discussed in the next section.

To check that the daily food intake data of Fijian and Indian households were realistic, the results were compared with two detailed nutrition surveys carried out over the entire Naduri village population by the Fiji School of Medicine personnel, namely Langley (1953) and Wilkins (1963). A marked consistency in the daily intake of kJ, protein and other nutrients (classified by crops, sub-by adult units) was found. Although the data on Indian food intake could not be checked against other studies because no surveys have been carried out, it was assumed that because the results were consistent between the present survey and that of Langley and Wilkins for the Fijian population they would also be similar for the Indian population, especially since the two communities are located in the same area.

Food Crop Dietary Preferences of Fijians and Indians

The subsistence as well as purchased food crops of the Fijians and Indians are very different. Tables 1 and 2, respectively, show the importance of the listed crops in the daily diets of the two races. The Fijians rely heavily on the traditional root crops such as cassava, sweet potatoes, taro and yams while the Indians consume rice, pulses, Irish potatoes, green beans and egg plants. One of the advantages of cassava and sweet potatoes as subsistence crops is that they can be planted and harvested throughout the year. Cassava can be left in the ground for several months without any great deterioration in quality or can be eaten for the three to four months from before full maturity to well after maturity. Sweet potatoes, taro and yams can be left in the ground for one to two months and therefore also have some storage capability. The rice and pulses of the Indians, on the other hand, are stored in barns and sheds after the harvest and are therefore available for consumption throughout the year. Irish potatoes are in production only during the late winter months and therefore most of the purchased crop consumed on the farm is imported from overseas.

The average daily kJ requirements of an adult Fijian and Indian are 11,750 kJ and 10,925 kJ, respectively. In the diet of Fijians cassava, sweet potatoes, taro and yams account for 50.7 percent of the daily kJ intake. Of this cassava and sweet potatoes contribute 30.7 percent and 13.2 percent of the kJ respectively and all of this is produced on the farm. Rice, pulses, Irish potatoes, green beans and egg plants account for 56.1 percent of the daily kJ intake in the Indian diet. Of this rice and pulses contribute 40.3 percent and 10.6 percent of the kJ, respectively. All rice and one third of pulse supplies are procued on the farm.

The important purchased food crop on the Fijian farms is taro, both corms and leaves, and this is mainly a result of cultural heritage. Prior to the introduction of cassava and sweet potatoes in Fiji in the late 1800's taro was the most important staple crop of the indigenous population and is still highly sought after even though the market price of taro is usually three to four times greater than that of cassava. Pulses are the important purchased food crop of the Indians, followed by Irish potatoes.

Whereas the staple food crops of the two communities supply just over half of the daily kJ requirements $adult^{-1}$, there are considerable differences in the protein supply from these crops. Most of the protein in the Fijian diet comes from fresh and tinned fish and meat, whereas the other third of the protein in the Indian diet is generally derived from sharps (coarse wheat flour) and some fresh

Table 1 Average Daily Requirements of kJ and Protein and Daily Food Cost: Fijian Household (n=9)

Staple food crops	Total kJ supplied $adult^{-1}$ day^{-1}	kJ produced on the farm $adult^{-1}$ day^{-1}	kJ purchased off farm $adult^{-1}$ day^{-1}	Protein supplied $adult^{-1}$ day^{-1}	Food cost $adult^{-1}$ day^{-1}
	kJ	kJ	kJ	g	g
Cassava	3,613	3,613	–	5.6	0.034
Sweet potatoes	1,553	1,553	–	4.5	0.016
Taro (corm + leaves)	448	21	427	2.4	0.014
Yams	343	260	83	1.1	0.010
Total	5,957	5,447	510	13.6	0.074
Percent of daily total	50.7	46.3	4.3	22.7	–
Percent of total food cost day^{-1}	–	–	–	–	22.4

Table 2 Average Daily Requirements of kJ and Protein and Daily Food Cost: Indian Household (n=5)

Staple food crops	Total kJ supplied $adult^{-1}$ day^{-1}	kJ produced on the farm $adult^{-1}$ day^{-1}	kJ purchased off farm $adult^{-1}$ day^{-1}	Protein supplied $adult^{-1}$ day^{-1}	Food cost $adult^{-1}$ day^{-1}
	kJ	kJ	kJ	g	g
Rice	4,400	4,400	–	20.3	0.076
Pulses	1,155	385	770	19.7	0.027
Irish potatoes	314	67	247	1.8	0.016
Green beans	134	113	21	1.8	0.019
Egg plants	126	109	17	1.3	0.008
Total	6,129	5,074	1,055	44.9	0.146
Percent of daily total	56.1	46.4	9.7	66.8	–
Percent of total food cost day^{-1}	–	–	–	–	58.2

and tinned meat and fish.

In terms of costs, cassava and sweet potatoes are relatively cheap crops while taro and yams are expensive. This is another reason why the former two crops dominate the diets of the Fijians. Most of the Indian staple crops are relatively expensive apart from egg plants. Although the daily staple food cost of the Indians is nearly twice that of the Fijians, the total daily food cost of the Fijians is higher because the Fijian diet relies heavily on purchased store foods (Chandra and De Boer, 1975). Some common purchased store foods of the Fijians, apart from tinned fish and meat, are biscuits, bread, tea and sugar.

Table 3 Efficiency Ratio and the Energy Purchasing Power of Crops: Fijian Farms (n=50)

Crops	Efficiency Ratio (E)	Energy Purchasing Power (EPP)	Crops	Efficiency Ratio (E)	Energy Purchasing Power (EPP)
Cassava	52	850	English cabbage	9	113
Sweet potatoes	60	785	Chinese cabbage	3	66
Taro	21	340	Tomatoes	5	84
Yams	66	305			
Irish potatoes	19	203	Chillies	4	40
Bananas	24	377	Rockmelon	5	95
Rice	17	576	Watermelon	14	115
Maize	39	2,710	Cucumber	4	60
Green beans	5	65	Peanuts	15	590
Egg plants	14	121	Passionfruit	17	183

Table 4 Efficiency Ratio and the Energy Purchasing Power of Crops: Indian Farms (n=73)

Crops	Efficiency Ratio (E)	Energy Purchasing Power (EPP)	Crops	Efficiency Ratio (E)	Energy Purchasing Power (EPP)
Rice	9	576	Cassava	42	850
Pulses	11	415	Sweet potatoes	44	785
Irish potatoes	11	203	Maize	22	2,695
Green beans	4	60	Watermelon	5	113
Egg plants	10	117	Rockmelon	3	94
English cabbage	5	108	Cucumber	3	60
Chinese cabbage	3	65	Pumpkin	4	190
Cauliflower	2	62	Okra	5	78
Tomatoes	4	82	Peanuts	18	575
Chillies	4	44	Passionfruit	8	183

Energetic Efficiency of Crop Production

Having reviewed the diet preferences of the Fijians and Indians and the importance of the various crops in the daily supply of kJ, protein and the cost of the food consumed, it is now possible to study the energetic efficiency of crop production between the two communities and the case with which the subsistence food needs of each group can be maintained by the farm produced crops.

Efficiency Ratios

The efficiency ratios and the energy purchasing power of the various crops on Fijian and Indian farms during the two years of study are shown in **Tables 3** and **4**, respectively. Comparisons of the two tables show large differences in the efficiency ratios. The E's of the Fijian subsistence crops are much higher than those of the Indians. The main reason for this is that the traditional root crops – cassava, sweet potatoes, taro and yams – give very high kJ of yield relative to the rice and pulses which are relatively low kJ yielders. Under present levels of farm management, edible yields of 6-7 kJ ha^{-1} of cassava and sweet potatoes are common whereas rice and pulses yield about 1.2 mt ha^{-1} and 0.3 mt ha^{-1}, respectively. The E's of the root crops are considerably higher than those of rice and pulses, even though the number of kJ kg^{-1} in the former crops are about a third of the latter. In other words, because the root crops, by their biological nature, are highly efficient energy storage systems (Coursey and Haynes, 1970), they yield greater kJ ha^{-1}, $manhour^{-1}$ or $\$^{-1}$ capital investment. Even on the Indian farms cassava and sweet potatoes have high E's. The high E's of the root crops means that these crops have a greater advantage over the traditional subsistence crops of the Indians because a kJ of food is much easier to produce in the Fijian farming system than in the Indian system. This is due largely to the effect of dietary preferences on the prevailing farming systems.

The ease with which the Fijians obtain their subsistence foods, in comparison with the Indians, can be used to explain in part why they have greater leisure preferences (non-farm work) than the Indians. Once the traditional subsistence food requirements of the Fijians have been satisfied, the rest of the time can be spent on attending to social obligations since the Fijian communal system demands that each young male devote some time to the upkeep of the village.

In contrast to the staple food crops, most of the vegetable and other similar crops have low E's in both farming systems because of the low kJ ha^{-1} these crops generate, with a tendency for the Fijian produced crop to have a higher E. The similarity in the E's of the vegetable crops in the two farming systems is due mainly to the similar agronomic practices applied to these crops. Further information on the energetics of crop production in the Sigatoka Valley have been reported recently by Chandra, Evenson and De Boer (1973; 1976) and by Chandra, De Boer and Evenson

(1974).

Other authors have also reported high E's for staple crops in subsistence agriculture in other parts of the world. Black (1971) reviewed the data of several authors in different parts of the tropical world and found the E's varied between 15–30 for hand cultivated rice, millet, maize and sorghum. Rappaport (1971) found that the primitive agriculturists in the highlands of New Guinea realized E's of about 16 on a total biomass of hand cultivated crops. Some of the crops grown by this community were cassava, sweet potatoes, taro, yams, bananas, maize, beans, cucumber, pumpkin and sugar cane.

Energy Purchasing Power

The energy purchasing power of the subsistence crops is much higher than that of other crops in both farming systems. The EPP of the Fijian subsistence crops is higher than that of the Indians. This means that it is cheaper for a Fijian family to meet the daily food requirements from the traditional root crops, such as cassava and sweet potatoes, than for an Indian family relying on rice, pulses, Irish potatoes, green beans and egg plants. As expected the vegetable crops are the most expensive form of kJ to consume. Maize has the highest EPP of all the crops but is not normally used as a staple crop, although on a few occasions green maize was eaten at home.

The high E's of the Fijians compared to the Indian subsistence crops indicated that the Fijians are more efficient producers of food, both in energy usage as well as in terms of returns. The Fijian farming system is more efficient as a semi-subsistence agriculture whereas the Indian system is more efficient in terms of commercial agriculture. Thus the use of energetics goes a long way towards explaining the productivity differences between Fijian and Indian farms.

Energetics and Agricultural Development Policy

Agricultural development implies a shift from a subsistence based economy to a commercial one, with shifts in resource use, new crops or specialization on a few crops. The greatest problem development planners will have is to argue a case for new resource adjustments which would lead to greater advantages over that of the present semi-subsistence systems. If resources are assumed to be scarce then it is difficult to envisage agricultural development not affecting the subsistence fraction of crop production. Yet it has been shown that the subsistence crops, especially in the Fijian farming system, easily provide a very large percentage of the daily kJ requirements of the farm family and have a desirable pattern of seasonal availability.

The farmers are and will be reluctant to sacrifice the security that staple crops offer, knowing well the risks and uncertainties of weather, prices and other exogenous factors that plague the commercial crops (Porter, 1959). This is one reason why even the most successful Fijian farmers, in terms of total gross output, rely on the traditional root crops for sale to meet their cash needs. Another reason is that the traditional root crops usually require very low cash investments as almost all planting material is freely available on the farms and there are no direct cash costs involved. However, the problem exists that although the subsistence crops require low inputs of the production factors, they are also the low priced crops when sold commercially. Hence, increasing factor inputs in such crops is unlikely to create substantial gains in family cash incomes. Growing the high energy crops best meets the subsistence needs of the family but not its cash needs. Theoretically, the implication is that each household has to strike a balance where, once the subsistence needs and dietary preferences for high energy crops have been satisfied, the remainder of the production factors can be put into high-value crops to meet the cash needs of the family. A major problem with this approach of increasing the cash fraction of the crops at the expense of the subsistence fraction, will be the low technological level of the farms which imposes a constraint on the production of cash crops, many of which can be grown successfully only in the winter months from May to October.

The case for agricultural development and a concentration of farm resources on high priced commercial crops has to be based on the cash needs of the farmers. At present both races have low cash needs, with the Fijians' cash requirements being lower than those of the Indians. Only when the cash needs of the Fijian and Indian farmers can be raised through a greater demand for goods and services will the production of more cash be generated. Such needs will be based on the aspirations of the farmers and developments elsewhere in Fiji.

The adoption of new technology would be made more difficult by the broad range of crops grown on the farms. A dramatic improvement in yield for any one crop would have a limited effect on income. Thus, allocating limited research resources poses problems for Fijian agricultural research administrators. Projections of the urban demand for food crops would help to pinpoint where to devote more effort (Hutchinson and Wilman, 1965). Another problem with new technology would be the possible undesirable effects of mechanization on the already serious under-employment off labour. However, this will have only minor consequences because most labour is used for hand harvesting tasks which machines cannot duplicate. The only tasks in which mechanization will reduce labour use are land preparation, covering and scarifying.

Agricultural development will mean that more inputs of energy, such as fuel for tractors, will be needed in the agricultural systems. Larger cash budgets will be required on the farms to meet the costs of fuel, fertilizers and other agricultural chemicals. On the national scale the marketing structure and the communication systems, both in terms of road network and dissemination of knowledge from the Department of Agriculture, will have to be improved. Farming will become more and more dependent on internationally marketed materials with a consequent dependence on international prices. More use of energy will mean that the E's of the crops will drop considerably and may even give values below one. This is true of the agriculture of developed nations such as in the United States where four kJ of energy are required to produce one kJ of food (Borgstrom, 1974) or Australia where it has been estimated that five kJ of energy are required in farming and processing to produce one kJ of food (Gifford and Millington, 1973). In terms of the world energy crisis there are several points of contention against high energy based agricultural development, espeically when the semi-subsistence system it is designed to improve is already highly successful in meeting the needs of the farmers.

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CURRENCY

All values are expressed in Fiji dollars. At the time of writing (November, 1978) $F1.00 = $NZ1.1351. ■■

Experiences with Solar Powered Communication System to Support Agricultural Development

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Introduction

Nepal has a total area of approximately 141,000km₂ (14 million hectares) of which four-fifths is hilly and mountainuous. The Kingdom is bounded by China in the north and by India in the west, south and east. The country lies between 80 and 88 degrees east longitude and between 26.5 and 30.5 degrees north latitude. The population is about 14 million (1) of which two-thirds are living in the hills. The hill area ranges in elevation from 750 m to 4,000 m. The climate varies from tropical in the Terai (the plain bordering India), sub-tropical in the Kathmandu valley to that of perpetual snow in the high Himalayas. The population density of the cultivated land is 1174 persons per km^2 in the mountain region, 1,002 in the hill region and 336 persons in the Terai region (2). Agriculture employs about 90% of the labour force. The GNP per capita is US $ 120 (3).

The rugged hills of Nepal with their limited transport, communi cation and other infrastructure facilities present a special challenge to development. Of the 55 hill districts, 42 districts, representing 62 percent of the land area and 41 percent of the population are not serviced by roads (4). At present the only means of transport for the remote areas is by STOL aircraft and by foot, including pack animals. Aircraft operations are highly affected by weather conditions while trekking to remote areas might take as much as 14 days.

Agricultural development efforts in Nepal in the last 20 years have been focused primarily on the Terai and the Kathmandu Valley while little attention has been paid to the hills. However, the present five year plan of His Majesty's Government emphasizes development of the hills. Small scale intensive agriculture is at present by far the most important activity in the hills and as several hill areas are food deficient it is appropriate that agricultural development receives considerable attention. The Hill Agriculture Development Project, initiated as a cooperative undertaking of HMG, UNDP and FAO reflects the growing concern of HMG about the hills. The immediate ob jectives of the project are to establish within the Ministry of Food, Agriculture and Irrigation a permanent data and documentation center for hill agriculture ; to provide technical and financial support to hill aguricultural developmnt activities ; to plan projects and programmes related to hill agriculture development and to formulate a long-term development policy and plan for hill agriculture. The project which became operational in July 1974 is located in the Ministry of Food, Agriculture and Irrigation.

Improvement of Communication

Agricultural officers working in the remote areas of Nepal have a difficult task. Inputs for improved methods are not available and communication with their head office in Kathmandu is extremely difficult. This difficult situation not only affects the development work but also has a psychological impact ; the field offiicer feels abandoned by his headquarters and isolated form family and friends. To improve communication between remote agricultural stations and the Departments of the Ministry of Agriculture the Hill

Fig. 1 Solar panel at Phikal Farm with broadband antenna in the background

Agriculture Developmet Project has installed since 1977 six wireless communication sets in agricultural hill stations in east Nepal (Phikal Cardamon Development Farm), north of Kathmandu (Sermathang Horticultural Farm), Far West (Jumla and Dolpa Horticultural Farms) and a base station in Kathmandu (Department of Agriculture). The unique thing about these radio stations for Nepal is that the equipment is powered by solar energy which has proved to be very successfull even during extremely rainy and cloudy periods. Engine-driven generators to power the radio sets could not be considered in remote areas because fuel would have to be carried in by porter as aircraft refuses to transport petrol for reasons of saftey. Moreover, the wireless sets are operated by unskilled staff and maintenance of generators would be non-existent.

The light and small solar panels do not require any fuel and are maintenance-free Surplus energy is stored in a standard automotive battery for use during periods of limited sunshine. The Single Side Band (SSB) transceivers have either 50 watt or 100 watt transmission power and are equipped with four frequencies. These transceivers are specially designed to be operated by persons without any special training in operation and maintenance and are coupled to a broadband antenna system. Installation of the complete solar powered set does not require any special skill as detailed installation instructions are provided by the supplier.

Specifications

100 Watt transceiver set

"Codan" type 6801 SSB/AM ; four fixed crystal frequencies (maximum which can be fitted is 10) ; Noise limiter switch ; Mute control ; CAW (clarifier) ; Emergency Call ; USB (Upper Side Band) Operated.

Power consumption (from battery) : Receive 250 mA (no signal), and Transmit 6 A (average).

50 Watt transceiver set

"Codan" type 7515, Power consumption (from battery) : Receive 250 mA (no signal) and Transmit 2.5 A (average)

other specifications similar to Codan type 6801.

Antenna

Type : "Codan Code 402 Broadband Antenna" ; complete assembly with coupling and mounting hardware. Support poles made in workshop in Kathmandu.

Lower Supprt Pole : galvanized pipe O.D. $3\frac{1}{2}$ inch ; 4.5 meters long of which 1.2 meter is sunk into the ground.

Higher Support Pole : galvanized pipe. O.D. 60 mm ; 15 meter high (3 sections).

Solar Cell Panels

Type : Solarex 480 D (with built-in blocking diode)

Output in full sun : 14 Volt nominal at 25° C.

Output current in full sun :

a) Single Panel (for 50 watt set) : 0.65 A at 25°C.

b) Double panel (for 100 watt set) : 1.3 A at 25°C.

Size : Single panel 15 × 15.5 inch : Double panel 15 × 32 inch.

Battery for energy storage : Heavy duty lead-acid battery (from local supplier) :

a) Single panel : 60 Ah.

b) Double panel : 120 Ah.

Power Supply Base Station (Dept. of Agriculture)

"Codan type 7113 AC power supply with option X ("No-Break" facility to enable uninterrupted communications in the event of a mains failure).

Output Voltage : 13±0.2 V DC,

Output Current : 12.5 A DC continuous duty,

Battery for "No-Break" facility : Heavy duty lead-acid battery 60 Ah.

Cost specification*

100-watt set, including double solar panel and antenna

……A $2,368

100-watt set for base station, including power supply and Emergency Call Decoder

……A $2,291

50-watt set, including single solar panel and antenna

……A $1,555

Local available inputs (1 US $=12 NRS)

Battery for double solar

※Imported equipment (Price in Australian Dollar F.O.B. Adelaide, Dec. 1976) 1 Australian Dollor= 13.5 Nepali Rupees.

panel……NRS 1,420
Battery for single solar panel……NRS 820
Antenna poles and material for installation……NRS 5,100

Results and Recommendations

The Codan transceivers are not the cheapest sets available in the market but these sets have been chosen because of easy operation (sets are operated by untrained operators), easy installation (even by unskilled persons) high reli ability and because they are maintenance-free. At present Codan offers a cheaper set which has the same capacity as the 6801 but without a few options and specifications which are not needed in remote areas anyhow.

Apart from a few minor problems the solar cell panels work very satisfactorily even in areas where cloudy and rainy weather occurs during several months of the year. The capacity of the batteries is too big and 100 Ah (double panel) and 50 Ah (single panel) batteries will be sufficient under present conditions. In case more transmitting time is needed the system can be extended with additional panels. The only maintenance required is topping-up the battery with distilled water. The main problem is that farm staff add too much distilled water which results in the battery "boiling over". Automatic battery filling cans have been supplied but these became faulty very quickly. Maintenance free lead-acid batteries could be considered worth the extra investment.

The Emergency Call Option has no practical use in a situation in which the system is used as the base station still would have to be operated for 24 hours. The system has been designed to wake up duty officers at night (flying-doctor ; fire brigade, etc.) which is not necessary for the system operated by the Department of Agriculture.

Although the system is very easy to operate (On/Off combined Loudness Switch and Channel Selector) even fewer switches are required for the remote outstations ; Side Band Selectr, Mute Control and Noise Limiter can be deleted. This would leave only three switches on the set which is an advantage especially with unskilled operators. Mute control is at present a standard facility but needs adjustment during installation and is not needed for outstations and the less sophisticated the set is, the more reliable it will be.

The system has been success fully in operation now for more than 1½ years and has facilitated agricultural development activities considerably. The experience is such that the solar powered system will be a great step forward in improving communications for remote areas. Additional sets are at present planned for other agricultural stations.

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■■

Current Status of Agricultural Mechanization in Fiji

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Abstract

Agriculture is the most important sector of the Fiji economy, both in terms of gross national product and the number of productive workers employed. The two major racial groups in Fiji are the indigenous Fijians who form 44 percent of the population and the immigrant Indians who comprise 51 percent. Small holder farming is the dominant with an average farm size of 2 – 4 ha per rural household which consists of 6.3 persons. The general level of farm mechanization is low. Most of the farm work is carried out manually and with the use of bullock and horse power. Only a few farmers own tractors and these are usually used in sugar cane production which is the major export crop. In the last two decades there has been a trend towards greater use of tractors for cultivation and other farm work. However the world energy crisis of the 1970's, leading to the high cost of imported fossil fuels, has slowed down the mechanization process considerably. Although this problem has not been given sufficient recognition by the appropriate authorities, there has been some tendency by small holder farmers to re-examine the advantages of appropriate technologies such as bullock and horse power. Recently agricultural engineering research has also been started by the Research Division of the Department of Agriculture to support the mechanization needs of the farmers.

* Presented at the XVI Annual Convention of the Indian Society of Agricultural Engineers, held at the Indian Institute of Technology, Kharagpur, (W.B.), India; December 18th–20th, 1978.

Introduction

Agriculture is the most important sector of the Fiji economy. In 1976 65 percent of the total population of 588,000 was dependent on agriculture for their livelihood[1]. Fiji has an area of 18,272 sq km of which 5,482 sq km are suitable for agriculture after moderate improvements in fertility, of the total population, respectively. Fiji has an area of 18,272 sq km of which 5,482 sq km are suitable for agriculture after moderate improvements in fertility, drainage and soil conservation measures[2]. However only 11.6 percent of the total area of Fiji or 2,120 sq km are suitable for arable agriculture[3]. This converts to 0.55 ha per head of rural population in 1976 or 3.47 ha per rural household. Most of the arable area of Fiji is already under cultivation and therefore the shortage of quality land is actue[4].

Small holder farming is dominant. Family labour is almost invariably used for crop production. The number of full-time workers on an average farm is 2 for farms operated by Fijians and 2.5 for those operated by Indians. Chandra[5] showed that in 1972 the gross output, defined as the value of all subsistence and commercial crops valued at the farm gate price, averaged $733 on Fijian farms and $1,446 on Indian farms.

Table 1 Ownership of Capital Goods and Equipment on Fijian and Indian Farms

Capital Goods and Equipments	Fijian Farmers*	Indian Farmers*
Horse	90	93
Ox	43	63
Tractor	3	32
Plough	90	100
Harrow	87	100
Scarifier	77	88
Wooden sledge	97	51
Hoe	100	100
Fork	73	23
Spade	97	78
Cane knife	100	100
Sickle	67	100
Maize sheller	3	27
Knapsack sprayer	50	88
Wooden treadle**	20	50

*Percent of 123 sample farmers studied who owned at least one capital good or equipment.
**Used for rolling twist tobacco leaves after curing.

Farm Technology

The general level of farm mechanization in Fiji is low. **Table 1** shows the ownership of items and equipment on Fijian and Indian farms. The Indians have considerably more oxen, tractors, maize shellers, knapsack sprayers and wooden treadles whereas the Fijians have more wooden sledges, forks and spades. A large number of farmers in both groups own horses which are needed for such tasks as uphilling row-planted crops as maize, broom corn, tobacco and sugar cane. Draught animals are extremely expensive relative to average farm incomes. During 1972 a horse sold for $100 and a pair of bullocks for $300. Very few farmers own tractors which range from 35–50 hp capable of one or two-disc ploughing. The wooden sledges are drawn by draught animals and are also used for transporting crops from farm to the homestead, drums of water from rivers to the house or for carrying store purchased household goods from the roadside to the farm. On Fijian farms most maize shelling is done by hand. The knapsack sprayers are used for spraying insecticides on vegetables or sugar cane. The wooden treadles are used to roll twist tobacco leaves into ropes after they have been cured.

The manual, animal and tractor based systems of crop production technologies in Fiji are now described separately although there is a considerable amount of overlap between the three systems. This description can be enhanced by the use of a simple concept called efficiency ratio (E) which is the ratio between the amount of food energy produced and the amount of energy expended to produce the commodity. The edible yield of crops is expressed in kilojoules (kJ) and is divided by the kJ of energy expended by man, draught animals and fossil fuels to attain that yield as described by Black[6]. The definition does not include the photosynthetic energy utilized by the crop. The high the E of a crop the more efficient that crop is in the energetic efficiency with which it uses resources to produce food under a cropping system of a given technology. The present discussion centres on food crops only but can be extended to all crops as has been done by Borgstron[7] in the United States and Gifford and Millington[8] in Australia. In Fiji a considerable amount of research on the energetics of crop production has been carried out by Chandra and colleagues[9,10,11] and these have been reported recently.

Manual Systems

Manual systems of crop production are mostly used in the cultivation and harvesting of cassava, sweet potatoes, taro and yams which are the staple food crops of the Fijians. Yields of these crops range between 6–9 mt/ha. Most of the land preparation for these crops is done by hand. For cassava, sweet potatoes and yams forks and horse drawn ploughs are used. Taro is still planted by the traditional method using a thick wooden stick to make holes in the ground in which the planting materials, which are the taro tops and suckers, are inserted. All planting material such as cassava pieces, sweet potato vines, taro tops and suckers and yam tubers are prepared using cane knives. Weeds are controlled with cane knives and hoes. All harvesting is done manually using forks. Harvesting is the most time consuming task and in cassava this represents 50–60 percent of the total manhours used in crop production.

The E's of cassava, sweet potato, taro and yams are 71, 82, 65 and 77, respectively. These are relatively high and indicates that in a semi-subsistence setting the returns to energy expenditure are greater than in a technologically advanced form of agriculture. The process of economic development depends, to a large extent, upon the substitution of capital for labour and this in turn has a pronounced effect upon the energetics of the food producing system. For example, it was shown by Chandra[9] that in the four sets of production technology – hand labour only (A), hand labour plus horses (B), hand labour plus horses and chemical fertilizers (C) and hand labour plus chemical fertilizers and tractors (D), the E's progressively decreased as the technology progressed from A to D.

Animal Systems

Animal based agricultural systems are the most common form of smallholder farming in Fiji. Draught animals are used for the production of almost all crops, the important ones being rice, pulses, vegetables and sugar cane. The draught animals used are horses and bullocks. On Fijian farms the common draught animals are horses whereas Indians have more bullocks. The draught animals are mainly used for ploughing, harrowing, scarifying and for the transportation of materials and goods on the farm.

It was also shown by Chandra[10,11] that the E's of rice, pulses and vegetables, grown predominantly using animal based power, ranged between 15 and 20. Compared to a predominantly manual form of agriculture the E's of the animal systems have dropped considerably. However, agricultural productivity, measured in terms of gross value of crops produced per manhour, increases several times.

Tractor Systems

On small holder farms tractors are mainly used for sugar cane production which is the major export crop in Fiji. However, only about 25 percent of the 15,000 sugar cane farmers own tractors and most of these are used in extensive agricultural systems such as on coconut plantations, dairy and beef farms. **Fig. 1** shows that in the last two decades there has been a trend towards greater usage of tractors for cultivation and other farm work[12]. The world energy crisis of the 1970's has slowed down the import of tractors in Fiji because of the high initial purchase price and the fuel cost which is presently $0.69/gallon for diesoline. Most of the tractors used on sugarcane farms are medium-sized, usually in the range of 35–50 hp. The tractors are used for ploughing, some harrowing, inter-row cultivation and for other farm work.

For tractor based systems the E's of the crops are the lowest, usually ranging between 5–10. However, agricultural productivity is high because of the substitution of capital for labour and is usually over 10 times higher than that generated under manual systems. Therefore, as agricultural development moves from a pure subsistence economy to a pure commercial one the E's of the crops decrease progressively with a concomitant rise in agricultural productivity. However, because production becomes more and more dependent on internationally traded commodities such as fossil fuels and capital-intensive items such as tractors, the risk and uncertainties in farming become greater. This is a major reason why there is now a world-wide awareness for the search of appropriate technologies for agricultural development.

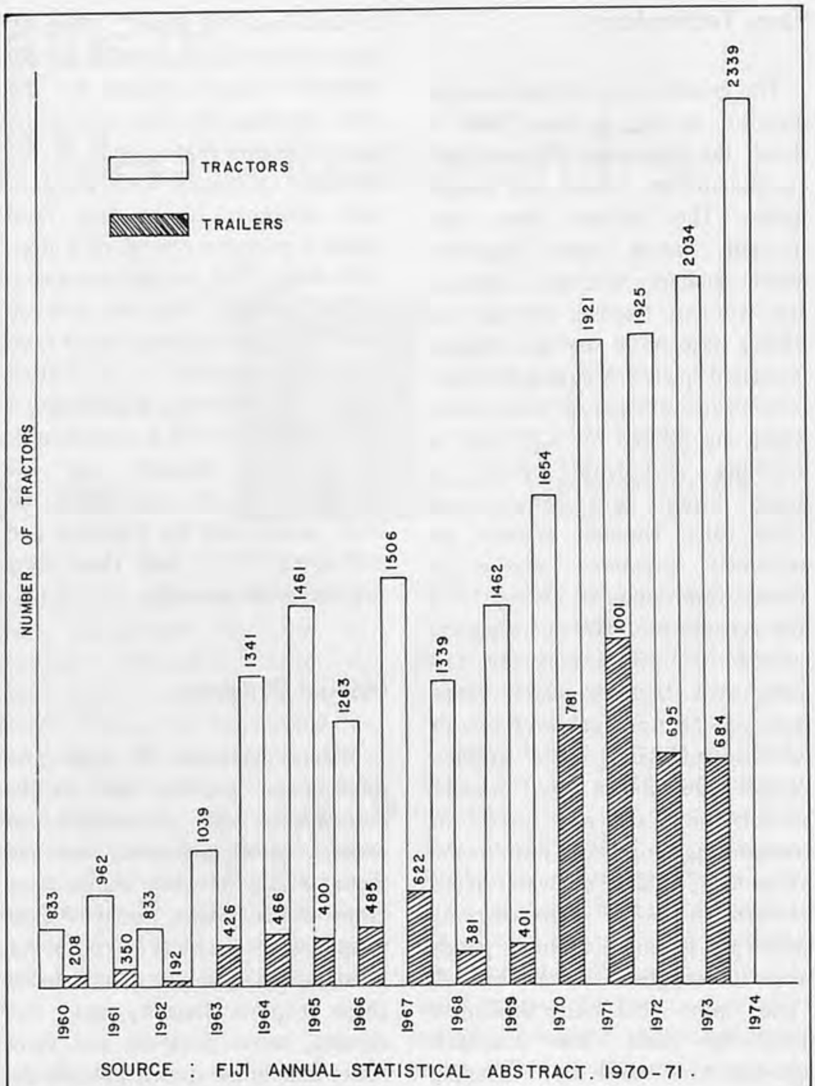

Fig. 1 Population of Tractors in Fiji

Engineering Research

A government initiated search for appropriate technology in Fiji began with the establishment of the Agricultural Engineering Section in the Research Division of the Department of Agriculture in 1976[13]. Research has been carried out on hand tools, animal drawn equipment, power operated equipment, crop mechanization systems and on evaluation of commercially produced small tractors. These are described below.

Hand tools – Inter-cultural hand tools such as the wheel hoe, Khurpa hoe, serrated blade hoe, plain blade and kasola hoe have been designed and developed for controlling weeds and loosening the soil in row planted vegetable crops. Such tools can be quickly adopted by a farm family, including women and children and thereby will enable a greater utilization of the available family labour on the farms. Some of these hand tools are shown in **Fig. 2.**

Animal drawn equipment – A ridger, furrower and a light duty mouldboard plough have been developed to replace the heavier equipment available previously as reported by Sharma[14]. This equipment enables easier breaking of

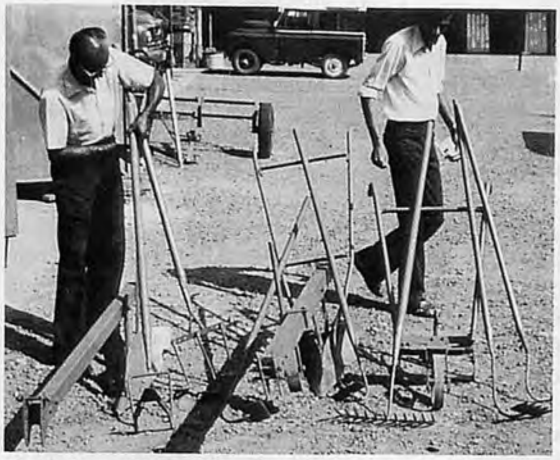

Fig. 2 Some of the intercultural hand tools

Fig. 3 An animal drawn groundnut harvester in use

clods and has been used successfully for the formation of ridges and furrows for the planting of cassava, taro, yam and ginger. Other machines that have been developed are a single row paddy drill and a groundnut harvester. The groundnut harvester has not been previously used in Fiji and should make significant savings in labour requirements once the machine is produced commercially. **Fig. 3** shows a groundnut harvester being used in the field.

Power operated equipment – Some power operated machines such as a winnower for paddy, pulses ans sorghum have been developed and these have been used successfully on research stations and farms where electric power is available. However, becauses most rural areas in Fiji are without electric power the impact of such machines will be limited. A power operated winnower is shown in **Fig. 4**.

Crop mechanization systems – A simple mouldboard has been modified into a tractor drawn cassava harvester which has considerably reduced the labour requirement in harvesting this crop. Trials carried out by Sharma[15] on a farmer's field showed that one man operating the harvester together with another person to haul out the tubers could harvest one hectare of cassava, producing 9 mt, in 15 hours. This compares favourably with two persons requiring 46 hours to harvest the same yield of cassava with forks and at the cost of a much larger volume of damaged tubers. Further research is underway to modify other existing machines for harvesting taro and planting ginger. **Fig. 5** shows a Cassava harvester being used in the field.

Evaluation of small tractors – Small tractors such as the Japanese Kubota and Korean Daedong are continuously evaluated at the research stations to suit the needs of different agronomic systems for the production of various crops such as rice, pulses and vegetables. Simple modifications as necessitated by differing soil and weather con-

Fig. 4 A power operated winnower for paddy, sorghum and pulses

Fig. 5 A tractor drawn cassava harvester being used in one of the crop mechanization project

ditions, are often made to these machines. The results of such evaluations are made readily available to the farmers.

Conclusions

The level of agricultural mechanization in Fiji is low and is likely to remain so because of the small holder system of agriculture which does not exhibit a need for capital – intensive agricultural development. In the long-run the world price of fossil fuel is likely to discourage farmers from buying tractors and other fuel consuming machines. The most appropriate production technology in Fiji may be a combination of manual, animal and tractor based systems which is already practised on most of the sugarcane and some vegetable farms. Such technology maybe especially suitable in Fiji as the rural population and the problem of unemployment and under-employment increase.

Note: – All values are expressed in Fiji dollars. At the time of writing (October, 1978)$F1.00=Rs9.730.

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Effect of Speed on Specific Draft of Moldboard and Disc Plows in Bangkok Clay

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Abstract

The effect of speed on specific draft and power requirement of a moldboard plow and a disc plow was determined. By conducting the experiments in the field the relations were developed between speed and specific draft for disc plow. No specific relationship was found between speed and specific draft for moldboard plow. Power requirement increased with speed for both moldboard and disc plows. Draft and depth were linearly related with some random deviations along the test run.

Introduction

Primary tillage operations have been the largest power consuming operations on a farm. Moldboard and disc plows are widely used as primary tillage implements.

Much work have been done on the moldboard and disc plows under controlled conditions but very few research workers have tried some tests in the field because of the difficulties encountered. Reed (1937) and Randolph and Reed (1938) studied the effect of soil types on plow bottoms and found that the magnitude of draft force is not only affected by the type of soil but also increased with travel speed. O'Callaghan and McCoy (1965) measured the forces on share, moldboard and coulter and found the major portion of increase in draft force due to increase in the forward speed of plow. To support the fact that draft force for tillage implements increases with increase in speed, Rowe and Barnes (1961) and Panwar, *et al* (1973) stated that the increase in shearing strength of soil with increase in strain rate is a prominent factor.

Dwyer (1969) conducted a field test on moldboard plow in an undulating unplowed field and found a proportional change in draft force with depth with some random deviations.

Reaves and Schafer (1975) conducted tests on three geometrically similar bottoms (40.6 –, 45.7 –, and 50.8 cm width of cut) at the National Tillage Machinery Laboratory (NTML). Ten to 12 percent less specific draft was found for 40.6 cm bottom other than two bottoms depending on speed in sandy loam soils. But 45.7 cm bottom took 6.5 percent more specific draft at 1.5 m/s and 11.0 percent more at 2.5 m/s than other two bottoms in Lloud clay. A 50.8 cm bottom required 10 to 12 percent less specific draft than other two when operated at normal operating depth of 20 to 25 cm.

Gordon (1941) reported a 40-percent increase in draft in the clay-loam and 90 percent in the fine sandy-loam when speed was increased from 1.34 to 2.68 m/s for a disc plow of 45 degree disc angle and 18 to 20 degree tilt angle. The draft of a disc plow was reduced when the disc angle was increased from 35 to 40 degree which resulted in a greater draft per unit width of cut (Harrison, 1977).

Taylor (1967) conducted field tests in two soil types in Australia. He operated a 60.96 cm plow disc at a 88.9 cm depth in a sandy-clay-loam and found a linear increase in draft force between disc angles of 32.5 and 55 degree. But, in a test in a gray-silty-clay at a depth of 12.70 cm, he observed that draft force increased with disc angle at width of cut of 20.32 cm, decreased at 10.16 cm cut, and remained constant at 15.24 cm cut.

These studies give an idea of the variation in draft force with speed, depth of cut, width of cut, and soil types and conditions. However, to establish relationship among these parameters extensive field tests need to be conducted.

Soil Analysis

The site selected for the field tests was 40 km north of Bangkok in the campus of the Asian Institute of Technology, Bangkok, Thailand. The soil in the region is known as Bangkok clay. Much work has been done on this soil in the Division of Geotechnical and Transportation Engineering of the Institute, but they deal only with the soil one meter below the top surface.

In order to know some basic properties of top 30 cm soil, tests were conducted and results are shown in **Table 1**. Soil strength parameters (Cohesion, c, and angle of internal friction, ϕ) which determines the shear strength of soil was obtained by using direct shear apparatus.

The type of shear apparatus used was shear box split into two halves. The lower half of the box is rigidly held in a position in a container which rests over slides and can be pushed forward at a constant rate. The upper half of the box bears against a calibrated steel proving ring. The inside dimensions of the shear box was 6 x 6 cm. Nine undisturbed soil samples* of size approximately 6 x 6 x 2.5 cm were tested at a shear rate of 1.22 mm/min (fastest rate available on the machine) under increasing normal load and the total shearing force was read from the calibrated proving ring dial at 0.2 mm increment of deformation until failure was reached.

Table 1. General Properties of Bangkok Clay

Sample Number	Clay Property		Average Value
1	Sand (2.00 – 0.06 mm)	%	18.0
	Silt (0.06 – 0.002 mm)	%	30.0
	Clay (<0.002 mm)	%	52.0
2	Liquid limit	%	47.8
3	Plastic limit	%	31.9
4	Plasticity index	%	15.9
5	Specific gravity		2.7
6	Natural water content	%	27.9
7	Dry unit weight	KN/m^3	14.6
8	Degree of saturation, range	%	80–100

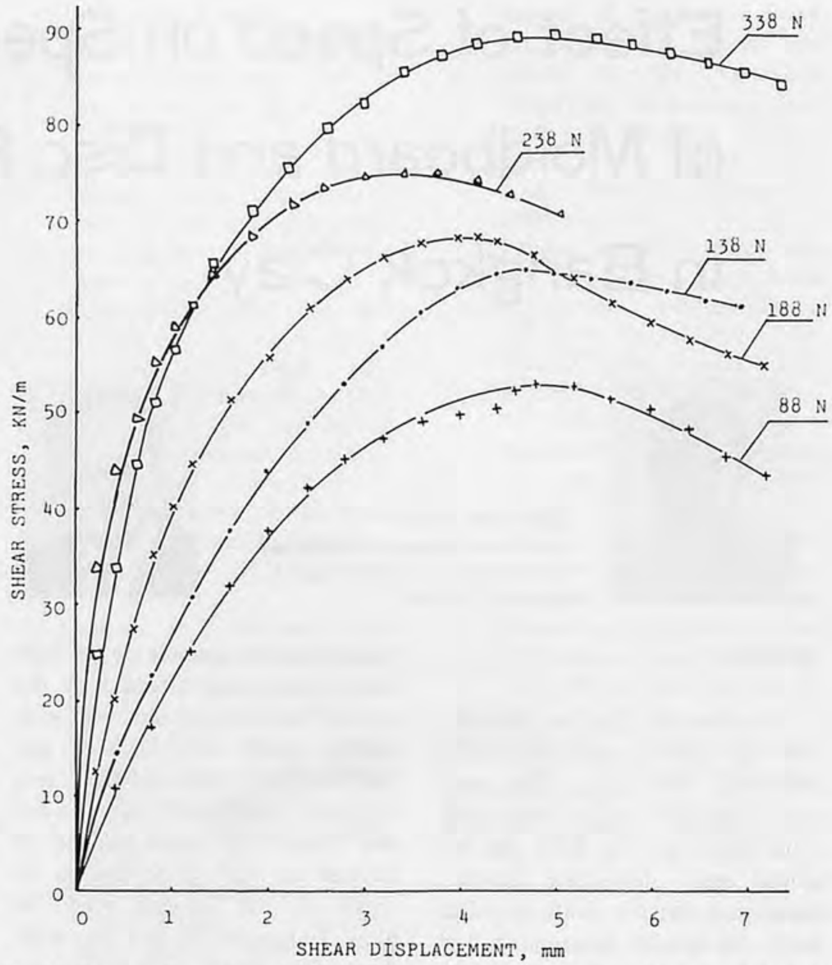

Fig. 1 Shear stress against shear displacement at five normal loads at average m.c. of 22.2 percent in Bangkok clay

Shear stress was plotted against shear displacement for all the samples. **Fig. 1** shows the shear stress against shear displacement for five different normal loads. Maximum values of shear stress from all the nine curves were plotted against corresponding normal stress (**Fig. 2**). A straight line was drawn from least square method. The intercept of the line with ordinate, which is cohesion, was 42.5 KN/m^2 and inverse of the slope of line, which is angle of internal friction, was 21.8 degree.

* Undisturbed samples were taken from 20 to 30cm of top soil by removing top 20cm soil, because it consists of grass roots and was not possible to take undisturbed samples.

Procedure

A 3-bottom moldboard plow (35.6 cm width of cut each) and a disc plow, with three discs of 45 degree disc angle and 17 degree tilt angle supplied by the Massey Ferguson Co. were selected for field tests. The power source for pulling the mold-board and disc plows was a Massey Ferguson MF 165 wheel tractor with maxim power of 46

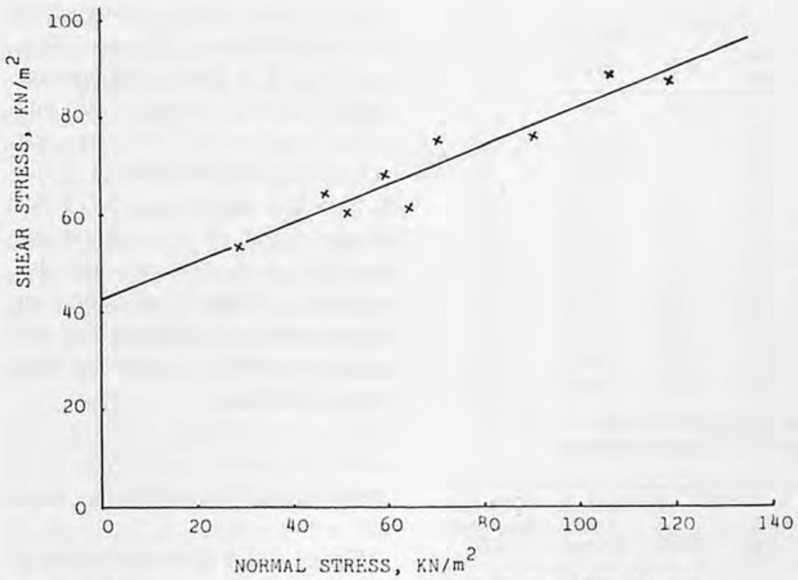

Fig. 2 Relationship between shear stress and normal stress in Bangkok clay

Fig. 3 General view of tractor implement and instrument

KW (62 hp) at 2,000 rpm.

The experimental field was unplowed for many years and had grass all over the surface. All the tests were conducted for 20 m run. Time was recorded by stop watch for calculation of average speed. The speed was gradually increased from 0.308 m/s to 1.130 m/s for 11 test runs for moldboard plow. In the case of disc plow, tests were conducted at two different moisture content levels. In one case, speed was increased from 0.234 m/s to 1.190 m/s for 14 test runs while in other case from 0.597 m/s to 0.816 m/s for 4 test runs. It was not possible to continue the tests at other speeds in the latter case on account of sudden rain. But these tests were considered for data analysis because it gives the idea of effect of moisture content on specific draft.

The response lever was set on fast side in all the tests with moldboard and disc plow. The draft control lever was set at different positions for both the plows but was set at one position for all the runs of a particular plow. The depth of cut, in the case of moldboard plow, was measured at every 50 cm distance of travel while in the case of disc plow it was measured at every one meter interval along the test run. The width of cut was also measured at different places in all the test runs of both the plows to determine the average width of cut in each case. Soil samples were taken before starting the tests for moisture content determination.

To measure the horizontal and vertical component of force in two lower links and compressive force in top link of a tractor, a 3-point linkage dynamometer, designed by Sirichaimanus (1977) and modified by Singh (1978) to suit the requirements of category I and II mounted implements, was used. The dynamometer was attached between the tractor and the implement. Plows were adjusted in the field for similar depth of cut in all furrows and also for side swings. The lower link force transducers were adjusted for their horizontal position and were checked from time to time during test.

Signals from force transducers were passedthrough a strain amplifier powered by tractor battery and recorded on SE Eight-Four portable tape recorder (self-powered). Signals were adjusted on the tape in first trial run and were checked from time to time throughout the test. Strain amplifier was calibrated from time to time also. Both the tape recorder and strain amplifier were kept on a trailer pulled by a MF 135 tractor moving parallel to MF tractor with the plow (Fig. 3).

The draft force was determined by algebraic sum of horizontal component of forces in top and lower links. The specific draft is the draft per unit cross-section of the furrow slice. The percentage slip for each test run was calculated by $(1 - \frac{v_0}{v_1} \times 100)$ where v_0 is speed at load, m/s, and v_1 is speed at no load, m/s. Power requirement in kilowat (Kw)

Table 2. Effect of Speed on Specific Draft and Power Requirement of Moldboard Plow (96 cm width of cut) at 29.6 percent Moisture Content in Bangkok Clay

Sample Number	Speed m/s	Slip %	Depth of Cut Aver. cm	Depth of Cut S.D.	Draft Aver. KN	Draft S.D.	Specific Draft KN/m²	Power Required KW
1	0.308	23.9	19.3	1.7	22.5	2.3	121.4	6.9
2	0.408	25.1	19.5	1.3	23.5	2.4	125.5	9.5
3	0.418	29.1	18.8	1.4	22.7	2.9	125.8	9.4
4	0.585	38.5	21.9	1.8	29.8	2.9	141.7	17.3
5	0.606	39.4	21.0	2.1	20.8	2.7	103.2	12.5
6	0.645	21.3	16.5	2.7	19.0	3.3	119.9	12.2
7	0.704	40.1	19.4	2.4	23.4	4.2	125.6	16.4
8	0.769	30.0	15.7	1.2	17.4	2.0	115.4	13.3
9	0.784	25.1	14.1	2.1	18.2	3.5	134.5	14.2
10	0.890	32.4	17.1	2.2	18.6	5.3	113.3	16.3
11	1.130	29.4	18.6	2.1	26.7	3.9	149.5	30.0

Table 3. Effect of Speed on the Specific Draft and Power Requirement of Disc Plow (99.4 cm width of cut) at 27.8 Percent Moisture Content in Bangkok Clay

Sample Number	Speed m/s	Slip %	Depth of Cut Aver. cm	Depth of Cut S.D.	Draft Aver. KN	Draft S.D.	Specific Draft KN/m^2	Power Required KW
1	0.234	20.6	16.7	2.0	24.5	1.4	147.6	5.7
2	0.310	23.5	15.6	1.4	26.7	1.5	172.2	8.3
3	0.334	30.1	17.7	1.6	26.4	1.5	150.1	8.8
4	0.432	26.8	14.4	2.0	22.2	1.6	155.1	9.6
5	0.435	32.3	14.9	1.5	26.1	1.5	176.2	11.3
6	0.441	19.1	13.8	1.4	22.7	1.8	165.5	10.0
7	0.499	22.3	11.9	1.0	18.3	1.4	154.7	9.1
8	0.548	28.7	16.1	1.1	25.7	1.7	160.6	14.1
9	0.615	29.2	12.5	1.7	18.3	1.5	147.3	11.2
10	0.889	15.1	10.9	1.5	19.6	1.6	180.9	17.4
11	0.889	19.1	13.5	1.3	25.0	1.4	186.3	22.2
12	0.976	21.6	12.6	1.5	25.2	1.6	201.2	24.6
13	1.010	23.3	11.2	0.8	21.2	1.3	190.4	21.4
14	1.190	19.7	10.5	1.3	20.3	1.4	194.5	24.2

Table 4. Effect of Speed on Specific Draft and Power Requirement of Disc Plow (99.4 cm width of cut) at 34.1 Percent Moisture Content in Bangkok Clay

Sample Number	Speed m/s	Slip %	Depth of Cut Aver. cm	Depth of Cut S.D.	Draft Aver. KN	Draft S.D.	Specific Draft KN/m^2	Power Required KW
1	0.597	24.1	16.4	1.7	21.1	1.3	129.4	12.6
2	0.629	23.3	15.8	1.5	19.0	1.2	121.0	11.9
3	0.651	19.1	15.1	1.4	20.1	2.0	133.9	13.1
4	0.816	14.3	14.5	1.4	19.9	2.0	138.1	16.2

for each test run was calculated by the multiplication of speed, m/s, and draft, KN. Speed, slip, average depth of cut, average draft and power requirement for each test run are reported in **Tables** 2, 3 and 4. Standard deviations (S.D.) for average depth of cut and average draft for each test run are also reported in **Tables** 2 to 4. The least square method for straight line was used to smooth the data for each set of test runs.

Results and Discussion

Figs. 4 and 5 show the effect of depth of cut on the average horizontal forces in top and lower links of a tractor along the test run in Bangkok clay. **Fig.** 4 shows the plot of average values of horizontal forces taken at every 50 cm of distance travelled along the test run for the moldboard plow. In both cases a linear relationship was observed between horizontal forces in

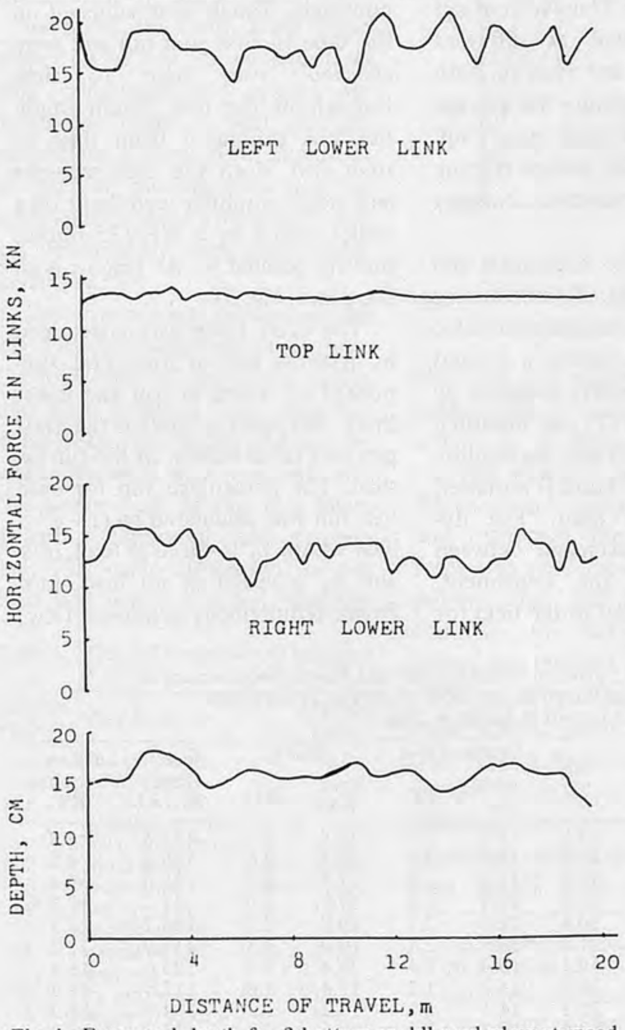

Fig. 4 Force and depth for 3-bottom moldboard plow at speed of 0.769 m/s

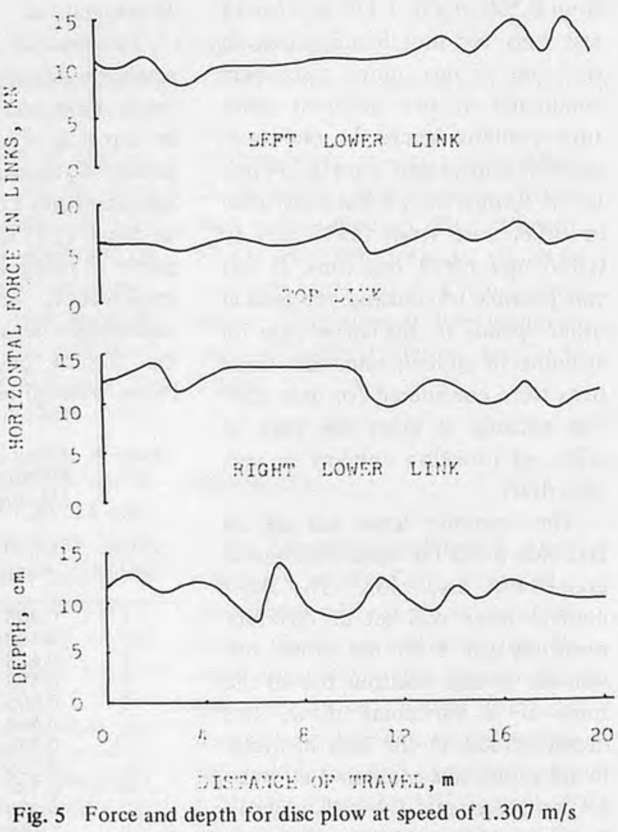

Fig. 5 Force and depth for disc plow at speed of 1.307 m/s

links and depth of cut with some random deviations. It is also clear from **Tables** 2 to 4 that with the change in depth of cut draft force changes.

Fig. 6 shows the relationship between specific draft and speed for the moldboard plow in Bangkok clay. Moisture content throughout the experimental area varied from 27.8 to 31.6 percent and an average moisture content of 29.6 percent was slightly less than the plastic limit. Points shown (**Fig.** 6) are very much scattered and hardly any relationship can be established. There is, however, a tendency for the specific draft to increase with speed. It is difficult to explain this behaviour although it may be due to the grass roots which were not uniformly scattered throughout the test area, change in moisture content and variation of soil properties. Compactness of soil was also varying with depth and from place to place. Efforts were made to determine the compactness of soil by hand cone-penetrometer and it was hardly possible to press up to 5–7 cm because of the stiffness of soil. No other mechanical cone-penetrometer was available.

The curve in **Fig.** 7 shows the relationship between the specific draft and speed for the disc plow at an average moisture content of 27.8 percent. A regression analysis for straight line by least square method gave the following equation:

$$D = 139.1 + 49.4\,S$$

where D = specific draft, KN/m^2

S = speed, m/s

The coefficient of correlation is found to be 81 percent. The average percent errors for this curve on the positive and negative sides were 4.2 and 5.7 percent of predicted value. The curve shows a linear increase in the specific draft with increase in the speed.

The effect of speed on the specific draft of the disc plow at an average moisture content of 34.1 percent is shown in **Fig.** 8. The

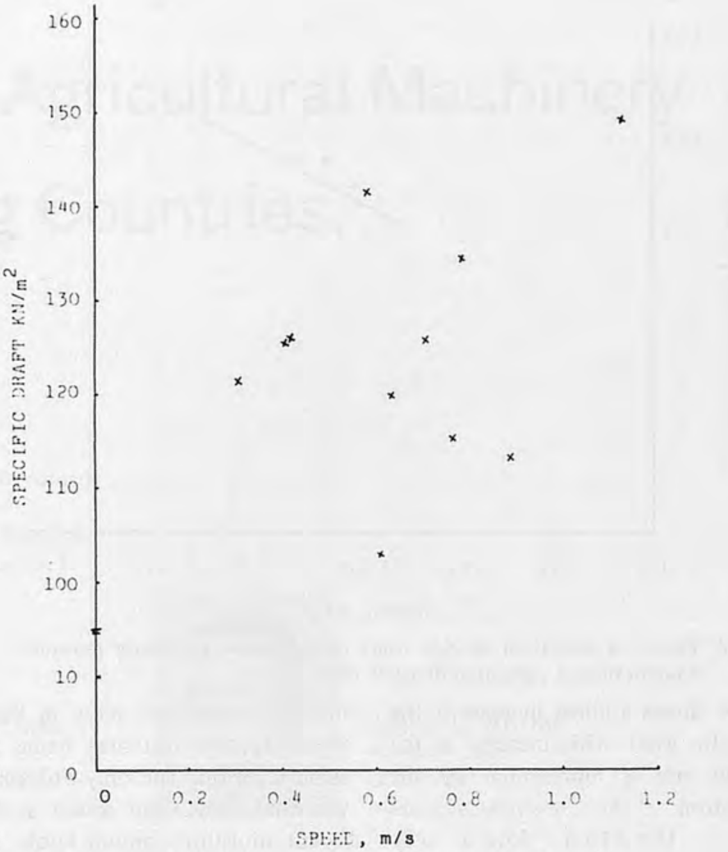

Fig. 6 Effect of speed on specific draft of moldboard plow at average moisture content of 29.6 percent in Bangkok clay

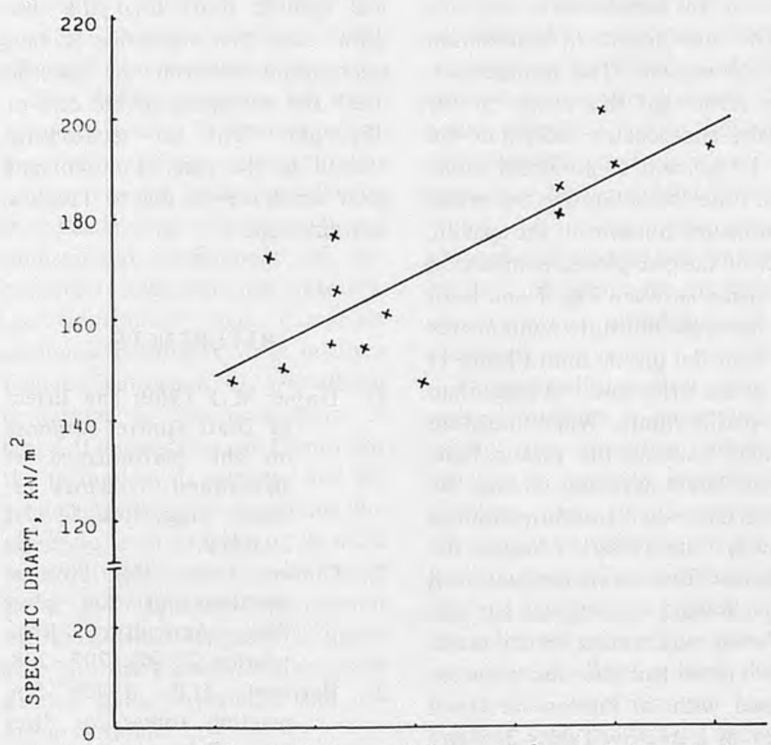

Fig. 7 Effect of speed on specific draft of disc plow at average moisture content of 27.8 percent in Bangkok clay

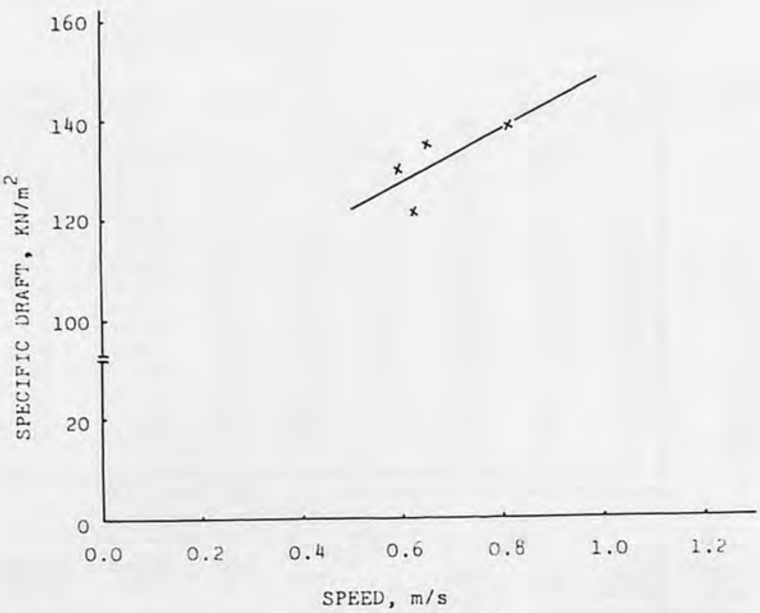

Fig. 8 Effect of speed on specific draft of disc plow at average moisture content of 34.1 percent in Bangkok clay

curve shows a linear increase in the specific draft with increase in the speed and is represented by the equation:

$$D = 116.6 + 55.6\ S \quad (2)$$

where D = specific draft, KN/m^2, and

S = speed, m/s

The coefficient of correlation was 78 percent. The average percent errors for this curve on the positive and negative sides were 4.6 and 1.1 percent of predicted value.

In order to determine the effect of moisture content on the specific draft of the disc plow a comparison was made between **Fig.** 7 and 8. In the first case moisture content was less than the plastic limit **(Table 1)** and in the latter case it is more than the plastic limit. When moisture content exceeds the plastic limit specific draft decreases. It may be stated that when moisture content exceeds the plastic limit, the adhesive force decreases and soil starts flowing on the plow surface.

Power requirement for the moldboard plow and the disc plow increased with an increase in travel speed of a tractor (**Tables** 2, 3 and 4) which limits high speed plowing.

If we compare the **Tables 2, 3** and **4** we see that the disc plow required a higher specific draft than did the moldboard plow in Bangkok clay, the test area being the same location. The only difference was that they were tested at different moisture content levels. No other explanation was found as to why the moldboard plow required less specific draft than the disc plow. Also it was possible to find relationship between the specific draft and the speed in the case of disc plow but no relationship existed in the case of moldboard plow which may be due to the plow bottom shape.

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Operation of Agricultural Machinery in Developing Countries

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Introduction

In developing countries, physical and environmental conditions are generally more severe. Soils are harder, dust and vibration problems are much greater, vegetation growth and resultant surface trash are considerable. Spare part availability, maintenance and repair facilities are quite poor and inadequate such that machines cannot perform satisfactorily for the period of intended design life. The operating skills are lower than the level commonly regarded as adequate for full life of the machines. Tractors are started by towing, and frequently operated in high gear which reduces tractor life.

Many problems are associated with the indiscriminate introduction into developing countries of the technology evolved in developed countries, since the technical, economic and social conditions are almost different. An intermediate level of technology is required. Appropriate mechanization together with other inputs represents a possible method of significantly improving agricultural productivity in developing countries which encounter possible adverse social effects of farm mechanization.

The defining feature of technological change is that it represents and, results in, a change in the productivity of resources. Change in the technology of production is a fundamental component of the structural alteration and resource use adjustment that comprises economic development. It involves the mechanization of agricultural operations in the production of crops. It depends on whether or not the technology is accepted and exploited primarily in expanding the aggregate level of output. In most cases farmers transfer from traditional to mechanized production methods, which requires a major step into the unknowns in terms of needed skills, experience and operating methods.

Many basic problems related to increasing the agricultural productivity of developing countries remain, despite the intensive efforts which are being made towards their solution assuming that some of the solutions which depend on effective soil cultivation operations are based on development of mechanization rather than on animal power. Cultural practices under different environmental conditions need improvement by dependable and profitable technology not already adopted and interactions among irrigation and agronomic practices to improve water utilization is encountered.

Operationally, in most cases, the tractor provides a greater power output, the immediate effect of which is to open the possibility of handling new or unmanageable machines and resulting in an expanded range of operations. More effective cultivation results in increased crop yields. The increased rate of work allows optimal timing of critical operations to further increase crop yields. By speeding the clearing of one crop and land preparation for the next, it is possible to achieve an increased intensity of cropping. More accurate sowing of seed and fertilizer allow greater yields, while the greater control offered by prescision implements also increases incomes through better quality products. Likewise, many other factors influence yield and considerable improvements can follow the balanced introduction of machines in agriculture. Machine technology is providing means to fully exploit the output potentials of the new high yielding varieties, fertilizers, chemicals and production techniques.

In areas where the wet growing seasons must eliminate the timeliness constraint, it is difficult to achieve this with the use of animal power because the force required to till hard, dry soil is substantial. A tractor draws larger implements, works longer hours and moves faster bringing much greater work achievement within a defined work period. It allows valuable operating benefits at critical times and is imperative where intensive production is attempted.

However, in a progressive enlargement of holdings, the farms are badly organized and saturated with irrationally used machinery. Therefore, a high amount of energy is consumed and lost. But in most of the agricultural conditions encountered, the quality of work is superior to that achieved by hand or bullock cultivation, in terms of depth of plow, degree of tillage and seed bed suitability for planting. Field operation principles must ensure that the equipment maintain effectively both quantity and quality of work, lasts a reasonable time and is available at all times.

This study was initiated in response to a set of coincidental concerns relating to the Pakistan mechanization program. It examines the effects of the introduction of tractor technology to farms in Sind. The assessment is based on information dealing with machine operations in relation to the rate of work on existing field conditions, area operated for major crops, estimated horse power, and unit cost of operations.

Methodology

The area of study covered 50 selected tractor farms of Sind, representing the universe in almost all respects from five districts; Tharparkar, Sanghar, Hyderabad, Nawabshah and Sukkur. The growers were interviewed, and data were obtained by experimental methods. The following analytical criteria were used:

1. Power Requirements

The power requirements of the various implements were assumed standard recommendations as follows:

Disc harrow	=	15 lbs/inch depth/disc
Disc/M.B. plow	=	7 $lbs/inch^2$
Cultivator	=	240 lbs/row
Combine	=	20 ft/ft cut
Grain drill	=	25 lbs/opener.

2. To Own or Hire a Machine

Per acre cost

$$= \frac{\text{Basic cost + Operating cost}}{\text{Area operated (acres)}}$$

If the cost proves to be higher than hire rate, the farmer is better off hiring tractors insted of buying one.

3. Field Potentials

$$Ef_p = Aw_h \times Ef_c$$

Where:

Ef_p = Effective field potential

Aw_h= Average working hours in a season under average conditions; and

Ef_c = Average effective field capacity

4. Field Machine Index

The field machine index was used to indicate the suitability of fields for machine use. The index of 95 is better than 85 when the index of 100 was maximum. The following formula was used:

$$FMI = \frac{A - B - C}{A - B} \times 100$$

Where:

A = Total time (min.) to cultivate an acre;

B = Total support function time (min.) other than turning; and

C = Total time (min.) spent for turning at row ends.

Results

The economic performance of a machine is the effectiveness with which power is applied to accomplish an operation. Thorough understanding of power and its optimum use is essential for good machinery management. A tractor must satisfy the normal requirements of agricultural machinery and perform necessary tasks. Progressive growers in Sind have purchased tractors as source of farm power. Tractor-power on farms will continue o be an absolute necessity. But the decision to select an optimum power unit is still controversial. There exist arguments in favour of both small and large tractors because rated power requirement differs with machines. The choice must assume that the scope of operations are those of the large tractors, including primary cultivation, secondary cultivation, planting, weeding and transport. Also, fuel consumption is directly proportional to engine would work near its maximum capacity. This gives a reduction in life expectancy of the machine. A conventional small tractor capable of carrying out a full range of agricultural tasks is not feasible on technical grounds. They are limited by their ability to perform all the functions that growers expect of a small tractor (Kilgour 1976).

On the other hand, a light weight tractor with small tyres cannot produce a high drawbar pull in conditions where traction is difficult. There conditions exist when there is a layer of loose dust on the surface of the soil which occurs after the harvest of root crops or when a wet surface layer overlays hard soil. Such conditions are frequently encountered in developing countries. It has been estimated that a draught of 4.5 KN (1,000 lbs) is required to pull a single tine or share at a depth of 150 mm (6 in). Under these conditions, a small tractor is unable to perform the necessary tasks (Crossley).

The criterion for tractor selection should be based on economy and efficiency of operation. The capacity or size of the power unit must match the amount of work with reference to timeliness and cost. The amount of use of a power unit is most important. Machinery power requirements depend on functional needs and rolling resistance which relate directly to the conditions of soil. Tillage implements involve functional resistance and machine weight is necessary for penetration. Land rollers or packers are unique machines for resistance. Trailled harvesting machines provide a functional load for power-take-off drive and rolling resistance loads for its drawbar. Drilling machines bear both functional and rolling resistance through drawbar. Functional requirements are highly variable depending on crop and soil conditions and draught also varies with soil moisture which increases on too wet and too dry soils. Presence of roots and depth of operations result in additional variability. Forward speed also causes significant variation in plow draught. The power requirement of harvesters also varies with crop yields, conditions and field rates.

The three power criteria are: per acre horse power requirements, horse power hour requirement and horse power required to drag an implement. The estimated horse power shows the power required to operate the existing implements with ease and safety. The draught requirement was assumed for various farm implements under average field conditions in estimating power required to mechanize farms in Sind. It should be mentioned that the depth of plow observed during the study was shallow. The soils of Sind are mostly hard and sticky. The growers are sometimes compelled to develop lands requiring greater horse power. The 45–65 hp tractors available are sufficient for the mechanization needs of Sind.

The power requirement calculated for various implements to do different jobs is shown in **Table 1**.

Machinery pools or tractor hire schemes are difficult to manage efficiently under the prevailing socio-economic conditions of farmers. The decision to own or hire tractor is very important. The owning an hiring rates for different operations are represented in **Table 2**.

The farmers' primary interest is in the amount of work done by machines in a given unit of time. If work capacity cannot be fully utilized because of limits to increases in cropping intensity or to small farm size, he may hire out tractor services. There exists an operative constraint on the availability of land on small farms. To justify the average annual working hours and effective use, field potentials were calculated as shown in **Table 3**.

In general, the quality of work in agriculture is subjective and cannot be checked frequently. Management can rely on spot checks in the field. Poor maintenance leads to time loss and costly repairs. Poor quality work may show up as unusually high rates of work and lower crop yields (Johnson 1978). Efficient machinery utilization is directly re-

Table 1. Average Horse Power Requirement for Various Farm Machines in Sind

Implement	Assumed Draft Requirement	Average Depth of Plow	Forward Speed of Tractor (MPH)	Actual Width of Implements (Feet)	Horse Power Requirement	
					Actual	Desired
Disc plow	7 lbs/inch²	0.75	2.50	3.50	21	55
Mould board plow	20 lbs/inch²	0.75	2.50	4.50	27	55
Disc harrow	15 lbs/inch depth/disc	0.60	3.00	8.00	22	45
Cultivator	240 lbs/row	0.33	3.00	7.25	20	45
Combine	20 ft lbs/ft cut	–	2.50	8.35	30	55
Grain drill	25 lbs/opener	–	3.00	6.00	29	55

Table 2. Average Owning and Hiring Rates for Various Farm Operations with Different Machines in Sind, 1975–76

(In Rupees)

Operation/ Implement	Average Owning Rates		Average Hiring Rate	
	Per Meter Hour	Per Acre	Per Meter Hour	Per Acre
Plowing				
Disc plow	14.60	28.48	30.00	58.50
M.B. plow	14.60	36.51	32.00	80.00
Tandem harrow	14.45	10.84	40.00	30.00
Cultivator	14.53	7.27	22.00	10.80
Levelling				
Leveller	13.87	–	30.00	–
Tracer blade	13.84	–	30.00	–
Bund making	14.02	–	33.00	–
Sowing	–	13.18	–	22.53
Channel making	14.29	–	33.00	–
Harvesting	–	34.14	–	45.15
Threshing	15.72	31.44	40.00	80.00

Table 3. Field Potentials of Various Implements Used on 50 Sample Progressive Farms, Sind, 1974–76.

Implement	Annual Work Hours/ Implement	Effective Field Potential
	Hours	Acres
Disc plows	567.18	303.50
M.B. plows	172.55	119.84
Tandem harrows	713.76	1,173.64
Disc harrows	320.60	555.44
Cultivators	573.49	988.33
Rotavators	35.01	23.43
Levellers	1,198.18	2,131.05
Wheat drills	73.42	92.51
Cane planters	402.50	493.15
Cotton drills	57.03	76.50
P.T.O. combines	256.82	280.44
Self-propelled combines	832.00	862.48

Table 4. Field Machine Index of Various Implements Used on 50 Sample Progressive Farms, Sind, 1975–76.

Implement	Average Size of Imple-ment	Total Time to Cultivate an Acre (A)	Total Support Function Time Other than Turning (B)	Total Turning Time (C)	FMI = A–B–C / A – B × 100 (Range)
	Feet	Hour	Hour	Hour	Percent
Disc plow	3.50	1.95	0.26	0.17	90.75
Mould board plow	4.50	2.50	0.25	0.33	85.73
Tandem harrow	7.25	0.75	0.09	0.08	88.70
Disc harrow	8.00	0.60	0.08	0.08	85.72
Cultivator	7.25	0.50	0.05	0.02	96.75
Rotavator	8.50	0.75	0.10	0.10	85.70
Wheat drill	6.00	0.60	0.08	0.05	90.76
Cotton drill	8.00	0.33	0.08	0.03	88.77
Cane planter	5.00	2.00	0.15	0.15	92.73
P.T.O. combine	8.25	2.00	0.25	0.25	86.80
Self-propelled combine	8.25	2.00	0.25	0.27	85.00

lated to row length. Larger fields are usually better suited to machine use than small fields. Long row fields are more efficient than short row fields. The term field machine index was used to indicate the extent to which fields were suitable for machine use. A field with an index of 95 was considered better adopted than 85, where 100 was considered maximum. Machine efficiency was determined for each field and the average for each type as indicated in **Table 4**.

Conclusion

Tractors for large farms must be of large size ranging from 45 to 65 hp with the exception of site specific requirements of smaller ones. The tractor work hours per year should be increased to reduce unit cost of operation and increase field potentials. The field machine index figures should be brought to or above 95 by improving field sizes and shapes. Tractor hire services need to be explored.

Acknowledgements

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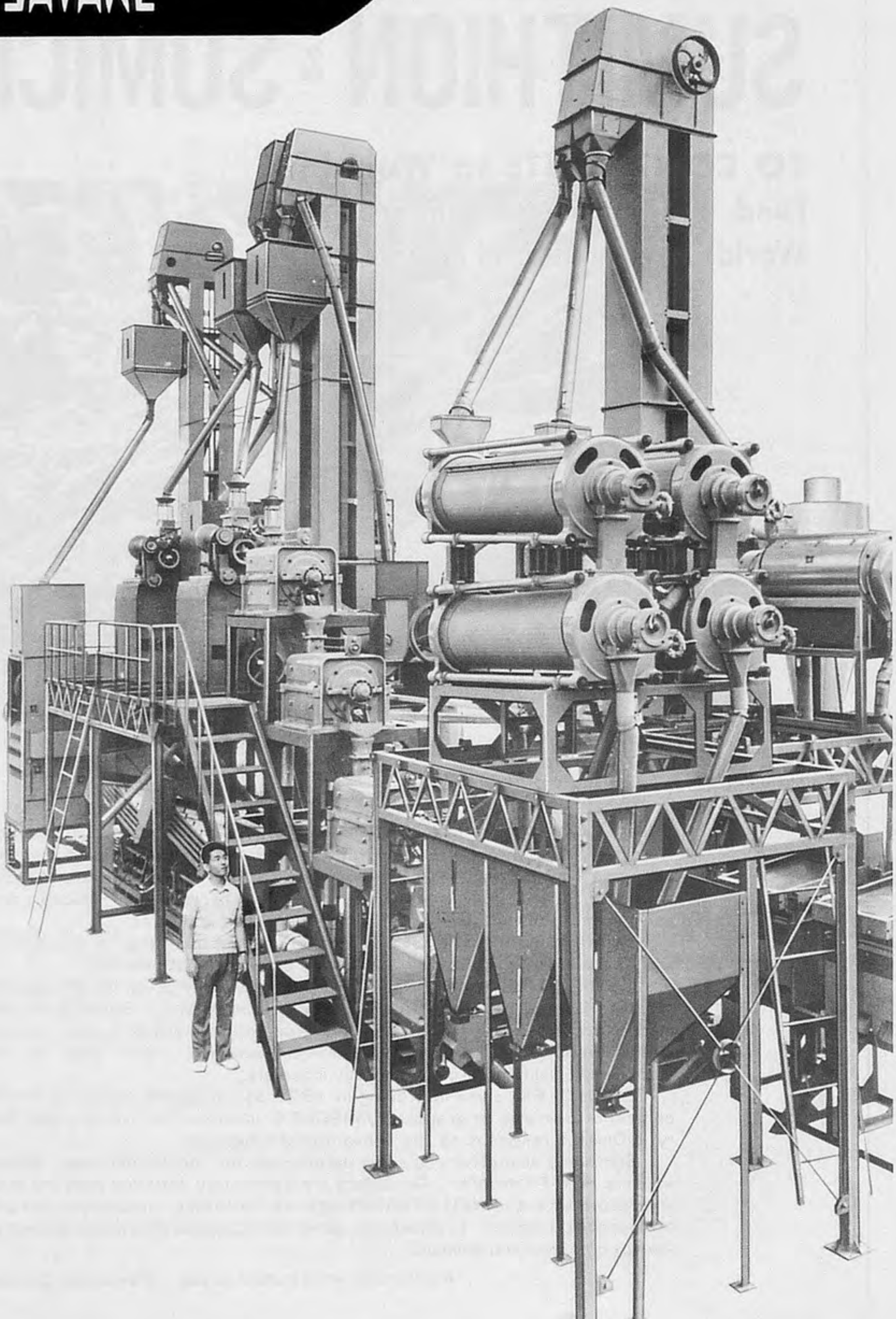

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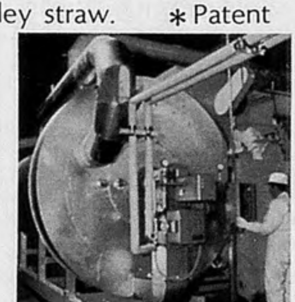

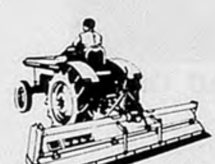

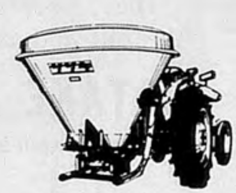

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Tractor Requirement in Sri Lanka

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Introduction

Rapidly increasing population and demand for food on the one hand, and shortage of farm labour on the other, have forced the farmers of the developed countries to turn to mechanization for food production. Mechanization was further facilitated by the use of large machines in the larger land holdings. In Sri Lanka although mechanization in agriculture commenced in the 40's, the actual need for mechanization, especially selective mechanization, was realised only in the 50's. Since then the use of two-wheel and four-wheel tractors has been an increasingly common feature in the agricultural sector, and the scale of increase may be seen from the increase in the number of tractors in the country over the past few years. The number of two-wheel tractors doubled from 3,200 in 1968 to 6,400 in 1972 and is still increasing[1,2]. Even though animal power is used in many small holdings throughout the Island, there is still a power gap for land preparation and harvesting. It was estimated in 1972[3] that the shortage of power, expressed in terms of the acreage producing low yields in the Amparai and Hambantota districts alone was around 18,300. The case is similar in many other districts. The land available for cultivation is far more than the area of paddy sown.

The total acreage of paddy sown in Maha* 1973/74 was 1,317,838 and is bound to be far higher when the proposed irrigation and settlement schemes are completed. The animal power available in the country is too small to cope with the cultivation of this area for food production. The shortage in animal power arises partly from the dwindling number and partly from the poor maintenance of the draught cattle. It is, therefore, necessary to make a reliable and realistic estimate over a period of 5 – 10 years on the number of tractors imported or manufactured in the country based on the following:

a) a reliable estimate of the number of agricultural holdings in the various size groups ½ – 1 acre, 1 – 2½ acres etc.;

b) a good assessment of the number of holdings in each category in which a tractor can be utilized efficiently; and,

c) a knowledge of the anticipated increase in the land area that will come under paddy cultivation annually, from the year of prediction.

* Maha-cultivation season from October to March

Estimation of Total Area Sown in 1978/79

The only available record on the number of paddy holdings is the 1962 agricultural statistics[4]. A survey on the holdings, which included all crops, is available for 1972 but is not complete. The Central Bank Annual Report gives the total area of paddy sown up to 1973/74[5]. It is, therefore, necessary to estimate the number of paddy holdings using the available data. The number of paddy holdings in the various size groups for Sri Lanka in 1962 is given below in **Table 2**.

As neither data giving area-wise breakdown of land holding nor that of the total number of holdings available for years other than the one given above, it was decided to use the above data for area as the basis for obtaining the number of holdings in the various ranges of land holdings. The total area cultivated was estimated in two ways: using the area sown for a number of years, and using the area sown district-wise of 1961/62 and 1973/74.
Although the results from the two methods were not substantially different the former method seems more reliable than the latter. The area available for cultivation in 1978/79 was estimated by extrapolating the regression line obtain

Table 1. Total Area Sown from 1960/61 to 1973/74

Year	Acre (Thousands)
1960/61	1,180
1961/62	1,135
1962/63	1,230
1963/64	1,349
1964/65	1,273
1965/66	1,323
1966/67	1,331
1967/68	1,147
1968/69	–*
1969/70	1,191
1970/71	1,147
1971/72	–
1972/73	1,179
1973/74	1,318

*Data not available

from the total acreage sown from 1960/61 to 1973/74. The regression line was found to be,

$$Y = 20112\,X + 949605$$

where, Y = The total area sown in acres, and

X = The number of years from 1960.

The regression coefficient is 0.853. The estimated paddy area sown in 1978/79 (X = 18) is 1,351,840 acres.

For the latter methods, the 1961/62 and 1973/74 areas of the districts were selected as they have the only published data available. The acreage sown in 1978/79 was estimated from the mean ratio of the increase in area between 1961/62 and 1973/74 extrapolated linearly to 1978/79 for each district. For instance, for Colombo district, the ratio of area between 1961/62 and 1973/74 is 1.059. This gives a ratio of 1.083 between 1961/62 and 1978/79. This procedure was repeated for the 22 districts and the mean was calculated. The overall mean increase in the ratio of area was 1.2491. Hence, the area sown in 1978/79 will be 1,417,960 acres.

Table 2. Distribution of Holdings and Area in Different Area Ranges, 1962

Land Holding (acre)	Number of Holdings	Area (acres)
less than ½	103,951	25,912
½ ~ 1	128,941	73,198
1 ~ 2½	189,540	295,148
2½ ~ 5	95,619	374,612
5 ~ 10	38,089	181,630
10 ~ 25	10,033	
above 25	1,480	184,688

Number of Holdings

The data for the number of holdings in the area ranged from 0 to 25. Above 25 acres for the year 1978/79 is not available. This must be estimated from the area calculated above. It will be incorrect to give equal weight to the different area groups because the land holding pattern has been affected by the Land Reform Act of 1973 and by the fact that allocation of lands in the new settlement schemes is mainly in the low area ranges. It is also important to remember that there will be an increase in the number of small holdings owing to the fragmentation of family land holdings. It is, therefore, reasonable to assume that:

a) there would be a small increase in the number of holdings below ½ acre and a substantial increase in the ½ – 1 acre range,

b) the increase in the two ranges 1 – 2½ and 2½ – 5 acres would be the highest, and

c) the increase in the larger area range would be minimal.

The above argument suggests a binomial distribution for the weighting function. A suitable distribution using the probability generating function $(q + pt)^n$ was selected. The increase in the number of holdings between 1961/62 and 1978/79 was then calculated using the ratio of area in the two cases mentioned above. The number of holdings in each area group was then obtained by multiplying this ratio by the number of holdings given in **Table 2** for 1961/62. The weighting function, the ratio increase in the number of holdings, and the number of holdings in each area group are given in **Table 3.**

Table 3. Weighting Function, Ratio Increase in Number of Holdings, and Number of Holdings in Different Area Range, 1978/79

(p=0.6; q=0.4; n=6)

Weighting Function	Area Range	Ratio Increase in Number of Holdings		Number of Holdings	
		1[a]	2[b]	1	2
0.1186	0 ~ ½	1.0227	1.0296	106,310	107,030
0.4443	½ ~ 1	1.0849	1.1068	139,890	142,710
0.8889	1 ~ 2½	1.1698	1.2214	221,720	231,500
1.0000	2½ ~ 5	1.1910	1.2491	113,880	119,440
0.5999	5 ~ 10	1.1146	1.1494	42,450	43,780
0.1501	10 ~ 25	1.0287	1.0374	10,320	10,410
0.0000	above 25	1.0000	1.0000	1,480	1,480

a) Ratio estimated for the area by method 1 (1,351,840).
b) Ratio estimated for the area by method 2 (1,417,960).

Calculation of Tractor Requirement

The average rate of work (ploughing, rotavating, and puddling) of a 5 – 7 hp two-wheel tractor is around 0.15 acre per hour with an annual use of 500 to 600 hours. Hence, the maximum area covered by working in the field alone will be between 75 and 90 acres for the two seasons. It is reasonable to assume that the two-wheel tractor can be used to cultivate 25 – 30 acres per season allowing for transport and other work outside the field. A similar calculation for a 35 – 45 hp tractor gives about 60 – 75 acres per season.

Local habits and practices in Sri Lanka cannot be changed immediately. Cultural and traditional influences apart, it is not economical to a farmer with small holding to own or to hire a tractor. Animal power and hand implements cannot be completely eliminated, and it is not desirable to do so. The number of tractors required for Sri Lanka is, therefore, estimated on the basis of the following assumptions.

a) All holdings less than ½ acre

will be cultivated with muscular power, human and animal.

b) In the ½ – 1 acre range, around 60% of the land holdings will use muscular power and of the rest (about 40 holdings) would share a two-wheel tractor. No four-wheel tractors will be used.

c) 60% of the 1 – 2½ acre range of land holdings will use two-wheel tractors at 20 holdings per tractor and the rest will be cultivated with muscular power. As in the earlier case no four-wheel tractors will be required.

d) Between 8 and 10 holdings in the 2½ – 5 acre range could share a two-wheel tractor economically and that about 10% of the 5 acre holdings will use four-wheel tractors, at one for every 15 holdings.

e) Thirty percent of the holdings in the 5 – 10 acre range will use four-wheel tractors and the rest will be cultivated by two-wheel tractors on the basis of one tractor for every 5 holdings. The four-wheel tractors will be used at the rate of 8 –10 holdings per tractor.

f) The 10 – 25 acre holdings is large enough for the farmer to exclusively own a two-wheel tractor economically. About 40% of the holdings will use two-wheel tractors. Of the rest, between 2 and 4 holdings will share a four-wheel tractor.

g) All holdings above 25 acres will use four-wheel tractors with each holding using a tractor.

The number of holdings per tractor was arrived at by using the work rate of the tractor and its annual use mentioned earlier. The assumptions were based on the data for tractor use in cultivation given in Reference 4.

The total number of tractors required for paddy cultivation will, for the two cases considered above, be as follows,

Case 1: 139,890 × 0.40/40 + 221,720 × 0.60/20 + 113,880 × 0.90/10 + 42,450 × 0.70/5 + 10,320 × 0.40 = 28,370.

Similarly, Case 2, the number of two-wheel tractors = 29,420.

The number of four-wheel tractors for each of the two cases above is estimated at 7,310 and 7,440, respectively.

The present populations of two-wheel and four-wheel tractors are estimated at 12,000 and 15,000, respectively. There are several other activities like construction, forestry etc., that are presently using four-wheel tractors and there is no reliable estimate of the number of tractors used mainly for paddy cultivation. Whereas in the case of two-wheel tractors, with the exception of a very small fraction used for haulage, they are used exclusively for cultivation purposes. The supply and demand trends, therefore, estimated only for the two-wheel tractors.

Supply and Demand

From the foregoing figures it is evident that the demand for tractors cannot be met immediately. A suitable import and production policy needs to be evolved so that the tractor requirement of Sri Lanka could be met in stages without undue strain on the economy. The evolution of such a policy would require a knowledge of the supply and demand patterns along with that of the life of the tractor.

Demand

It is reasonable to assume that the proposed accelerated irrigation schemes will bring a considerable extent of land under paddy cultivation within the next few years. This increase, as mentioned earlier, will be in the 2 – 5 acre range. The number of two-wheel tractors required every year can thus be predicted if the total area coming under paddy cultivation every year is known. For, instance, the additional number of tractors required to meet an increase in cultivation area of 10,000 acres would be around 500 units.

Supply

The supply policy must be such that the demand is met smoothly over a period of few years, but, of course, allowing for replacements. Given the demand trend and the replacement pattern over a period of few years, a constant or variable rate of import and production can be obtained.

Replacement of Tractors

It has been estimated[1] that two-wheel tractors with an annual use of about 600 hours has a life of around 7 years. The tractors that come into use this year would not require immediate replacement. But there is a good chance that some of the already existing tractors would need to be replaced within the next few years. The rate of replacement will, therefore, increase until around the seventh year. After that the replacement rate will match the supply rate.

Example :

Assume that;

a) the present requirement of tractors of the country is N_r (total)

b) the number of existing tractors is N_c,

c) the annual increase in land area demands an increase of n tractors every year for the next few years (say 10),

d) the annual import and production rate is constant at N_p, and

e) the rate of replacement after 6 years is also N_p.

Then the cumulative demand, supply, and replacement curves are given by the expressions,

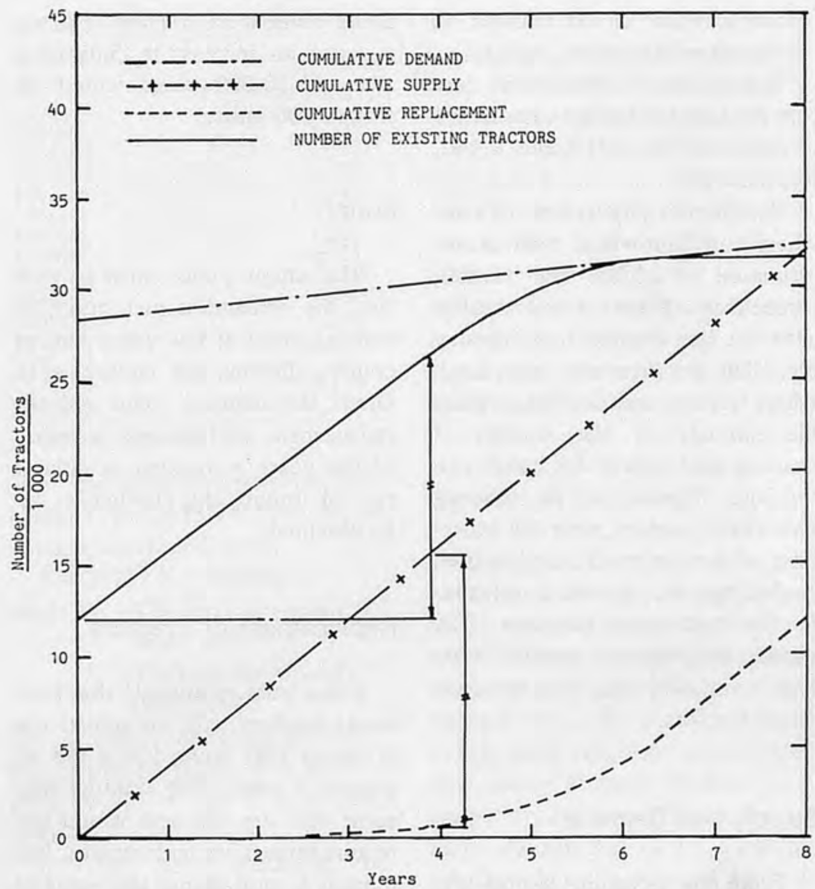

Fig. 1 Cumulative demand, supply, replacement and the number of existing tractor

$(N_r + nx)$, $N_p x$ and $N_p e^x$ when x 6 and $N_p x$ when x 6, respectively.

From these curves the existing tractor curve can be obtained by adding the difference between the cumulative supply and replacement curve to N_e for any year. Fig. 1 shows these curves for $N_r = 28400$, $N_e = 12{,}000$, $n = 500$ and $N_p = 4{,}000$. It is easy to see from these curves by varying the supply rate or supply curve and replacement curve, assuming that the demand projection is correct, that the supply could meet the demand within a specified period. The assumptions made in the above example permit the entire demand to be met in six to seven years.

Conclusions

The number of tractors required for paddy cultivation in Sri Lanka can be estimated using the existing data giving a realistic value. The number of existing tractors can then be estimated given the supply and demand. This would be useful in formulating the import and production policy. The number of tractors needed for paddy cultivation by 1978/79 is estimated at 28,400. The demand could be met in about seven years if the import and production rate is around 4,000 a year provided that the demand is 500 tractors per year. The procedure described could be adopted to predict the number of tractors and to formulate a policy for import and production even if the demand and supply are variable.

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Bullock Farming vs. Tractor Farming

by
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Introduction

Agriculture is the mainstay of Pakistan's economy. Despite the productivity break-through commonly referred to as the green revolution, the yield per acre of all the major crops grown in the country is very low compared with those in many other countries.

The yield per acre can be increased by using better cultivation techniques, better seeds, adequate manuring, plant protection and such other measures. Efforts to intensify agricultural production through improved cultivation require the introduction of improved farm implements as well as an increase in traction power per unit area. The type of agricultural tools and implements which are used in the country are primitive. Their replacement by improved tools would enable a greater volume of work to be accompanied with less efforts and time.

The major portion of power input in Pakistan is supplied by bullocks. Bullock cultivation is favoured firstly because the majority of cultivators are small and individualistic. A pair of bullocks as traction unit suits small holdings in the country. Secondly, the cost of animals and associated implements is small and within the financial capacity of most farmers. Thirdly, they cost little in terms of foreign exchange. On the other hand, a limited draft power of bullocks is a major constraint in using improved implements. Unless soils are light, animals are not effective to plough land without irrigation or heavy rains. The tractors can do deep ploughing, subsoiling and rotating much more effectively which require considerable power that is usually beyond the capacity of draft animal.

Two aspects of tractor cultivation are important in Pakistan. Firstly, by replacing draft animal, tractor frees land for cash and food crops which would otherwise be needed for feeding animals. Secondly, tractor is a substitute rather than a complement to labour.

These two techniques of production together their implement have certain merits and demerits which affect their efficiency. For obtaining high level of efficiency in agricultural operations, proper combination of resources is considered very essential. It is, therefore, necessary that a study be carried out based on the optimum use of tractor in one case and the bullock, on the other. This study will indicate the real impact on yields, costs, gross and net benefits to the cultivator on tractor and bullock cultivated farms.

The work done by Ali (2) shows that the average yeild of wheat, cotton and sugarcane was higher by 10.1 to 17.6 per cent, 11.3 to 44.3 per cent and 44.6 to 74.2 per cent on mechanized farms as compared to 13.3 acres and 27.8 acres bullock farms. Similarly, total input, gross income and net income were higher by 8.6 to 10.5 per cent, 30.9 to 41.9 per cent and 135.8 to 174.2 per cent, respectively, on tractor farms.

Haq (4) reported that the average yield of wheat and cotton was less by 6.9 to 9.8 per cent and 1.8 to 5.9 per cent on mechanized farms as compared to bullock farms of the size 13.3 acres and 27.8 acres, while that of sugarcane was higher by 44.6 to 74.5 per cent on mechanized farms. He also reported that the total input and net income per acre in crop production was higher by 53.9 to 60.3 per cent and 174.3 to 253.0 per cent on mechanized farms as compared with bullock farms of the size of 13.3 acres and 27.8 acres.

Khan (5) found that the average yield of wheat, cotton and sugarcane was higher by 28.8 to 33.8 per cent, 22.0 to 24.4 per cent and 24.6 to 35.6 per cent, respectively, on tractor farms as compared to 10–16 acres and 22–28 acres bullock farms. He also concluded that net income was higher by 320.5 to 479.9 per cent on tractor farms compared with bullock farms.

In all the above studies bullock farms of different sizes were compared with mechanized farms of different sizes. This to a great extent masked the true economics.

In this study the effect of varying sizes was eliminated and optimum size as suggested by experts was taken for tractor farms, (1, 3, 6, 7, 8, 9, 10) and bullock farms

(11). Moreover, in the previous studies any increase in yield on tractor farms was attributed to the use of tractor when in fact it was largely due to other inputs like fertilizer, water, seed etc; as the farmers often increase their use when they begin using the tractor.

Methodology

For the present study Layallpur district except Jaranwala tehsil was selected, where bullocks are the main farm power source. Tractors are also used as farm power source. The farms were optimum size. For a 35–45 H.P. tractor, the optimum farm size was 100–115 acres, for one pair of bullocks, 10–14 acres; and for two pairs of bullocks, 27.75 acres. Twenty five farms, each for tractor and bullocks were selected for detailed investigation. On all these farms water from tubewell was also available in addition to that of canal.

A comprehensive pretested interview schedule was used for collecting the data by interview method.

Results and Discussion

Tractor farms and bullock farms were compared with respect to land use, cropping pattern, cropping intensities, yield rates, farm expenditure, water use, fertilizer use, farm income and response to water and fertilizer.

Land utilization – The cultivated area as per cent of the farm area was essentially of the same order (i.e., 98–99 per cent) on both types of farms.

Cropping patterns – Food crops, including wheat, rice and maize collectively covered 43.3 per cent and 49.3 per cent on tractor farms and bullock farms, respectively (Table 1). Wheat was the principal crop accounting for 36.9 per cent and 34.4 per cent on tractor farms and bullock farms, respectively. Rice and maize constituted 3.0 and 7.4 per cent on tractor farms and 6.85 and 8.0 per cent on bullock farms.

Cash crops including cotton, sugarcane, vegetables and other crops occupied 45.5 per cent and 30.1 per cent on tractor farms and bullock farms, respectively. On tractor farms cotton (21.0 per cent) was the most important cash crop followed by sugarcane (11.9 per cent) and vegetable (9.7 per cent). On bullock farms sugarcane (16.0 per cent) was the most important cash crop, followed by cotton (10.0 per cent).

The area allocated to vegetables was negligible as areas planted to other crops (2.9 per cent and 3.8 per cent on tractor farms and bullock farms, respectively).

Fodders occupied 11.2 per cent and 20.6 per cent of the total cropped area on tractor farms and bullock farms, respectively.

It was, therefore, concluded that tractor farms are devoting more area to cash crops and less area to fodder and food crops as compared to bullock farms.

Cropping intensity – On both types of farms cropping intensity averaged 140 per cent.

Yield rates – The average yield of wheat, maize, cotton and sugarcane was higher by 7.3%, 15.8%, 13.1% and 2.4% on tractor farms as compared to bullock farms. The differences in the yield were, however, non-significant. (Table 2).

Input per acre – Total inputs and labour inputs were lower by 5.7% and 29.8% on tractor farms as compared to bullock farms, while capital input was higher by 7.0%. The difference in labour input was highly significant but not for the total input and capital input factors.

Water use – The amount of water applied per acre to wheat, maize, cotton and sugarcane was lower by 11.6%, 17.5%, 18.5% and 12.9% on tractor farms as compared to bullock farms. The difference in water application was highly significant for cotton and maize, but not for wheat and sugarcane.

Fertilizer use – The amount of fertilizer applied per acre in wheat and cotton was higher by 10.1% and 12.2% on tractor farms as compared to bullock farms while the amount applied per acre to maize and sugarcane was lower by 8.1% and 14.6% on tractor farms as compared to bullock farms. However, the difference in the application of fertilizer was non-significant for all the crops.

Gross and net incomes per acre – Gross and net incomes were higher by 1.4% and 27.5% on tractor farms as compared to bullock farms. But the difference was not significant.

Table 1. Cropping Patterns on Bullock and Tractor Farms

Crop	Bullock Farm	Tractor Farm
	–per cent of cropped area–	
Food grains		
Wheat	34.4	36.8
Rice	6.9	2.9
Maize	8.0	3.4
Sub-total	49.3	43.1
Fodders	20.6	11.2
Cash Crops		
Cotton	10.0	21.0
Sugarcane	16.0	11.8
Garden	0.3	9.7
Oilseeds	1.6	0.7
Gram	0.1	0.1
Others	2.1	2.4
Sub-total	30.1	45.7
Grand Total	100	100

Table 2. Minimum, maximum and average yields of different crops and Value

(Unit: Maunds per acre)

Crop	Bullock Farm			Tractor Farm			Value of 2
	Minimum	Maximum	Average	Minimum	Maximum	Average	
Wheat	20.59	40.54	28.70	22.52	36.89	30.79	2.97 N.S.
Maize	8.11	27.03	18.14	13.51	36.04	21.00	.786N.S.
Cotton	7.21	18.02	11.19	9.01	18.02	12.64	.685N.S.
Sugarcane	345.95	778.38	491.46	345.95	810.81	503.03	.100N.S.

N.S. Non-significant at 5 per cent level.

Water and fertilizer response – The values of three variables YLD, FRT and WAT represent yield, fertilizer, and water, respectively. The data were analysed for these variables and the regression equation was used of the type YLD = a + b FRT + c WAT. For wheat crop the regression equations were set as YLD = 11.69 + 0733 FRT + .61352 WAT for tractor farms and YLD = 7.74 + .0848 FRT + .0609 WAT for bullock farms. R^2 was 0.5038 and 0.7416 for tractor farms and bullock farms. F value was 11.7 and 32.8 for tractor farms and bullock farms, respectively, indicating that R^2 was significant at 1% and 5% confidence levels.

For cotton crop the regression equations were set as YLD = 4.41 + .0512 FRT + .3555 WAT and YLD = 4.21 + .0774 FER + .1900 WAT for tractor farms and bullock farms, respectively. F value was to 13.3 and 19.0 for tractor farms and bullock farms, respectively, indicating that R^2 was significant at 1% and 5% confidence levels.

For sugarcane crop the regression equations were YLD = 311.75 + 0.79 PER + 2.6144 WAT for tractor farms and YLD-247.61 + 2.3319 FER + .998 WAT for bullock farms, respectively. F values were 5.9 and 10.6 for tractor farms and bullock farms, respectively, indicating that R^2 was significant at 5% level for tractor farms and 1% and 5% confidence levels on bullock farms.

If fertilizer and water were kept at zero level the value of constant 'a' is greater on tractor farms as compared to bullock farms for all crops, indicating theoretically that the yield per acre of wheat, cotton and sugarcane is higher by 13.8%, 1.8% and 13.0%, respectively on tractor farms as compared to bullock farms.

The following conclusions can be drawn from this study:

1. Land use was particularly of the same magnitude under bullock and mechanized cultivation. No significant advantage may be gained as far as land utilization is concerned even by adopting a given technology at the expense of others.

2. Mechanized farms employ a much better cropping pattern than the bullock farms. Cotton and vegetables are particularly suitable for mechanized farms, thus enhancing the supply of a valuable exportable product (cotton), as well as helping enrich the nutritional standards. Mechanization may prove an effective measure to change the cropping pattern to bring forth better result.

Tractor cultivation released about 10 per cent of the fodder area which was diverted to cash crops.

3. As indicated none of the studies so far conducted to compare the tractor and bullock cultivation on yield rates. In this study, however, attention was paid to eliminating the effect of size by selecting the optimum cultivation units. Secondly, it isolated the effect of various inputs like fertilizer and water. Seeds were not considered as these were of the same quality on both types of farms under study. In this way, the real contribution of tractor and bullock cultivation towards yields was isolated. Tractor cultivation was more productive as it increased wheat yield by 13.8, cotton by 1.8 and sugarcane by 13.0 per cent more than those obtainable under bullock cultivation. Incidentlly, these three crops account for about 80 per cent of the total cropped area when fodders are not considered.

4. Gross income per acre was higher on tractor farms by about 1.4 per cent only. This may appear strange, especially in view of the positive effects of tractors on yields. Gross income was influenced greatly by the cropping pattern, especially sugarcane acreage which was relatively higher on the bullock farms.

5. Farm expenditures were less on tractor farms by about 5.7 percent primarily due to the low input of labour. Net income was higher, by 27.5% on tractor farms than on bullock farms.

6. Roughly about 1/3 of the labour force engaged on bullock farms was displaced with the introduction of tractor cultivation. Displacement of labour was higher on the smaller farms and may act as a great deterrent to mechanized cultivation, especially when no alternative employment opportunities exist.

7. Great possibility exist, however, to further reduce costs on mechanized farms. Most of the operations like harvesting are still not mechanized and usually casual hired labour has to be employed to do the job. By fully mechanizing all the farm operations more benefits can be derived.

Suggestions

Despite the desirable effects of tractor cultivation on yield rates of crops, especially wheat and sugarcane, there was very little difference in the gross income on the tractor and bullock farms. The latter type of farms made up the deficiency by using higher input of water and labour. In other words, inputs like water and fertilizer, etc., can substitute effectively for tractors. In the first instance, therefore, it might be advisable to concentrate on the inputs like water, fertilizer, seed, etc., as these would necessitate a minimum of consolidation, pooling of land, etc., which are a must for the introduction of mechanized cultivation on a large scale. Use of these inputs is very low and can yield positive returns even if it increased many times. Moreover, inputs like water, fertilizer, seed and insecticides are labour intensive and can thus utilize the surplus labour available in the country. On the other hand, tractor displaces the labour which is practically unskilled making its absorption in the industrial sector still more difficult. Job opportunities in the latter sector are not only very limited but also their rate of expansion is disappointingly slow and may not cope with a situation where lot of labour is displaced by a large scale mechanization programme.

The desire for farm mechanization should keep the following factors into consideration so as to minimize its disadvantages:

1. Wherever mechanization is desired, it should be complete as far as possible. A full range of implements should be maintained to do the various types of operations on the farms. By spreading the fixed cost over a large number of operations, costs per unit is less.

2. The minimum size of holding should not be less than 100 acres for a 35–45 H.P. tractor. Those who have smaller holdings than this usually will either under-utilize it or deploy it to non-agricultural operations, especially haulage in cities. The loaning agency of the Department of Agriculture must ensure a proper utilization of tractors in the interest of agriculture.

3. As far as possible efforts should be made to start manufacturing of tractors and implements in the country. This would go a long way in expanding job opportunities for the displaced labour as well as to solve the spare parts problem which is so acute at present.

4. Repair facilities should be augmented in order to improve the efficiency and increase useful life of the machines/implements.

5. Proper attention should be paid to training a requisite number of skilled workers who should undertake manufacturing/assembling and repairing of machines.

6. In order to increase the efficiency of skilled workers in assembling and repairing of machines, the number of tractor makes should be reduced to the minimum. The most adaptable types may be selected giving full attention to competition in the supply of tractors.

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Cost-Benefit Analysis of Irrigation at the Chanasutre Land Consolidation Project, Thailand

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Introduction

That the spending of public fund on the irrigation development in the last 20 years was improperly and inefficiently allocated has been recently acknowledged. A large portion of both the national budget and foreign loans was directed to large scale dam and tank irrigation constructions, while the small scale irrigation networks such as canals or water-ways and drainages at the farm level were almost neglected due to the lack of well-prepared plans and, above all, necessary fund for further implementation. Hence, the irrigation system as a whole has been inefficient and of little use. As a measure to improve the situation, the idea of formulating a comprehensive irrigation structure or so-called land consolidation project was first conceived and set forth in 1968 after the confirmation of bilateral assistances from the Netherlands, Taiwan, and Australian governments. Three separate areas in the Northern Chao Phaya Basin were then chosen for the implementation of the pilot projects.

Among the projects that one located in the Chanasutr district, Singburi, about 140 kms north of Bangkok was the most interesting. This project was designed not only to serve the demonstration and experimental purposes, but also to upgrade and make a better use of the existing irrigation facilities and to establish a model against which an economic appraisal can be made and used as a benchmark for further expansion[1/]. Land consolidation, as implemented in the Chanasutr pilot area comprises: 1) construction of farm roads, minor irrigation networks, and drainage system 2); rearrangement of farm holdings in between the newly constructed irrigation ditches and drains 3); and clearing and levelling of arable land to improve the on-farm control. The project covers 11,500 rais of land located in between the Noi river main drain and 4L-1R canal.

The present paper reports on the results of a cost-benefit analysis of the Chanasutr Land Consolidation Project (herein abbreviated, CLCP). The study involved analyses of economic changes brought about by investigating a selected group of farmers who have been assumed representative of all farmers in the total area. More specifically, it seeks to, by use of the cost-benefit analysis technique, estimate the costs and returns of the project which are expected to be realized from both private and social viewpoints[2/]. The appraisal was based on a comparison of costs and benefits 'with' and 'without' the project. The paper is divided into sections, beginning with a brief description of the pre-project conditions to serve as a background and basis for comparison and the methodology and assumptions. The project impact was then analyzed in terms of changes in cropping intensity, yields, cash inputs, and labor requirement, and based on these changes the B/C ratios and the internal rate of return (IRR) were calculated. Sensitivity analysis as an allowance for risk or uncertainty was also considered in this section. Some general conclusions are drown from the analysis.

The basic data used in the study were mainly taken from (8) with some modifications and adjustments whenever deemed necessary. According to this technical note, the data were said to be the result of the surveys made during 1970–74, consisting of 130 random sample farmers. Out of the total 460 farms in the project area, thus, the samples accounted for about 28 per cent of the population.

[1/]Following the appraisal of this pilot project, the World Bank later on supported its expansion by making available a credit of about US$5.5 million for an area of 100,000 rais adjacent to the project site.

[2/]Squire, L and Van der Tak (9; pp. 55–56) suggest that the project's worth should be evaluated at market, at efficiency, and at social prices. Since the distributional impacts are ignored in this paper, we will deal with market and efficiency prices, the prices that correspond to the private and social viewpoints.

Pre-project Conditions

The prevailing agricultural pattern before the introduction of the CLCP was characterized by monoculture crop production. Crop production depended entirely upon natural conditions. Self-sufficiency with low level of cash inputs used and output produced was also the main character. Due to poorly designed irrigation facilities of the previous project and soil topographic conditions, rice cultivation was completely done in the wet season when water permitted while about 95 per cent of land left uncultivated in the dry season. Paddy yields averaged 400 kgs/rai for those transplanted rice and 320 kgs/rai for broadcasting. In 1968, before the project implementation, with the cropping intensity of 100 per cent in the wet season, two types of rice cultivation averaged 45 per cent for broadcasting and 55 per cent for transplanting. The labor input averaged 2–3 persons per family. With the average yield of 325.5 kg paddy/rai and price of 1.05 Baht/kg paddy, the gross production value averaged 341.0 Baht/rai. Substracting this amount from production cost of 269.4 Baht/rai[3/] the net value comes to 70.6 Baht/rai or about 0.82 million Baht for the whole area.

Methodology and Assumptions

Since the nature of the irrigation project involves the creation of common or public good the product of which will be sold directly in the free market, the problem of benefit estimation is obviously difficult. In other words, the project's output price is indeterminate. In such a case, the direct benefits of the project have to be estimated indirectly by forecasting the changes in agricultural or other outputs that will result from changes in inputs associated with the project, valuing these changes in outputs and deducting the opportunity cost of the change in the inputs (4; p. 57) which this analysis followed. Specifically, the estimates of benefits and costs can be worked out by computing the value of marginal or incremental output and that of incremental cost resulting from the implementation of the project. Then, the cost-benefit procedures can estimate the B/C ratio and rate of return to investment. Generally, evaluation of a project can be done by considering the main aspects, i.e., economic and financial aspects. In other words, a project can be evaluated from the national and private viewpoints. For the present study, as indicated earlier, both aspects were considered and the calculation of the net incremental benefits and costs pertaining to the two standards have been worked out on the assumptions that 1) externalities are trifle and can be ignored; 2) the project, with the 4-year construction period and usable life of 30 years, (started in 1969 became partly operational during the construction period and reached its full development in 1977) and thereafter the net incremental benefits and costs are assumed to be constant; 3) it is likely that the investment cost varied across the land types and farm locations, but due to the lack of data the average cost per rai has been used instead; 4) in some cases when the traded and non-traded components of inputs are extremely difficult to distinguish, we assumed the proper proportions for this case; and 5) the discount rate that reflects the opportunity cost of capital is assumed to be somewhere in the range of 8–15 per cent.[4/]

[3/]The total production cost of 269.4 Baht/rai, excluding imputed land cost, consisted of cash inputs and family labor cost valued at the market prices. This cost is estimated to be 190.8 Baht/rai, valued by the shadow prices of respective inputs and family labor cost. (N.B. one rai is equivalent to 0.16 ha. and one Baht is equivalent to about US$ 0.05)

Estimates of Benefits and Costs

Benefits

Benefits are represented as an increase in the farmers' annual net income with the complementing and supporting services provided by the project over the net annual income data from the project comservices. Practically, the benefits to ivestment are estimated using farm income data from the project command area and pre-project farm data as proxies for the 'with' and 'without' project. For the project in question, on the above basis, the stream of benefits can be defined as 1) the net annual increment in output value; 2) the possibility of a second crop; and 3) the reduction in damaged areas. Using the average farm gate and f.o.b. prices during 1970–74 for the 'with' case and the farm gate and f.o.b. prices in 1968 for the 'without. case, and summing up all categories of benefits, the total annual net increment in benefits are 1,822.5 Baht/rai during 1970–74 and expected to increase by 10 per cent after the full development. From the national and social viewpoints, the benefits realized during the same period are 937.1 Baht/rai, and are expected to increase by the same amount.

Costs

The project cost has three components; the investiment cost, the operation and maintenance costs, and the farmers' farm production cost. The investment cost consisted of expenditures on land survey, land clearing and levelling, excava-

[4/]J.Price Gittinger (2; p.90) indicates that almost all countries seem to think it lies somewhere between 8–15 per cent. However, if the project analyzed yields an IRR higher than the range, the problem of choosing the true discount rate will become less important and can be dismissed.

Table 1. Annual Incremental Benefits and Costs Associated With CLCP

(Unit: Baht per rai)

	Non-project 1968	Project 1970–74		Net Increment 1970–74		Total 1970–74
		Wet	Dry	Wet	Dry	
Benefits:						
Social benefits	855.0	1,196.7	1,480.8	341.7	1,480.8	1,822.5
Private benefits	341.0	547.9	730.2	206.9	730.2	937.1
Costs:*						
Investment costs:						
Social cost	–	413.0	413.0	413.0	413.0	826.0
Private cost	–	561.0	561.0	561.0	561.0	1,122.0
Maintenance costs:						
Social cost	10.0	22.5	22.5	12.5	12.5	25.0
Private cost	10.0	22.5	22.5	12.5	12.5	25.0
Production costs:						
Social cost	190.8	352.4	449.9	161.6	449.9	611.5
Private cost	359.4	499.5	554.8	140.1	554.8	694.9

*All costs are assumed to increase by 10 per cent from 1975 to 1999.

Table 2. B/C Ratios, Net Benefits, and IRRs; the CLCP

(B-C in million Baht)

Item	Discount Rate 8%		Discount Rate 12%		Discount Rate 15%	
	B/C	B-C	B/C	B-C	B/C	B-C
Social viewpoint	2.73	78.7	2.55	49.6	2.42	36.6
Private viewpoint	1.11	6.6	1.03	1.5	0.98	-0.6
Social viewpoint; IRR			91.61%			
Private viewpoint; IRR			14.85%			

tion of ditches and drains, farm roads, irrigation structures, and supervision and administration. This cost averaged 826.0 Baht/rai for the social value and 1,122.0 Baht/rai for the private value.[5] The operation and maintenance cost, on the incremental basis, was estimated to be 25 Baht/rai[6]. Farm production cost was complicated by the fact that many farm inputs contained both traded and nontraded items. Furthermore domestic and import components were prevalent. Attempts have been made to distinguish the share of import components on such factors as machinery used in the project construction, farm machinery, fertilizers, chemicals and fuel used by farmers as inputs in agricultural production.[7] Seed, for instance, represented a traded good that has been valued at f.o.b. price. After allowing for adjustments corresponding to their shares and values, the social costs of material cash inputs are estimated to be 67.2 Baht/rai for the 'without' case and 196.4 and 191.5 Baht/rai for the wet and dry seasons for the 'with' case. Their individual costs are 84.0 Baht/rai for the 'without' case and 178.5 and 176.8 Baht/rai for the wet and dry seasons for the 'with' case.

The other two input are land and labor costs. Most of the area is suitable to rice. However, it does not precluded other crops. Hence the alternative use of land is possible, particularly in the dry season after the project is completed when its opportunity cost is no zero. The estimation of land cost from the social viewpoint, therefore, is to determine the value of other crops that would have been realized had there been no rice grown. For the wet season the alternative use of land is not possible, except for rice. Therefore, we assumed the opportunity cost of land to be equal to zero. But in the dry season, such crops as mungbeans and other minor crops, (soybeans and sugar cane) are possible. In this case land cost is the net benefit from growing mungbeans, the principal crop, and is assumed to be 66.4 Baht/rai. For labor cost which consisted of hired and unpaid family labors, we adopted the wage of 12 Baht/day, the weighted rate on annual basis, as a proxy for the shadow wage rate. The labor cost would be higher in the case of private viewpoint and the prevailing hiring rate of 18 Baht/day is used which more or less reflected the market rate at that time.

The broad components of benefits and costs and their net values are then summarized and presented in **Table 1**. It should be noted that due to different ways of pricing, in all cases, the social values are fairly high as compared with the private ones.

B/C Ratios and Internal Rate of Return

Results of the benefit-cost ratios, net benefits, and IRRs are shown in **Table 2**. Past capitalized benefit and cost streams are computed and based on these figures, two future benefit and cost streams are projected and then discounted by three different interest rates into their present values to derive the B/C ratios and net benefits.

The internal rate of return which bypasses the predetermined discount rates, is a worked out by

[5]The investment cost of 1,122.0 Baht/rai was valued at the market price. However, expenditures other than land survey and supervision and administration included import taxes and duty. Excluding these taxes on each item, we derived the social cost of 826.0 Baht/rai.

[6]The O&M cost entirely consisted of domestic components which all was public service. Most cost items could not be determined by the relevant market price but some are possible. To avoid the difficulties and since the amount was too small, it was assumed to be the true social cost.

[7]To estimate the import component of the farm machinery, we first separated land preparation cost into two parts, i.e; machinery and draft animal costs. The machinery cost contains domestic and import components and needs identifying the shares. Using the data estimated by the NSO pertaining to the share, i.e., 68.3 per cent for the import component, we derived the foreign cost by multiplying land preparation and machinery costs by this share and then deducted the taxes and duties charged at the port of entry to obtain the final cost. For fertilizers, chemicals, and fuel, we valued them by using their respective c.i.f. prices.

setting the difference between the capitalized present values of benefits and costs equal to zero. The data in **Table 2** indicate the relative impacts of changes in the B/C ratios and B-Cs corresponding to changes in the discount rates. Under varying discount rates, the project is profitable in all cases from the social standpoint. The ratios are 2.73, 2.55, and 2.42 corresponding to the discount rates of 8, 12, and 15 per cent, respectively. However, the project fails as the B/C is less than unity when discounted by 15 per cent. Given the discount rate of 12 per cent, standard rate of capital cost in Thailand, the B/C ratios are 2.55 and 1.03, while the B-Cs are 49.6 and 1.5 million Baht, the present project is clearly profitable from both standpoints. The IRRs of 91.61 and 14.85 per cent imply that the earning power of the capital invested are well in excess of the capital cost charged either at 8 or 12 per cent.

Sensitivity Analysis

As a means for risk allowance, sensitivity analysis is done allowing the two most likely situations to occur: a reduction in benefits due to crop damages of 10 per cent and an increase in farm production cost of the same percentage. Under this type of analysis, the project justification seems changed considerably, particularly from the private viewpoint. As indicated in **Table 3**, all standard indicators estimated under the social standard remain acceptable, while some of them have the ratios less than unity under the private one.

From the two assumptions, reduction in benefits due to crop damages has more pronounced effects upon the project justification. However, on average, the returns realized under the two possible assumptions are still marginally profitable, though there are some signs of commercial losses from the private view.

Table 3. B/C Ratios, Net Benefits, and IRRs Under Sensitivity Analysis

(B-C in million Baht)

Item	Discount Rate 8%		Discount Rate 12%		Discount Rate 15%	
	B/C	B-C	B/C	B-C	B/C	B-C
(Damaged loss, 10%)						
Social viewpoint	2.46	66.3	2.29	41.5	2.18	30.4
Private viewpoint	1.00	0.06	0.93	-2.82	0.88	-3.92
Production cost increase 10%						
Social viewpoint	2.48	74.1	2.32	46.4	2.20	34.1
Private viewpoint	1.01	0.72	0.94	-2.67	0.89	-3.98

Social viewpoint;	Damaged loss 10%,	IRR	77.68%
Social viewpoint;	Production cost increase of 10%,	IRR	78.71%
Private viewpoint;	Damaged loss 10%,	IRR	9.27%
Private viewpoint;	Production cost increase of 10%,	IRR	9.51%

Conclusion

The results of the analysis suggest that the land consolidation project, with the type and structure as implemented in Chanasutr, is a socially and economically limited profitable investment. This conclusion is substantiated by the outcomes based on both normal and sensitivity analyses. However, it should be noted that as indicated earlier the CLCP was implemented and organized by making use of the past investment of the Greater Chao Phaya Irrigation Development Project. If we take these sunk costs to be an additional cost of the CLCP, of course, the B/C ratios, B-Cs, the IRRs would be somewhat lower. But how much they would have been reduced depends upon the magnitude of those sunk costs. The present analysis ignores these costs completely due to difficulties encountered in spreading out the Chao Phaya cost to the whole vast area of approximately 5.7 million rais. The time element also poses some difficulties to capitalize those costs and benefits. However, with the CLCP as a separate undertaking, it is clear that the results do permit a firm generalization for any further expansion if organized and implemented in this way.

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The Combined Effect of Organic Manures and Inorganic Fertilizers on Quality and Yield of Boro Rice IR-8

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Abstract

The combined effect of chemical fertilizers and organic manures on the yield and quality of rice grain and straw were studied in the experiment. The organic manures applied were cowdung, rice straw and poultry manure (10 ton/ha) with supplemental NPK fertilizers in different combinations – 184 kg N/ha, 184 kg P/ha and 92 kg K/ha. Quality was expressed in terms of protein and starch content in both rice grain and straw, whereas yield was represented by total weight of grain and straw with definite yield contributing characters.

In all cases organic manure played a vital role in affecting yield and yield contributing characters with or without supplemental NPK fertilizers. Among all the organic manures, poultry manure coupled with different treatments of chemical fertilizers seemed to have pronounced effect on the aforesaid characters, e.g.; tiller per hill, fertile grain, infertile grain per panicle, weight of 1000 grains and grain yield. Others showed insignificant results. The same trend remained valid in respect of protein and starch content in rice grain and straw where, among the three organic manures, poultry manure significantly increased both protein and starch content; the treatment having no organic manure gave the lowest yield and less impact on yield contributing characters showing a decrease in protein and starch content.

Introduction

Under constant cultivation our soils are losing organic matter faster than it can be replaced. A decrease in soil organic matter results in compact soils. Shallow roots are developed in drought and clody soils. Organic matter can be replenished by liberal use of farm yard manure, cow dung, compost, poultry manure, etc. No investment is so far being incurred in adding organic wastes to the soil but only careful collection and maintenance of it would serve the purpose. In spite of the increasing demand for synthetic N-fertilizers, the addition of organic matter to soils through various organic manures or wastes would not be reduced because organic matter, besides supplying some amount of all the essential elements, serves important physical, chemical and biological properties in soil congenial for successive crop growth. In fact, a group of popular writers have gone so far as to state that manured crops are superior to commercially fertilized crops for human consumption.

A new and serious situation has now developed with the shortage of mineral fertilizers with five-fold increase in price during the recent years. These have placed mineral fertilizers almost out of reach of farmers in a large number of developing countries at a time when there is an ever-increasing need to step up food production.

In order to feed the increasing population and to attain self-sufficiency in food efforts are being made by the developing countries to increase the yield of rice by using organic residues available to them and the process of organic deposition, taking place under traditional system of agriculture could be mobilized as a source of organic fertilization.

Kick *et al.* (1955) stated that in long term, open air pot experiment on different soil types, the effects were compared of equivalent amount of the farm yard manure, straw and mineral NPK corresponding to the nutrient supply from 30 tons/ha manure every two years. With an equal supply of PK straw produced higher cereals yields during two years after application than did mineral fertilizer or especially farm yard manure in the first year, but overall efficiency during six years was not superior to that of the mineral fertilizer.

Steigorwald (1956) observed that in the field experiment with 2–9 years trials on a sandy loam soil, combined application of organic manures with mineral NPK, vegetable crops yielded considerably more than when only either fertilizer was applied.

Ansorge (1966) reported that long term manuring increased Mg, B, Cu, Mn and Mo levels in the soil. Humus levels were increased. In another experiment Ansorge (1967) observed that N fertilization with and without manure on cereals increased yield with the same degree.

Sengupta M.B. (1966) revealed from a long term yield trials that in the 6th and 7th year of the experiment farm yard manure produced the highest yield of wheat and distinctly superior to the NP treatments. With the progress of the experiment the yield increased significantly with farm yard manure as compared with the other two fertilizers. The experiment also indicated that prolonged use of chemical fertilizers alone had an adverse effect on the nitrogen content in the grain which becomes apparent only after a few years of cropping.

Lenhe (1968) found that in a long term trial on a light loamy sand exclusive application of mineral fertilizers, organic manure or green manures, without NPK did not result in a maximum production (cereals and root crops); only the combined effects of both mineral and organic materials gave consistently high yields and a simultaneous preservation of the humus reserves in soil.

The present investigation was therefore undertaken to study the response of IR-8-288-3, a high yielding variety of rice of Boro season, to the different organic manures with various combination of supplemental NPK fertilizer application on the yield and quality, in a typical rice growing soil of the Brahmaputra alluvium at Mymensingh.

Material and Methods

The experiment was conducted on a typical rice growing land of the Bangladesh Agricultural University Farm, Mymensingh. The experiment was laid out in split plot design with three replications, 32 treatment combinations and 96 plots in all to study the response of IP-8 different organic manure, e.g.; cowdurng, poultry manure, rice straw in combination with supplemental NPK fertilizers on the yield and quality. All the organic manures (10 tons/ha) were applied in the individual main plot according to the design and well incorporated by spading several times, 20 days before the transplanting. The rate of inorganic fertilizers was 184 kg N/ha, 184 kg P/ha and 92 kg K/ha in the form of urea, Triple Super Phosphate and Muriate of Potash. The unit plot size was (355 cm x 305 cm) 402,175 sq. cm. having a spacing of 61 cm in between the unit plot.

Table 1 presents the soil characteristics of the experimental site.

Four days before transplanting the required irrigation water was allowed to enter into each individual plot in order to make the soil muddy by spading. Three days prior to transplaning the total amount of T.S.P. and muriate of potash and half of the total urea were applied to each of the split plot. After spading several times, the land was ready for transplanting. Half of the urea fertilizer was applied in two instalments at the tillering stage and at the time of flower initiation as top dressing.

Seedlings of 30 days old were uprooted from the seed bed previously raised in the University farm and were transplanted in the plots, keeping a constant spacing hill to hill of 6 inches and row to row 10 of inches. Prior to harvesting, the number of effective tillers

Table 1 Morphological and Chemical Characteristics of Soil

Morphological Description Field description of the area	Locality:	Bangladesh Agricultural University Farm, Mymensingh				
	Soil tract:	Brahmmaputra alluvial				
	Topography:	Almost level				
	Previous crop:	Aman paddy				
	Drainage:	Free				
	Texture type:	Silty loam				
	Depth	% Sand	% Silt	% Clay		
	0"–6"	13.78	68.02	18.20		
	0"–9"	19.05	65.52	15.43		
	Average	16.41	66.77	33.62		
	Depth	% Total nitrogen	% of available P_2O_5	% of available K_2O	% of organic matter	pH
Chemical Nature	0"–6"	0.14	0.15	0.20	1.44	7.00
	0"–9"	0.06	0.09	0.17	1.39	6.75
	Average	0.10	0.12	0.19	1.42	6.88

per hill were counted and after harvest the data was collected for fertile and infertile grains per panicle, percent of filled grains, weight of 1000 grains, grain yield, straw yield. The grains and straw were chemically analysed for protein and starch to evaluate their quality. The data were processed and the mean differences were adjudged using Duncan's New Multiple Range. The methods of chemical analyses followed were mostly those outlines in A.O.A.C.

Results and Discussion

The average yield of rice grain and straw were significantly influenced by different organic manures in combination with the NPK fertilizers.

It is apparent from **Table 2** that poultry manure applied at the rate of 10 tons/ha coupled with NPK fertilizers produced the highest grain yield 6.16 kg per plot. The interaction of poultry manure with NP, rice straw with NPK and poultry manure with control NPK fertilizers showed insignificant results. The lowest grain yield of 2.23 kg per plot was obtained from the interaction of organic manure control and phosphatic fertilizer. However, the poultry manure with nitrogenous fertilizer resulted in average higher grain yield whereas the control manure without N fertilizer produced lower grain yield. It appears that poultry manure with NPK fertilizer is the ideal combination (Sharma 1966).

Table 2 indicates also a highest yield 14.12 kg per plot of straw by the application of poultry manure with NP fertilizer. The lowest yield of 3.94 kg per plot was jointly represented by the interaction of all control with phosphatic fertilizers with slight variations. However, poultry manure with N fertilizers gave the highest yield of straw whereas the control manure with N fertilizer produced the lowest yield of straw per plot.

The effect of poultry manure with NPK fertilizer yielded 20.50 tillers per hill, the highest among all the interactions. The lowest number of total tillers (7.67 per hill) was shown in the use of organic manure control with K but their variation was insignificant. Poultry manure with NPK fertilizers produced a greater number of fertile grains per panicle. All the organic manures produced more or less similar results regarding the production of infertile grains per panicle.

Rice straw manure applied at the rate of 10 tons/ha with no NPK produced the highest grain weight 30.67 gm/100 grain while the lowest grain weight 27.95 gm/100 gm was a result of the interaction

Table 2 Effect of interaction between organic manures and chemical fertilizers on the yield contribution characters of Boro rice IR-8.

Interaction between organic manures and chemical fertilizers (Treatment)		Grain yield kg/plot	Straw yield kg/plot	No. of tillers per hill	No. of fertile grain/panicle	No. of infertile grain/panicle	Weight of 1000 grains (gms)
Control (O)	N P K	2.31 ef	3.94 a	9.00 a	82.17 a	11.47 a	29.17 def
	$N^0 P^0 K^0$	2.67 ef	7.61 a	14.83 a	92.90 a	12.77 a	28.35 hij
	N $P^0 K^0$	2.23 f	3.94 a	9.83 a	74.73 a	7.37 a	29.26 def
	N^0 P K^0	2.25 f	4.38 a	7.67 a	72.23 a	19.00 a	29.18 def
	$N^0 P^0$ K	3.41 def	8.16 a	16.97 a	85.97 a	10.33 a	28.83 fgh
	N P K^0	3.93 bcdef	7.66 a	12.50 a	96.43 a	9.00 a	30.20 ab
	N P^0 K	2.29 f	4.49 a	10.67 a	72.67 a	5.30 a	29.12 efg
	N^0 P K	3.29 def	6.89 a	13.17 a	103.43 a	13.73 a	28.76 fgh
Rice straw (R)	N P K	2.55 ef	5.14 a	10.33 a	78.10 a	8.40 a	30.67 a
	$N^0 P^0 K^0$	3.65 def	8.59 a	17.17 a	109.70 a	18.00 a	29.39 de
	N $P^0 K^0$	2.58 ef	4.93 a	12.50 a	88.77 a	9.33 a	29.57 de
	N^0 P K^0	2.51 ef	4.99 a	8.50 a	88.57 a	7.48 a	29.27 def
	$N^0 P^0$ K	4.14 bcdef	7.73 a	16.50 a	99.93 a	12.43 a	30.66 a
	N P K^0	3.92 bcde	7.56 a	17.33 a	104.63 a	19.20 a	30.40 ab
	N P^0 K	2.60 ef	4.38 a	8.67 a	84.73 a	9.63 a	30.10 bc
	N^0 P K	4.27 abcdef	8.59 a	13.17 a	100.77 a	18.70 a	30.28 ab
Poultry manure (P_1)	N P K	4.22 abcdef	9.08	16.00 a	107.13 a	10.40 a	28.62 ghi
	$N^0 P^0 K^0$	5.89 abc	13.08 a	16.00 a	113.50 a	17.87 a	29.38 de
	N $P^0 K^0$	4.08 bcdef	8.87 a	14.00 a	105.00 a	14.70 a	28.21 ij
	N^0 P K^0	3.66 def	7.07 a	16.17 a	109.93 a	13.57 a	28.84 fgh
	$N^0 P^0$ K	5.94 ab	14.12 a	18.17 a	114.17 a	18.77 a	29.51 de
	N P K^0	5.09 abcd	12.48 a	14.48 a	129.07 a	22.83 a	29.57 de
	N P^0 K	3.93 bcdef	7.33 a	13.00 a	100.33 a	13.83 a	29.44 de
	N^0 P K	6.16 a	13.30 a	20.50 a	115.03 a	26.27 a	29.70 cd
Cowdung (C)	N P K	2.34 ef	5.03 a	9.13 a	90.73 a	13.10 a	29.27 def
	$N^0 P^0 K^0$	3.82 def	8.21 a	12.67 a	102.30 a	14.67 a	28.21 ij
	N $P^0 K^0$	3.02 def	4.82 a	9.13 a	80.77 a	8.80 a	27.95 j
	N^0 P K^0	2.29 f	4.93 a	8.17 a	82.70 a	8.27 a	29.11 efg
	$N^0 P^0$ K	4.44 abcde	7.67 a	12.67 a	103.30 a	10.43 a	30.07 bc
	N P K^0	3.89 cdef	8.32 a	14.67 a	105.57 a	9.87 a	30.51 ab
	N P^0 K	2.37 ef	5.25 a	9.50 a	92.30 a	12.77 a	28.38 hij
	N^0 P K	3.81 def	8.10 a	17.33 a	109.97 a	22.40 a	28.64 ghi

*In a column the figures having common letters do not differ significantly.

Table 3 Effect of interaction between organic manure and chemical fertilizers on the protein and starch content of rice grain and straw.

Interaction between manures organic and chemical fertilizers (Treatment)		% protein in rice grain	% protein in rice straw	% starch in rice grain	% starch in rice straw
Control (O)	N P K	6.94m	3.53 lm	58.24 a	18.52 ij
	$N^oP^oK^o$	7.45 i	3.86 ef	57.65 a	18.18 jk
	$N\ P^oK^o$	6.90 m	3.54 klm	59.60 a	18.49 ij
	$N^oP\ K^o$	6.95 m	3.56 jklm	61.22 a	18.27 jk
	N^oP^oK	7.46 i	3.87 ef	57.54 a	17.68 l
	$N\ P\ K^o$	7.48 i	3.66 hij	59.75 a	18.38 ij
	$N\ P^oK$	6.94 m	3.56 jklm	62.12 a	18.53 ij
	$N^oP\ K$	7.65 h	3.87 ef	57.15 a	17.73 kl
Rice straw (R)	N P K	7.12 kl	3.63 ijkl	59.60 a	18.80 hi
	$N^oP^oK^o$	7.65 h	4.12 b	58.76 a	18.53 ij
	$N\ P^oK^o$	7.10 l	3.55 klm	62.15 a	20.86 ab
	$N^oP\ K^o$	7.13 jkl	3.51 m	62.35 a	30.45 bc
	N^oP^oK	7.45 i	3.70 ghi	60.18 a	18.83 hi
	$N\ P\ K^o$	7.49 i	3.69 ghi	60.20 a	19.58 efg
	$N\ P^oK$	7.25 i	3.64 ijk	63.12 a	21.35 a
	$N^oP\ K$	7.25 i	3.93 de	63.16 a	18.65 hij
Poultry manure (P_1)	N P K	7.23 jk	3.66 hij	62.25 a	19.14 gh
	$N^oP^oK^o$	9.49 a	4.24 a	62.30 a	19.39 fg
	$N\ P^oK^o$	7.82 f	3.76 gh	62.23 a	20.16 cd
	$N^oP\ K^o$	7.69 gh	3.87 ef	66.49 a	20.05 cde
	N^oP^oK	8.15 bc	4.01 bcd	64.23 a	19.99 cd
	$N\ P\ K^o$	8.25 b	4.10 bc	64.12 a	19.91 de
	$N\ P^oK$	7.89 ef	3.93 de	66.44 a	20.17 cd
	$N^oP\ K$	8.46 a	4.05 bc	65.12 a	20.04 cde
Cowdung (C)	N P K	7.18 jkl	3.63 ijkl	61.28 a	19.63 ef
	$N^oP^oK^o$	7.81 fg	4.00 cd	66.69 a	19.93 de
	$N\ P^oK^o$	7.42 i	3.61 ijklm	64.27 a	21.22 a
	$N^oP\ K^o$	7.51 i	3.62 ijkl	64.26 a	21.20 a
	N^oP^oK	7.98 de	3.77 fj	64.17 a	21.12 a
	$N\ P\ K^o$	8.16 bc	3.76 gh	63.92 a	20.95 ab
	$N\ P^oK$	8.07 cd	3.64 ejk	64.21 a	21.23 a
	$N^oP\ K$	8.23 b	4.03 bcd	64.32 a	19.87 def

*In a column the figures having common letters do not differ significantly.

of cowdung with only P application. This weight was identical with that of cowdung with N, poultry manure with P, control manure with N, and cowdung with PK fertilizer. However, the different organic manures with nitrogenous fertilizer produced maximum 1000 grain weight.

The highest protein content of rice grain (9.49% **Table 3**) was gained through the use of poultry manure at the rate of 10 tons/ha with nitrogenous fertilizer. This was followed by the interaction of poultry manure with NPK fertilizer. The lowest protein percentage (6.90) was obtained from the interaction of manure control with phosphatic fertilizer. The percentage of protein in straw varied from 4.24–3.51 and was insignificant.

The starch synthesis in rice grain was found to be highest (66.49%) (**Table 3**) owing to the poultry manure application coupled with potassic fertilizer. The lowest (57.18%) came from the control manure with NPK. The highest average starch content in rice straw was observed in the interaction of rice straw with PK fertilizer (30.45 percent) and the lowest (17.68%), with NP of control manure.

Grain yield and grain protein showed a positive relationship and was statistically significant with the value r = 0.78. There was also a decreasing trend in grain protein with the rise in grain yield. But the rate of fall of protein was not as prominent as the rate of rise (**Fig.1**).

Fig. 2 shows a positive and significant relationship between grain yield and grain starch having r = 0.52, where % starch also indicated a slight fall with the rise in grain yield.

The line of regression in **Fig. 3** shows a direct correlation between the straw yield and percentage of straw protein which was statistically significant having r = 0.83 indicating a straight rising trend.

The relationships between straw yield and straw starch showed no insignificant relationships having r = –0.02 (**Fig. 4**). The line of regression on the **Fig. 5** explains the negative relationship between the percentage of straw protein and percentage of straw starch.

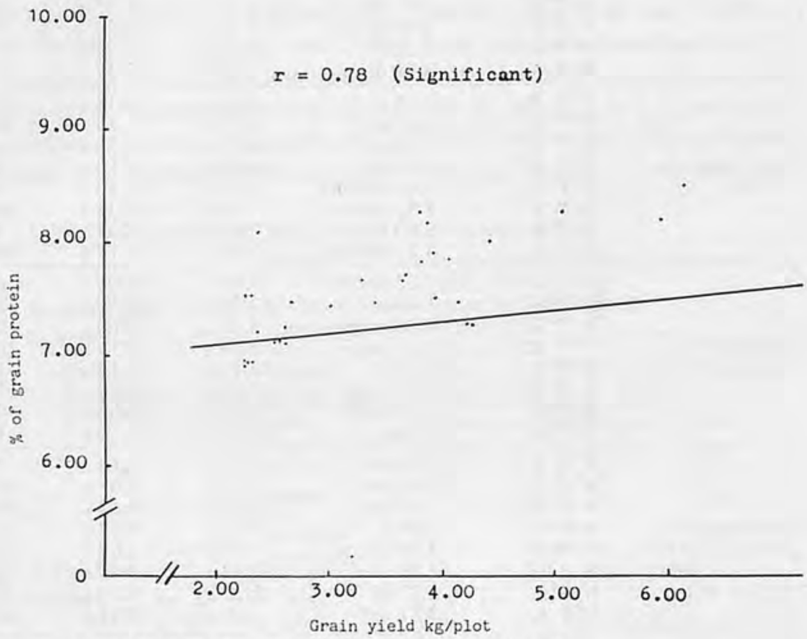

Fig. 1 Correlation between grain yield and grain protein (%)

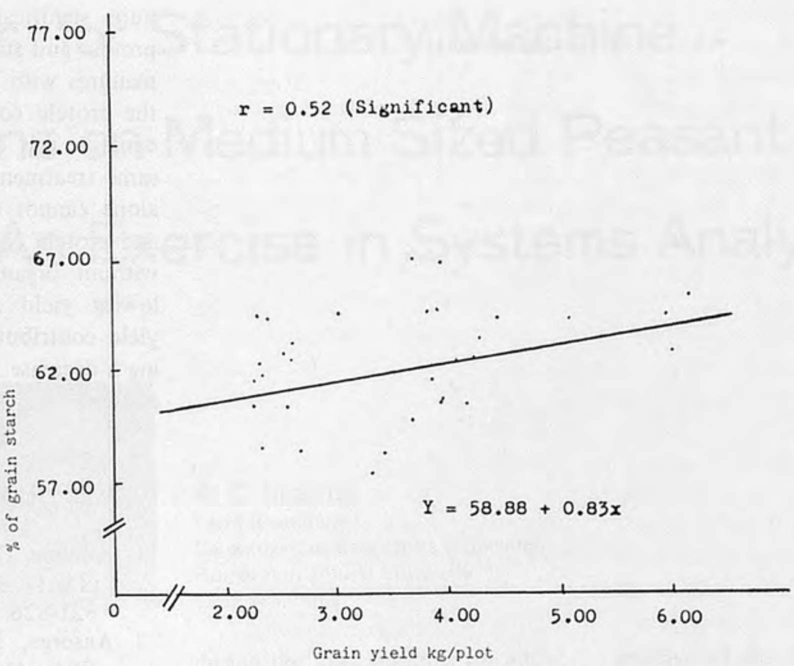

Fig. 2 Correlation between grain yield and grain starch (%)

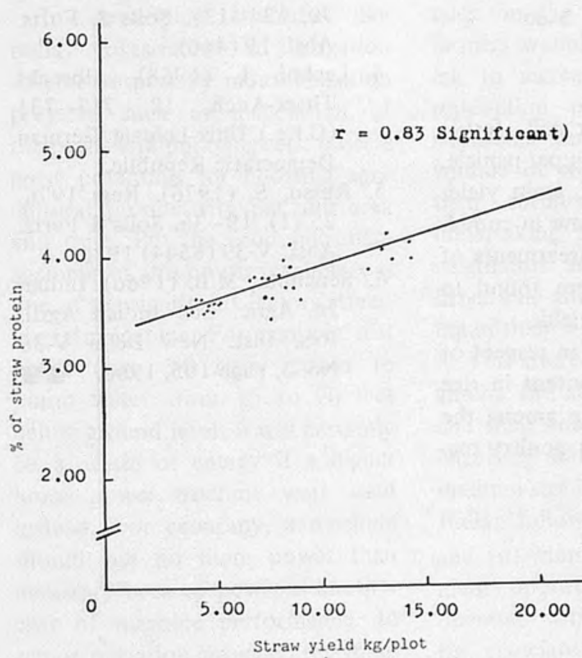

Fig. 3 Correlation between straw yield and straw protein (%)

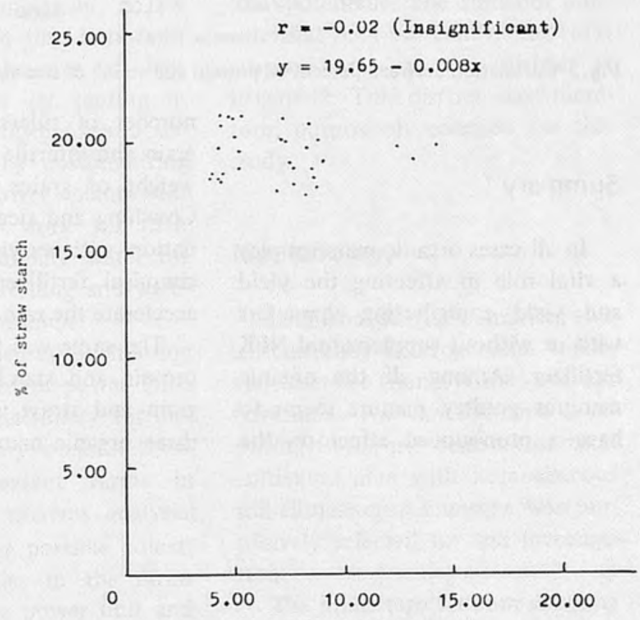

Fig. 4 Correlation between straw yield and straw starch (%)

Table 4 Summary of analysis of variances on yield and yield contributing characters of Boro rice IR-8

Sources of variation	Degrees of freedom	Mean sum of squares					
		Grain yield kg/plot	Stray yield kg/plot	Number of tiller per hill	Number of fertile grain/panicle	Number of infertile grain/panicle	Weight of 1000 grains (gms)
Replication	2	4.33**	30.43	20.69	3,549.75	293.66	0.04
Organic Manure (M)	3	19.83**	114.74	101.81**	2,936.12	221.40	5.36**
Error I	6	0.11	72.67	4.30	598.44	38.62	0.04
Fertilizer (F)	7	7.44**	47.42**	72.76**	813.36**	164.45*	2.67**
M x F	21	0.34*	1.70	11.54	178.55	26.07	0.82**
Error II	56	0.11	1.22	11.04	148.31	42.96	0.04

Note: * and ** significant at 5% and 1% level of significance respectively.

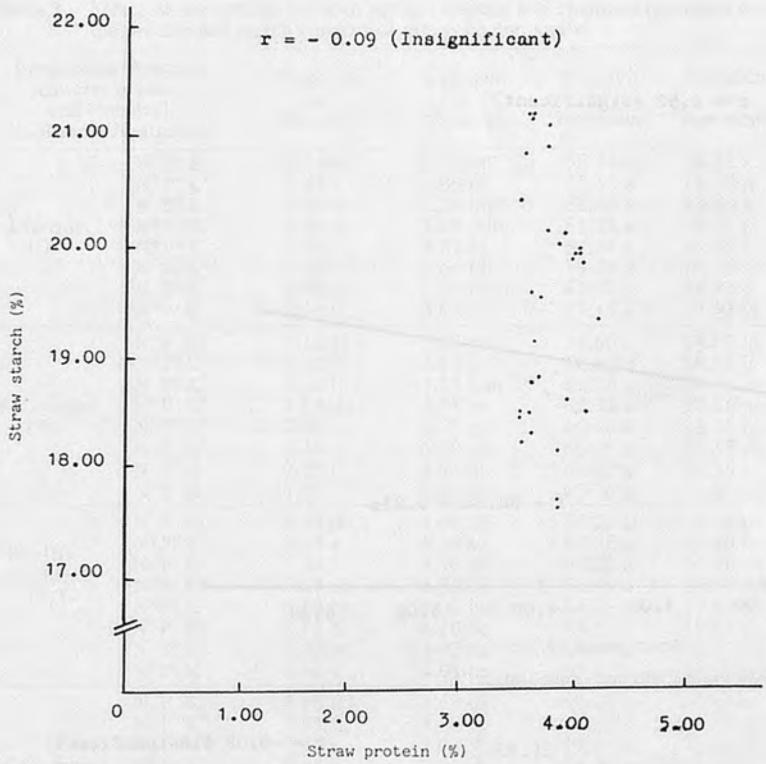

Fig. 5 Correlation between percent of protein and starch of rice straw

Summary

In all cases organic manures play a vital role in affecting the yield and yield contributing characters with or without supplemental NPK fertilizer. Among all the organic manures poultry manure seems to have a pronounced effect on the number of tillers per hill, fertile grain and infertile grain per-panicle, weight of grains and grain yield. Cowdung and rice straw in combination with varying treatments of chemical fertilizer were found to accelerate the rate of yield.

The same was true in respect of protein and starch content in rice grain and straw where among the three organic manures poultry manure significantly increased both protein and starch content, poultry manures with N fertilizer increased the protein content whereas starch content was the least under the same treatment. Chemical fertilizer alone cannot enhance both starch and protein content. The treatment without organic manure gave the lowest yield and less impact on yield contributing characters showing a decrease in protein and starch content.

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Decisions for Stationary Machine Operations on Medium Sized Peasant Farms in India: An Exercise in Systems Analysis

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Introduction

In developing countries like India, investments in irrigation schemes, especially minor irrigation projects, such as installation of tubewells and pumping sets, possess great potentials for boosting agricultural productivity per unit area and time. But the economic management of this power machinery is one of the significant factors affecting farm income. For example, if it needs only 5.0 horse power to pump water from 15 to 20 feet below ground level, it will certainly be a waste of energy if a higher horse power machine were used instead. For economy, a machine should use no more power than necessary because power is another cost of machine performance. In minor irrigation projects, the minimum horse power machine essential for lifting underground water may, however, turn out surplus even during the critical periods due to the small size of the farm. Most of the enterprising farmers therefore utilize the excess capacities of their machines for mechanizing other stationary farm operations such as crushing, shelling, threshing and chaffing, which would release human and animal labour, at least during the peak periods, for adopting more intensive cultivation practices on the farm. Again, a few farmers would also find it rewarding to increase the size of their production plants by renting in additional land and/or expand the volume of work by custom-hiring their surplus power plants for undertaking such work for their neighbours as pumping water for irrigation, and threshing and shelling of their farm produce.

This study aimed at (i) choosing among the alternative power units and their allied machinery for mechanising stationary operations on medium-sized peasant farms in India, following systems analysis; and (ii) examining possible adjustment opportunities in the farms operated with the power unit and its associated machinery system thus selected.

India is one of the developing countries where a good deal of emphasis is being laid on helping the farmers acquire independent irrigation plants for providing assured water for their crops. This is especially true of the Intensive Agricultural District Programme (I.A.D.P.) areas. Ludhiana district of the Punjab State of this country is considered to be the most progressive of the I.A.D.P. districts in the matter of exploitation of irrigation potentials. The statistics indicate that 83.4 per cent of the total cropped area of this district is irrigated*. This district was, therefore, purposively selected for this study.

Methodology

Ludhiana district comprises two agriculturally heterogeneous tracts, viz., *non-bet* (non-riverine) and *bet* (riverine). The *non-bet* area comprising 87.11 per cent of the total cultivated area with homogeneous soil-climate-crop complex was purposively selected for this investigation.

The multistage random sampling technique was used for this inquiry. The villages formed the primary and operational holdings, the ultimate units of study.

The investigation was taken up in nine villages selected randomly without replacement.

The operational holdings in all

* Economic and Statistical Adviser to Government Punjab, Statistical Handbook of Punjab 1972–73, Publication No. 183, Chandigarh, 1973, p. 23.

the nine selected villages were pooled, arranged in the ascending order of size of cultivated area and divided into three categories on the basis of the cumulative totals along the ogive curve. The distribution of the cultivated area was thus transformed to obtain the size-ranges of small, medium and large holdings as below 5.07 ha, 5.07 – 8.90 ha and 8.90 ha and above, respectively. The present inquiry was restricted to the medium sized farms in the range of 5.07 – 8.90 ha.

The design of the study provided: (i) a sample of farms, irrespective of their sizes, for (a) identifying the most popular power units and their complete machinery systems for stationary farm operations; and (b) developing their technical coefficients for the study zone; and (ii) another sample of farms representing the medium holdings size-group for making rational farm management machinery sample (i).

For selecting the first sample of farms, the holdings in the selected villages were stratified by the type and size of the power units and their associated machinery systems for stationary farm operations. Fifteen holdings each were randomly selected for the most popular size (Appendix I) of diesel engine (5.0 H.P.) and electric motor (5.0 H.P.) for developing the technical coefficients of various power-machine combinations for these jobs. The input-output coefficients thus generated were rationalized in consultation with agricultural engineers of the Punjab Agricultural University.

The second sample of farms was obtained by randomly selecting 10 per cent of the holdings in the medium-size group. This provided a sample of 43 medium-sized holdings for this investigation.

The selected holdings were further sub-classified as unmechanized and mechanized holdings*. The suitable power unit and its machinery system for stationary farm jobs was identified by developing a synthetic farm situation, representing the farming characteristics of unmechanised holdings in the sample and working out optimum plans for this situation by introducing the popular power units and their complete complement of associated equipment for operating at the improved level of technology, following the systems analysis approach, through linear programming technique using the model:-

Objective function

$$Z_0 = P_1 X_1 + \cdots + P_n X_n \text{ to be maximised}$$

Subject to

$$a_{11} X_1 + \cdots + a_{1n} X_n \leqslant C_1$$
$$a_{21} X_1 + \cdots + a_{2n} X_n \leqslant C_2$$
$$a_{m_1} X_1 + \cdots + a_{mn} X_n \leqslant C_n$$
$$X_1 \geqslant O; X_2 \geqslant O; \cdots ; X_n \geqslant O.$$

Where Z_0 represents returns over total variable farm expenses and fixed costs of power unit and equipment**. P_1; . . . . .; P_n are returns from crop activities X_1; . . . . .; X_n respectively and a_{11} . . . . .a_{1n}; . . . . .; a_{m1} . . . . .a_{mn}; are input for X_1; X_2; . . . . ; X_n activities with resources C_1; C_2; . . . . . C_n.

This profit maximisation model provided for appropriate land use capability classification (Appendix II) and included *Kharif* (summer) and *rabi* (winter) capital borrowing and labour hiring activities for the peak periods at the prevalent market rates.

Among the alternative power units and their machinery systems, the most suitable was assumed to be one which yielded the highest returns over total variable expenses and fixed costs of power unit and equipment and at the same time ensured optimal use of scarce farm resources.

The adjustment opportunities in respect of the slack resources on the synthetic farm situation were explored by including activities relating to land renting-in and custom-hiring of power-machine combinations in the linear-programming problem matrices. The optimum plans, thus developed, yielded useful information on the direction in which the slack resources could be gainfully employed on various farm situations for maximising returns over total variable expenses and fixed costs of power units and their allied equipment.

Choice of Power Unit and Allied Machinery System

It was hypothesised that a 5.0 H.P. (horse power) diesel engine or a 5.0 H.P. electric motor and associated equipment (Appendix III) could mechanize lifting of water for irrigation and other stationary operations on medium sized crop farms in the *non-bet* area of Ludhiana district.

The problem matrices, identifying resource restrictions on the synthetic farm under investigation and input-output coefficients for various crop enterprises at the improved level of technology using alternative power-machine combinations, were set up (Appendices IV and V) and programmed by using the linear programming technique. The normative plans, thus obtained, for different farm situations are given in **Table 1**.

It is evident from **Table 1** that the optimum enterprise mix, total cropped area and the intensity of cropping were the same on both the

* A mechanized holding was assumed to be one where the farmer used a diesel engine or an electric motor or a tractor or a combination of these motive powers and their allied equipment for farm operations.

** The return over total variable expenses and fixed costs of power unit and equipment represented the gross margins less the fixed costs of power-machine combinations. The fixed costs of power units and their equipment were included in the analysis because the purchase of costly machines involved long term farm management decisions.

Table 1 Optimum Enterprise Mix and Returns on Synthetic Medium Sized Farm Operated at the Improved Level of Technology With Different Power Units and Allied Equipment

Grop Enterprise	Operated With Bullocks and a 5.0 H.P. Diesel Engine and Allied Machinery (ha)	Operated With Bullocks and a 5.0 H.P. Electric Motor and Allied Machinery (ha)
A. *Kharif*		
American cotton	2.23 (17.76)	2.23 (17.76)
Sugarcane	(13.22)	(13.22)
Groundnut	2.44 (19.43)	2.44 (19.43)
Kharif fodder (fixed activity)	0.78 (6.21)	0.78 (6.21)
Sub-total	7.11 (56.60)	7.11 (56.60)
B. *Rabi*		
Mexican wheat	4.93 (39.25)	4.93 (39.25)
Rabi fooder (fixed activity)	0.52 (4.14)	0.52 (4.14)
Sub-total	5.45 (43.39)	5.45 (43.39)
C. Total cropped area	12.56 (100.00)	12.56 (100.00)
D. Total cultivated area	7.11	7.11
E. Intensity of cropping	176.65	176.65
F. Returns over total variable expenses and fixed costs of power and equipment (Rs.)	28,957.17	31,732.57

Note: Figures in parentheses indicate per cent of total cropped area.

Table 2 Quantum of Slack Resources and Marginal Value Productivities of Limiting Factors in Respect of Normative Plans for the Synthetic Medium Sized Farm Operated at the Improved Level of Technology With Different Power Units and Allied Equipment

Farm Resource	Unit	Operated with Bullocks and a 5.0 H.P. Diesel Engien with Allied Machinery		Operated with Bullocks and a 5.0 H.P. Electric Motor with Allied Machinery	
		Quantum of Slack Resource	M.V.P. of Limiting Factor (Rs.)	Quantum of Slack Resource	M.V.P. of Limiting Factor (Rs.)
Kharif Land					
For maize and cotton	Hectares	0.00	1,224.54	0.00	1,961.43
For sugarcane	"	0.52	0.00	0.52	0.00
For groundnut	"	0.00	1,001.64	0.00	1,433.39
Rabi Land					
For wheat	"	0.00	2,025.64	0.00	2,239.54
For sugarcane	"	0.00	2,475.56	0.00	2,350.21
For gram and barley	"	2.88	0.00	2.88	0.00
Permanent Labour					
15th to 30 to April	Man Hours	0.00	0.96	0.00	0.96
1st to 31st May	"	109.80	0.00	190.61	0.00
1st October to 30th November	"	816.51	0.00	863.85	0.00
Bullock Pair					
15th to 30th April	Hours	66.24	0.00	66.24	0.000
1st to 31st May	"	321.21	0.00	321.21	0.00
1st to 30th June	"	396.08	0.00	396.08	0.00
1st October to 30th November	"	663.88	0.00	663.88	0.00
Diesel Engine/Electric Motor					
15th April to 30th June	"	754.93	0.00	861.77	0.00
1st October to 30th November	"	787.95	0.00	835.28	0.00
Working Capital					
Kharif cash	Rupees	0.00	1.02	134.44	0.00
Rabi cash	"	0.00	1.02	0.00	1.02

situations, viz., operated with the 5.0 H.P. diesel engine and with the 5.0 H.P. electric motor and their associated machinery systems. The distribution of the area among various crops indicated that only the best paying crops were included in the cropping patterns depending upon the use of capability classification of the available land resource. Sugarcane, the best paying crop enterprise and having overlapping land classification with maize and cotton land in *kharif* (summer) and wheat land in *rabi* (winter), covered the entire area (1.66 ha) on which this crop could be raised in *kharif* and *rabi* seasons. American cotton was allocated the land fit for maize and cotton after sugarcane (2.23 ha). The whole of the groundnut land (2.44 ha) was earmarked for this crop. Mexican wheat, being the most paying *rabi* crop, was included for the entire *rabi* land after sugarcane (4.93 ha). The *kharif* and *rabi* fodders were the fixed farm activities. This allocation of the available area among various crops indicated that the entire cultivated land was occupied by crops in both cases, however, was 176.7 per cent.

The returns over total variable expenses and fixed costs of power unit and equipment were greater in the case of the motor operated organisation (Rs. 31, 732.57) than the engine operated (Rs. 28,957.17) The higher returns in the former case were due to the higher working capacity and lower operational costs of electric motors as compared with diesel engines of the corresponding hose power.

The position of the surplus resources and the M.V.Ps. of the restricing factors for the two normative situations are presented in **Table 2.**

It is clear from **Table 2** that both the stationary power units (diesel engine and electric motor) were surplus to the needs of the synthetic midium-sized farm during the peak periods. The engine had surplus capacity in the peak periods to the extent of 755 hours from 15th April to 30th June and 788 hours from 1st October to 30th November. This surplus constituted 63 and 83 per cent of the total resource available for planning during these periods. The surplus capacity of the electric motor was estimated at 862 and 835 hours in these periods, respectively.

This accounted for 72 and 88 per cent of the total resource available for planning during these periods. Obviously, the surplus capacity of the motor was more than that of the engine.

As expected, the bullock labour was surplus in all the peak periods to the same extent in both cases.

Permanent labour was surplus on both the organizations during the peak periods 1st to 31st May and 1st October to 30th November. The surplus of this resource during these periods was greater on the situation operated with the electric motor. This resource was, however, scarce from 15th to 30th April on both the organisations.

Kbarif cash available for investment was surplus to the extent of Rs. 134.44 in the case of motor-operated organisation. The working capital for *rabi* was a scarce resource in both cases.

The M.V.Ps. of most kinds of land were higher on the motor-operated situation than those on the engine operated. In both cases, *rabi* land for sugarcane had the highest M.V.P. It was followed by *rabi* land for wheat and *kharif* land for maize and cotton.

The patterns of additional resource requirements for the normative plans in respect of the two organizations are shown in **Table 3.**

The optimum plan for the motor operated situation involved less hiring of casual labour and less borrowing of working capital as compared with the engine operated organisation.

It is concluded from this analysis that the optimum crop mix on both farm organisations comprised the most profitable enterprises. The electric-motor operated situation yielded higher returns over total variable expenses and fixed costs of power unit and equipment than the engine-operated one. The 5.0 H.P. diesel engine as well as the 5.0 H.P. electric motor and their machinery systems were surplus to the needs of the synthetic medium sized farm under investigation. The latter had a larger surplus than the former. The patterns of M.V.P.s of the limiting factors in both the cases indicated that the scarce resources: land, permanent labour and working capital, were complementary to the surplus resources. The latter, could, therefore, be more fully exploited by acquiring the restricting resources for increasing returns from these farm organisations, as is evident from the adjustment opportunities discussed below.

Table 3 Additional Resource Requirements for the Normative Plans For Synthetic Medium Sized Farm Operated at the Improved Level of Technology With Different Power Units and Allied Equipment, Study Area

Particulars of additional Resource	Unit	Operated with Bullocks and a 5.0 H.P. Diesel Engine with Allied Machinery	Operated with Bullocks and a 5.0 H.P. Electric Motor with Allied Machinery
Casual Labour			
15th to 30th April	Man Hours	330.31	310.01
Working Capital			
Kharif cash	Rupees	123,58	–
Rabi cash	"	6,191.46	5,289.08

Table 4 Adjustment Opportunities With Slack and Hired Resources on Synthetic Medium Sized Farm Operated at the Improved Level of Technology With Different Power Units and Allied Equipment

Adjustment Opportunities	Unit	Operated with Bullocks and a 5.0 H.P. Diesel Engine with Allied Machinery	Operated with Bullocks and a 5.0 H.P. Electric Motor with Allied Machinery
Enterprise Mix			
American cotton	Hectares	0.34	0.98
Groundnut	"	14.91	14.31
Mexican wheat	"	15.25	15.29
Custom-hiring of Power Unit and Machinery			
D.E./E.M. for Threshing*	"		
15th April to 30th June	Hours	–	240.95
D.E./E.M. for Irrigation			
1st October to 30th November	"	445.47	582.42
Hiring-in Resources			
Land			
For maize, cotton, wheat, gram and barley	Hectares "	0.34	0.98
For Grouundnut, wheat, gram and barley	"	14.91	14.31
Casual Labour			
15th to30th April	Man Hours	540.77	703.56
1st to 31st May	"	1,949,95	1,722.81
1st October to 30th November	"	2,660.86	2,525.04
Working Capital			
Kharif cash	Rupees	8,025.82	7,610.84
Rabi cash	"	16,287.64	14,992.91
Returns Over Total Variable Expenses and Fixed Costs of Power and Equipment	"	29,275.10	36,885.82

Note: D.E. Stands for Diesel Engine, E.M. Stands for Electric Motor.

Adjustment Opportunities

It was hypothesised that returns over total variable expenses and fixed costs of power unit and equipment on the synthetic medium-sized farm operated at the improved level of technology with bullocks and a 5.0 H.P. diesel engine or a 5.0 H.P. electric motor with allied equipment for stationary farm jobs, could be optimised through proper exploitation of slack resources, by making desirable adjustments, including renting-in of land for crop production and custom-hiring of surplus power and equipment for work on other farms.

While working out desirable adjustments, sugarcane crop activity was not included, because *kharif* and *rabi* lands suitable for this enterprise were not available

Table 5 Slack Resources and Marginal Value Productivities of Limiting Factors After Making Desirable Adjustments on Synthetic Medium Sized Farm Operated at the Improved Level of Technology With Various Power Units and Allied Equipment

Resource	Unit	Operated with Bullocks and a 5.0H.P. Diesel Engine with Allied Machinery		Operated with Bullocks and a 5.0H.P. Electric Motor with Allied Machinery	
		Extent of Slack Resource	M.V.P. of Limiting Factor (Rs.)	Extent of Slack Resource	M.V.P. of Limiting Factor (Rs.)
Kharif Land					
For maize and cotton	Hectares	0.00	685.03	0.00	752.17
For groundnut	"	0.00	685.03	0.00	752.17
Rabi Land					
For wheat	"	0.00	214.97	0.00	147.83
For gram and barley	"	18.13	0.00	18.17	0.00
Permanent Labour					
15th to 30th April	Man Hours	0.00	0.96	0.00	0.96
1st to 31st May	"	0.00	0.96	0.00	0.96
1st October to 30th November	"	0.00	0.76	0.00	0.76
Bullock Pair					
15th to 30th April	Hours	43.15	0.00	0.00	3.39
1st to 31st May	"	187.21	0.00	166.81	0.00
1st to 30th June	"	393.54	0.00	388.79	0.00
1st October to 30th November	"	0.00	32.73	0.00	42.40
Diesel Engine/Electric Motor					
15th April to 30th June	"	0.00	7.50	0.00	5.20
1st October to 30th November	"	0.00	1.47	0.00	3.65
Working Capital					
Kharif cash	Rupees	0.00	1.02	0.00	1.02
Rabi cash	"	0.00	1.02	0.00	1.02

for rent.

The optimum combinations of adjustment alternatives with slack and hired resources on the synthetic medium-sized farm operated at the improved level of technology with different power units and their equipment were determined by constructing problem matrices and solving them by the simplex method of linear programming analysis. The results thus obtained are indicated in **Table 4**.

It is clear from **Table 4** that adjustments for profit maximization could be made on both the situations through hiring-in of suitable lands and hiring out of a part of the surplus power-machine hours. The engine operated organisation rented in 0.34 ha of maize and cotton land for the cultivation of American cotton and 14.91 ha of groundnut land. These *kharif* lands were put under Mexican wheat in the following *rabi* season. The motor-operated situation acquired 0.98 ha of the former category of land for American cotton and 14.31 ha of the latter category for groundnut production. These lands were also utilised for Mexican wheat in the *rabi* season.

The unused power-machine resources, after providing for the rented land, were hired out. The diesel engine and its equipment was given on hire for 446 hours as against 582 hours of the electric motor and its equipment during 1st October to 30th November for pumping water for irrigation. Besides, the latter was also hired out for 241 hours from 15th April to 30th June for undertaking threshing operations of wheat crop.

An examination of the casual labour hiring activities indicates that the motor-operated situation needed relatively smaller amounts of this resource as compared with the engine-operated organisation except during 15th to 30th April. The requirements of casual labour in this period were higher on the former situation because of larger area planted to American cotton.

The borrowing activities show that the engine-operated organisation borrowed more capital than the motor-operated situation in both seasons.

The returns over total variable expenses and fixed costs of power unit and equipment were higher on the motor-operated situation (Rs. 36, 885.82) than the engine operated organisation (Rs. 29, 275.10).

The unused resources and the M.V.P.s of the limiting factors under the two optimum plans are shown in **Table 5**.

The analysis in **Table 5** shows that bullock pair resource was surplus in both cases from 1st to 31st May and from 1st to 30th June. It was also surplus during 15th to 30th April on the engine-operated situation. The M.V.P. of this resource was Rs. 32.73 per bullock pair hour on the engine-operated organisation during the period 1st October to 30th November. The marginal value productivities of this resource on the motor operated situation were Rs. 3.39 and Rs. 42.40 per bullock pair hour during 15th to 30th April and 1st October to 30th November, respectively.

The diesel engine and electric motor resources were fully utilized in these normative plans. The M.V.P.s of the diesel engine and the electric motor during the 15th April to 30th June were Rs. 7.50 and Rs. 5.20 and from 1st October to 30th November Rs. 1.47 and Rs. 3.65 respectively.

Conclusions

The 5.0 H.P. electric motor and its machinery system has larger surplus capacity and was more profitable than the 5.0 H.P. diesel engine and its allied equipment on the synthetic medium-sized farm pursuing a system of double cropping at the improved level of technology. This was because an electric motor has a higher working capacity than a diesel engine of the corresponding horse power and was cheaper to operate with the former than with the latter.

The analysis of adjustment opportunities suggests that the returns on both farm organisations (operated with bullocks and a 5.0 H.P. diesel engine and bullocks with a 5.0 H.P. electric motor along with their equipment) could be increased by making fuller utilisation of slack and other complementary resources and custom-hiring activities. The farm situation operated with the bullocks and the electric motor and allied equipment earned more returns through these adjustments than the one operated with the bullocks and the diesel engine with associated machinery system.

It is concluded in this study that the electric motors of 5.0 H.P. with complete machinery system should be installed for mechanising stationary operations on the medium-sized farms in the operational area of this study where electricity was available. Diesel engine of 5.0 H.P. and allied equipment could be profitably employed for this purpose where electric current had not been extended.

Appendix I Frequency Distribution of Power Sources, by Size, Sample Villages

Power Source	Horse Power	Number
Diesel engines	5.0	629
Diesel engines	7.5	Nil
Diesel engines	10.0	10
Electric motors	5.0	20
Electric motors	5.0	2
Electric motors	10.0	Nil

Appendix-II Land Use Capability Classification

The classification of land resource use capabilities on selected holdings presented peculiar problems because the same plot of land, in many cases, was found suitable for raising more than one crop in the same season. Different plots of land were, therefore, classified according to their use capabilities assuming that the irrigation facilities were available to the entire cropped area.

1. *Kharif* land suitable for *desi* (local) maize, hybrid maize, *desi* cotton, American cotton and *Kharif* fodder.
2. *Kharif* land suitable for sugarcane. This category was not mutually exclusive from land in category No. 1. Sugarcane therefore, competed with crops grown in category No. 1.
3. *Kharif* land suitable for groundnut. The upper layer of this land was lighter in texture while the lower layer was relatively heavier. This category of land was mutually exclusive from lands in categories 1 and 2 and other *Kharif* crops were not planted in this area.
4. *Rabi* land suitable for *desi* wheat and Mexican wheat.
5. *Rabi* land suitable for sugarcane and *rabi* fodder. This category of land overlapped with that in category No. 4. Sugarcane and *rabi* fodder, therefore, also competed with the crops grown in category 4.
6. *Rabi* land suitable for gram and barley. This area was mutually exclusive from the area in category 5 but was not so from that in category 4. Gram and barley crops, therefore, competed with *desi* and Mexican wheats grown in category 4 land.

This resource use capability classification of available land permitted the competition for land among not only seasonal crops but also of the annual sugarcane crop with the crops grown in both *Kharif* and *rabi* seasons as shown in the problem matrices in Appendices IV and V.

Appendix III Machinery Systems by Power Units for the Mechanization of Stationary Farm Operations

Farm Operation	Particulars of Machinery	Unit	Size of Machine: Diesel Engine (5.5 H.P.)	Size of Machine: Electric Motor (5.0 H.P.)
Pumping water for irrigation	Pump	cm.	6.35 x 7.62	10.16 x 10.16
Sugarcane crushing	Cane crusher	Roll in cm.	22.86	25.40
Maize shelling	Sheller	Shelling plate (Diameter in cm)	53.34	76.20
Threshing and winnowing of wheat and barley	Thresher	Threshing beater (Diameter in cm.)	70.00	76.00
Chaff cutting	Chaff cutter	Feeding mouth in cm.	25.4 x 10.16	25.4 x 10.16

Appendix IV Resource Restrictions and Problem Matrix of the Synthetic Medium-Sized Farm Operated at the Improved Legel of Technology with Bullocks and a 5.0 H.P. Diesel Engine

R_i		Rs. X_i/P_i		790.53 *Desi* Maize (P_1)	1043.17 Hybrid Maize (P_2)	707.51 *Desi* Cotton (P_3)	2116.84 American Cotton (P_4)
Kharif land for maize and cotton	(P16)	3.89	Hectares	1	1	1	1
Kharif land for sugarcane	(P17)	2.18	"	0	0	0	0
Kharif land for groundnut	(P18)	2.44	"	0	0	0	0
Kabi land for wheat	(P19)	6.59	"	0	0	0	0
Rabi land for sugarcane	(P20)	1.66	"	0	0	0	0
Rabi land for gram and barley	(P21)	2.88	"	0	0	0	0
Permanent labour from 15th to 30th April	(P22)	461.43	Man Hours	0	0	205.55	258.16
Permanent labour from 1st to 31st May	(P23)	986.20	"	311.32	311.32	54.84	54.84
Permanent labour from 1st October to 30th November	(P24)	1929.54	"	137.56	170.73	116.13	162.97
Bullock pair from 15th 30th April	(P25)	228.80	Hours	0	0	59.19	67.38
Bullock pair from 1st to 31st May	(P26)	433.30	"	75.59	75.59	31.37	31.37
Bullock pair from 1st to 30th June	(P27)	429.00	"	0	0	7.41	7.41
Bullock pair from 1st October to 30th November	(P28)	872.30	"	5.22	7.02	0	0
Diesel engine from 15th April to 30th June	(P29)	1194.97	"	12.35	12.35	44.46	44.46
Diesel engine from 1st October to 30th November	(P30)	949.81	"	9.78	14.67	9.88	19.76
Kharif cash	(P31)	2365.40	Rupees	493.07	921.43	460.54	632.13
Rabi cash	(P32)	1408.03	"	0	0	0	0

Appendix IV (Continued)

R_i / P_i	7553.90 Sugar-cane (P_5)	1399.32 Ground-nut (P_6)	2313.56 *Desi* Wheat (P_7)	2986.64 Mexican Wheat (P_8)	1110.81 *Desi* Gram (P_9)	710.63 Barley (P_{10})	0 Casual Labour Hiring Activities: 1st to 30th April (P_{11})	0 Casual Labour Hiring Activities: 1st to 31st May (P_{12})	0 Casual Labour Hiring Activities: 1st Oct. to 30th November (P_{13})	-1.02 Capital Borrow-ing Activities: Cash (P_{14})	-1.02 Capital Borrow-ing Activities: *Rabi* Cash (P_{15})
P16	1	0	0	0	0	0	0	0	0	0	0
P17	1	0	0	0	0	0	0	0	0	0	0
P18	0	1	0	0	0	0	0	0	0	0	0
P19	1	1	1	1	1	0	0	0	0	0	0
P20	1	0	0	0	0	0	0	0	0	0	0
P21	0	0	0	0	1	1	0	0	0	0	0
P22	42.09	0	29;65	29.65	137.94	56.86	-1	0	0	0	0
P23	56.91	0	95.85	133.80	0	0	0	-1	0	0	0
P24	19.76	163.51	64.47	64.47	60.76	64.47	0	0	-1	0	0
P25	7.41	0	0	0	36.63	3.58	0	0	0	0	0
P26	7.41	0	6.12	8.08	0	0	0	0	0	0	0
P27	9.88	0	0	0	0	0	0	0	0	0	0
P28	0	2.58	41.00	41.00	41.00	41.00	0	0	0	0	0
P29	79.04	12.35	24.84	36.42	0	14.90	0	0	0	0	0
P30	19.76	9.88	12.35	12.35	0	12.35	0	0	0	0	0
P31	77.12	389.88	0	0	0	0	0	0	0.75	-1	0
P32	1675.63	0	450.12	914.29	156.25	222.12	0.94	0.94	0	0	-1

R_i = Returns over total variable expenses and fixed costs of power and equipment
X_i = Resource level
P_i = Activities.

Appendix V Resource Restrictions and Problem Matrix of the Synthetic Medium Sized Farm Operated at the Improved Level of Technology with Bullocks and a 5.0 H.P. Electric Motor

R_i		X_i/P_i		920.50 *Desi* Maize (P_1)	1171.79 Hybrid Maize (P_2)	785.85 *Desi* Cotton (P_3)	2205.41 American Cotton (P_4)
Kharif land for maize and cotton	(P16)	3.89	Hectares	1	1	1	1
Kharif land for sugarcane	(P17)	2.18		0	0	0	0
Kharif land for Groundnut	(P18)	2.44		0	0	0	0
Rabi land for wheat	(P19)	6.59		0	0	0	0
Rabi land for sugarcane	(P20)	1.66		0	0	0	0
Rabi land for gram and barley	(p21)	2.88		0	0	0	0
Permanent labour from 15th to 30th April	(P22)	465.28	Man Hours	0	0	201.85	254.46
Permanent labour from 1st to 31st May	(P23)	987.49		307.62	307.62	51.14	51.14
Permanent labour from 1st October to 30th November	(P24)	1,933.39		122.16	147.61	113.66	158.03
Bullock pair from 15th to 30th April	(P25)	228.80	Hours	0	0	59.19	67.38
Bullock pair from 1st to 31st May	(P26)	443.30		75.59	75.59	31.37	31.37
Bullock pair from 1st to 30th June	(P27)	429.00		0	0	7.41	7.41
Bullock pair from 1st October to 30th November	(P28)	872.30		5.22	7.02	0	0
Electric Motor from 15th April to 30th June	(P29)	1,202.98		8.65	8.65	32.12	32.12
Electric Motor from 1st October to 30th November	(P30)	953.66		2.08	3.11	7.41	14.82
Kharif cash	(P31)	2,390.79	Rupees	428.49	839.33	513.01	578.41
Rabi cash	(P32)	1,469.67		0	0	0	0

R_i / P_i	8042.45 Sugar-cane (P_5)	1433.39 Ground-Nut (P_6)	2408.37 *Desi* Wheat (P_7)	3115.91 Mexican Wheat (P_8)	1134.65 *Desi* Gram (P_9)	762.73 Barley (P_{10})	0 Casual Labour Hiring Activities: 15th to 30th April (P_{11})	0 Casual Labour Hiring Activities: 1st to 31st May (P_{12})	0 Casual Labour Hiring Activities: 1st Oct. to 30th November (P_{13})	-1.02 Capital Borrow-ing Activities: *Kharif* cash (P_{14})	-1.02 Capital Borrow-ing Activities: *Rabi* cash (P_{15})
P16	1	0	0	0	0	0	0	0	0	0	0
P17	1	0	0	0	0	0	0	0	0	0	0
P18	0	1	0	0	0	0	0	0	0	0	0
P19	1	0	1	1	1	1	0	0	0	0	0
P20	1	0	0	0	0	0	0	0	0	0	0
P21	0	0	0	0	1	1	0	0	0	0	0
P22	37.15	0	29.65	29.65	137.94	51.96	-1	0	0	0	0
P23	49.50	0	87.69	121.84	0	0	0	-1	0	0	0
P24	14.82	161.04	60.77	60.77	60.76	60.77	0	0	-1	0	0
P25	7.41	0	0	0	36.63	3.58	0	0	0	0	0
P26	7.41	0	6.12	8.08	0	0	0	0	0	0	0
P27	9.88	0	0	0	0	0	0	0	0	0	0
P28	0	2.58	41.00	41.00	41.00	41.00	0	0	0	0	0
P29	59.28	8.65	20.76	30.44	0	12.46	0	0	0	0	0
P30	14.82	7.41	8.65	8.65	0	8.65	0	0	0	0	0
P31	39.53	369.21	0	0	0	0	0	0	0.75	-1	0
P32	1427.10	0	389.50	831.31	141.78	188.64	0.94	0.94	0	0	-1

Effect of Stage of Harvest on the Yield and Quality of Seed and Fibre in Jute

by

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Introduction

Jute is a commercial crop in Bangladesh. Its share in the total foreign exchange earnings of the country is about 90 percent.

The jute growers in Bangladesh do not grow a separate jute crop for seed. They grow the crop mainly for the fibre and a portion of the crop usually at the corner or at the end of the field, is kept for the production of seed.

Whether jute is grown for fibre or seed it must be harvested at such a stage of plant growth so that maximum yield with best quality produce may be obtained.

Jute fibre of commerce is a best fibre obtained from the skin of a bark of the stem of the plant, and hence, a jute crop for fibre is usually harvested long before the plants bear mature seeds (Kundu *et al*, 1959). It has been found that a jute crop grown for seed also gives jute fibre of commerce but the quality of the fibre is usually very poor because of the advancement in the growth of the plants (IC.J.C., 1959, 1963 and Kundu *et al*, 1959).

In the production of seed in jute the main objective is to produce as much good quality seed as possible. As a seed crop of jute also gives jute fibre of commerce, it is also desirable to that much of the fibre of tolerable quality is obtained without sacrificing either the yield or the quality of the seed produced.

It is, therefore, very useful for the jute growers and researchers in jute to know the effects of the plant growth stage at harvest on the yield and quality of seeds and fibre of jute.

The aim of this study was to investigate the effects of the method of planting and the stage of plant growth at harvest on the yield and quality of seeds and fibre in jute.

Methods and Materials

This study was conducted at the Bangladesh Agricultural University Farm, Mymensingh during the period from April to November, 1973, on a medium high land. The soil is sandy loam in character with the pH varying from 6.6 to 6.8. The experimental area is under the subtropical climate which is characterised by its heavy precipitation during the months of April to October, The information in respect of rainfall, temperature and hamidity is shown in **Table 1**.

Two species of jute, *Corchorous capsularis* and *Corchorous olitorious* were planted in broadcast sowing and line sowing. The crop was harvested at five maturity stages: one fruit maturing stage; 25% fruits maturing stage; 50% fruits maturing stage; 75% fruits maturing stage; and 100% fruits maturing stage.

In the line-sown crop seeds were sown with a spacing of 30 cm x 10 cm. In the broadcast method seeds were sown by hand over the entire area. The treatment combina-

Table 1. Distribution of monthly rainfall and average maximum and minimum temperature, March – December 1973

Month	Total rainfall* (inch)	Average Temperature** (°F) Maximum	Minimum
Mar.	0.68	92.4	66.3
Apr.	7.56	94.1	66.3
May	12.97	91.2	71.4
Jun.	20.84	85.5	77.6
Jul.	8.68	85.4	78.8
Aug.	20.32	86.8	78.4
Sept.	1.02	87.3	75.6
Oct.	5.05	86.6	75.3
Nov.	3.05	84.6	65.3
Dec.	1.40	78.6	56.6

Source: * Collected from Hydrology office, Water Development Board, Mymensingh.
** Collected from Meteorological Department, office of the Deputy Commissioner, Mymensingh.

Table 2. Performance of *Corchorus capsularis* and *Corchorus oliterious* on the yield of seed and fibre

Species of Jute	Plant height (m)	Plant diameter (cm)	Yield: Fibre* (md/ac)	Yield: Stick (md/ac)	Yield: Seed (md/ac)	Branch/ Plant (No.)	Fruits/ Plant (No.)	Seeds/ Fruit (No.)	100 seed weight (g)	Quality (percent): Top	Mid-dle	Bot-tom	C-Bot-tom	X-Bot-tom	Stick
Corchorus capsularis	2.55b	1.06a	32.9a	74.42a	6.4a	4.19a	49.90a	23.73b	2.37a	0	0	0	4.02b	39.63a	56.23
Corchorus olitorious	3.46a	0.87b	35.2a	74.12a	2.5b	2.86b	11.60b	85.10a	1.68b	0	0	0	4.72a	40.09a	55.28
Mean	3.01	0.97	34.05	74.27	4.5	3.52	30.75	54.41	2.02	0	0	0	4.37	39.86	55.76

*1 md (maund) = 82.28 lb = 37.32 kg.
Figures with letter in common do not differ significantly.

tions were: species 2 x method 2 x stage 5=20. There were 4 replications. The size of the plot was 1/198th of an acre.

The land was prepared by ploughing six times with the country plough. At the time of final preparation, the land was manured with cowdung at the rate of 4,073 lb. per acre. In addition, 18 lb of N, 20 lb of P (elemental), and 38 lb of K (elemental) per acre were applied in the unit plots through urea, triple superphosphate, and muriate of potash. Half of N and the whole of P and K were applied one day before seeding. The rest of the N was top-dressed four weeks after seeding.

On finally prepared plots, seeds were sown on 27 April, 1973. For row sowing 30 cm apart furrows were opened by small hand plough and the dry seed of *C. capsularis* (7 lb/acre) and *C. olitorious* (5.5 lb/acre) were sown by hand in the furrows. Broadcast plots were sown by scattering the seeds by hand. After sowing the seeds were covered with soil by hands in the row sown plots and by laddering in the broadcast plots. The experimental crop was hand-weeded thrice, 15, 30 and 45 days after sowing.

The crop was harvested on different dates depending on maturing stage from 30.9.73 to 1.11.73. The observation was made on the following plant features: Plant height (cm), plant diameter (cm), skin area (cm^2), percentage c-bottom fibre, percent x-bottom fibre, percent stick fibre, branch/plant (No.), fruits/plant (No.), 100 seed weight (gm), seed yield (md/acre) and per-

Table 3. Performance of line and broadcast methods of sowing on the yield of fibre, seed and quality of both fibre and seed

Method of planting	Yield of green plants (md/ac)	Yield: Fibre (md/ac)	Yield: Seed (md/ac)	Percent: C-Bottom	X-Bottom	Stick	Top	Mid-dle	Bot-tom
Row sowing	405.4b	32.2b	4.1a	4.36a	39.57a	56.06a	0	0	0
Broadcast	449.6a	36.8a	4.8a	4.38a	40.15a	55.49a	0	0	0
Mean	427.5	34.00	4.5	4.37	39.86	55.77	0	0	0

*1 md. (maund) = 82.28 lb = 37.32 kg.
Figures with letter in common do not differ significantly.

Table 4. Effect of stages of harvest on yield of fibre, stick and seed

Stage of harvest	Plant Dia-meter (cm)	Yield of green plants (md/ac)*	Branch/ plant (No.)	Fruits/ plant (No.)	Seeds/ fruit (No.)	Dry Yield: Fibre (md/ac)	Stick (md/ac)	Seed (md/ac)
1 fruit maturing stage	1.02a	468.4a	3.48a	26.69b	64.81a	32.3a	72.60a	3.5b
25% fruit maturing stage	0.94a	462.3ab	3.30a	26.06b	52.63a	35.1a	77.20a	4.0b
50% fruit maturing stage	0.94a	419.0ab	3.63a	31.25ab	58.19a	36.0a	81.28a	4.8ab
75% fruit maturing stage	0.92a	408.9b	3.61a	34.94a	52.56a	36.3a	78.91a	4.8ab
100% fruit maturing stage	0.99a	379.0b	3.60a	34.81a	43.88b	32.6a	64.46a	5.1a

*1 md (muand) = 82.28 lb = 37.32 kg.
Figures with letter in common do not differ significantly.

Table 5. Effect of stages of harvest on quality of jute fibre and seed

Stages of harvest	Fibre Quality (Percent): Top	Mid-dle	Bot-tom	B-Bot-tom	C-Bottom	X-Bottom	Stick	Seed Quality: 1000-seed weight (g)	Germination (%)
1 fruit maturing stage	0	0	0	0	4.98a	46.45a	48.31c	1.71b	34.63d
25% fruit maturing stage	0	0	0	0	4.46ab	43.36a	52.48b	1.96a	44.63c
50% fruit maturing stage	0	0	0	0	4.22b	38.08b	57.69a	2.09a	59.81d
75% fruit maturing stage	0	0	0	0	4.19b	36.83b	59.18a	2.08a	82.38a
100% fruit maturing stage	0	0	0	0	4.02b	34.58b	61.20a	2.19a	77.06a
Mean	0	0	0	0	4.37	39.86	55.77	2.01	59.70

Figures with letter in common do not differ significantly.

cent of germination.

The skin area of a plant was calculated by the following formula:

$$SA = \pi d h$$

where SA = skin area.
π = 3.1428
d = mean plant diameter in cm
h = plant height in cm

The data recorded in the experimental plots were analysed and the significance of the mean differences was adjusted in the New Multiple Range Test (Steel and Torrie, 1960).

Results and Discussion

The results of the study are shown in **Tables 2–3** and **Figs. 1–7**. The differences in crop characters due to the two species and methods under study are shown in **Figs. 1** and **2 (Tables 2** and **3**). The effects of different stages of harvest are presented in **Figs.** 3, 4, 5, 6 and 7 (**Tables 4–5**).

The two species of jute were different in their performance in respect of plant height, plant diameter, green skin to green plant ratio, the number of branches per fruits, percent C-Bottom, 100 seed weight and seed yield (**Table 2**).

The *olitorious* plants were taller than the *eapsularis* plants. The mean diameter of the latter plants was thicker than that of the former. The green skin to green plant ratio was higher in the *capsularis* jute.

There was no variation in fibre yield but the quality of *olitorious* fibre was a little better in the sense that comparatively higher percentage of C-Bottom fibre was obtained from this species.

The numbers of branches and fruits per plant were statistically higher for the *capsularis* jute. The number of seeds per fruits, however, was higher for *olitorious* jute. In the total production of seed there was a great difference between the two species. *Capsularis* produced much higher yield of seed (6.4 md/acre) than did *olitorious* (2.6 md/acre).

Between the two methods of planting the broadcast-sown crop gave significantly higher yield of fibre than that of row-sown crop but there was no variation in the quality of fibres obtained from the two methods of planting (**Table 3**). The yield were high in the broadcast sowing method because of higher plant population.

The stage of harvest did not influence the fibre yield altough it greatly affected the quality of the fibre which progressively deteriorated with the delay of harvesting (**Table 4**).

The effect of stage of harvest on the quality of fibre and seed in jute is sown in **Table 5**.

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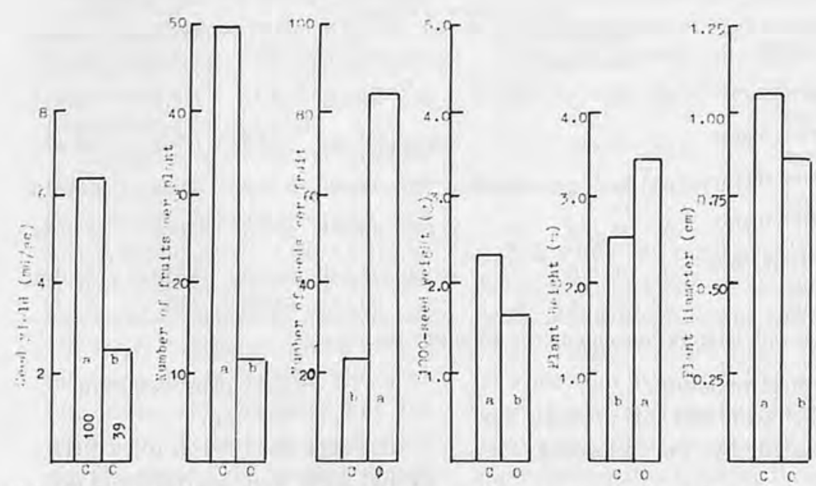

Fig. 1 Seed yield, average number of fruits per plant, average number of seeds per fruits, 1000-seed weight, plant height and average plant diameter in *Corchorus capsulatis* (C) and *Corchorus olitorius* (O) species of jute. Alphabets inside the columns indicate statistical significance. In each character, columns having no common alphabet are statistically significant. Values inside the columns indicate their relative indices.

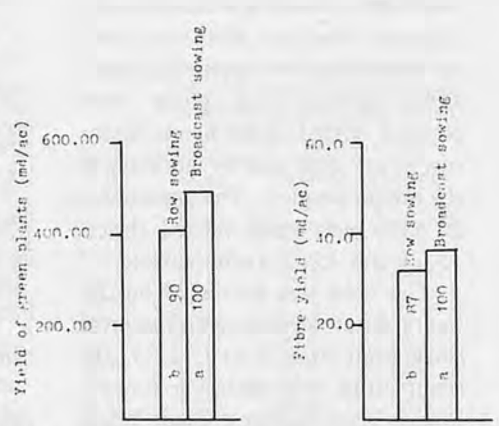

Fig. 2 Effect of methods of planting on the yield of green plants and the fibre yield in jute. Alphabets inside the columns indicate statistical significance. In each character, columns having no common alphabet are statistically significant. Values inside the columns indicate their relative indices.

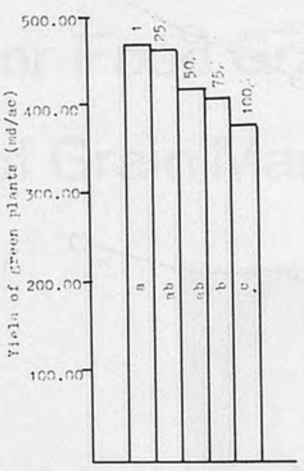

Fig. 3 Effect of stages of harvest on the yield of green plants in jute. Alphabets inside the columns indicate statistical significance. Columns having no common alphabet are statistically significant.

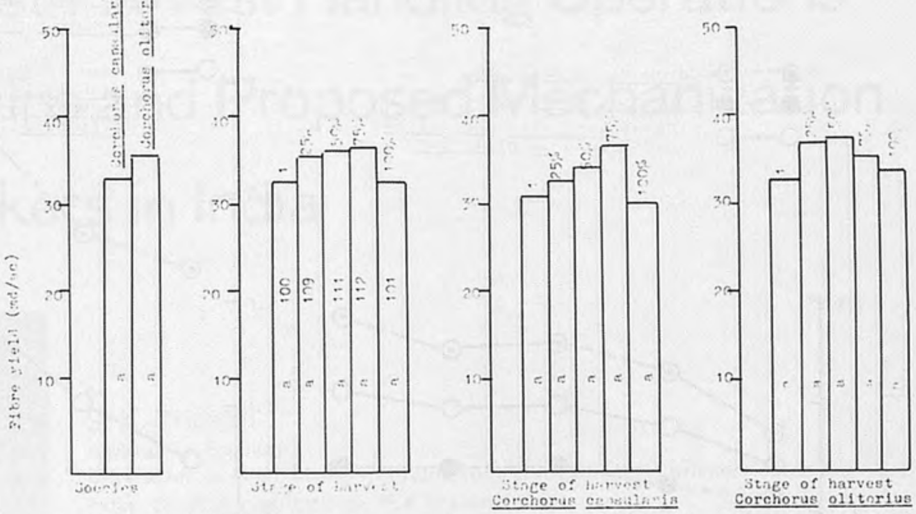

Fig. 4 Influence of species, stages of harvest and their interaction on the fibre yield in jute. Columns having no common alphabet are statistically significant. Values inside the columns indicate their relative indices.

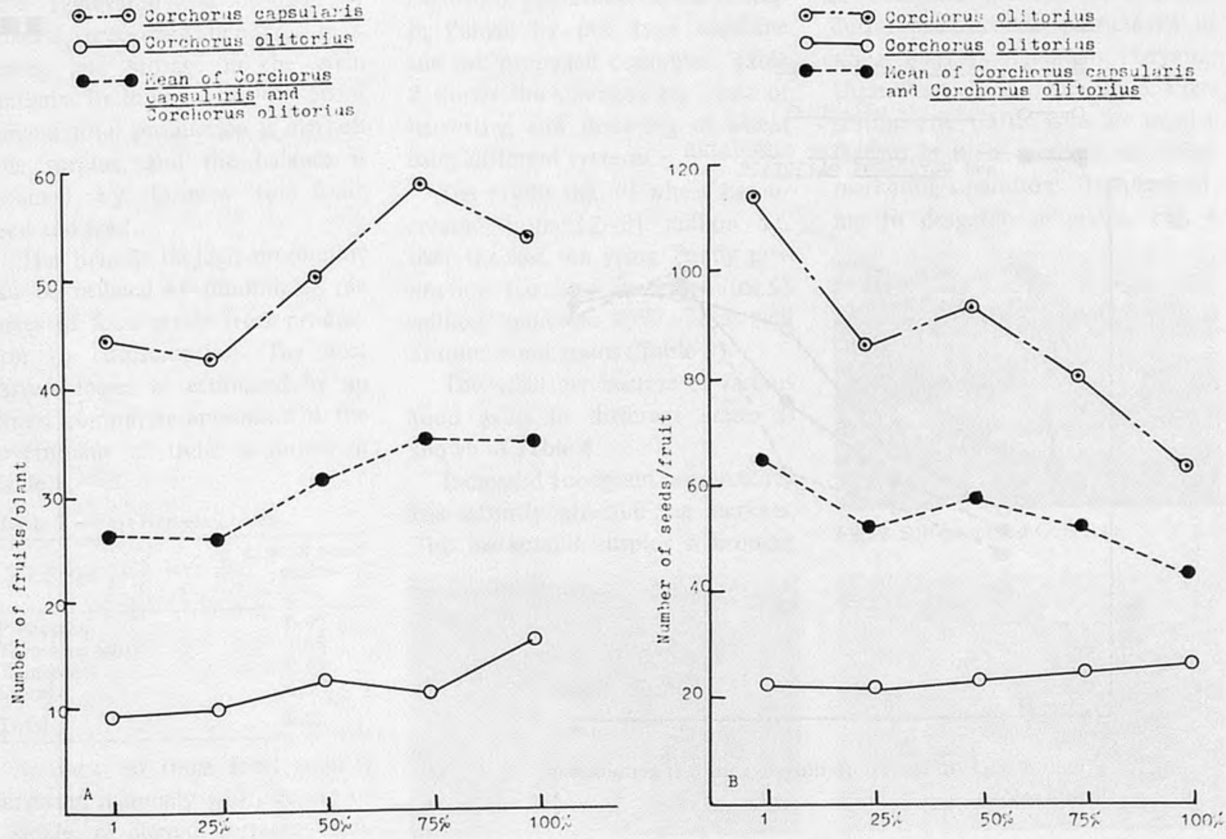

Fig. 5 Effect of stages of harvest and their interaction on the number of fruits per plant (A) and the number of seeds per fruit (B) in jute.

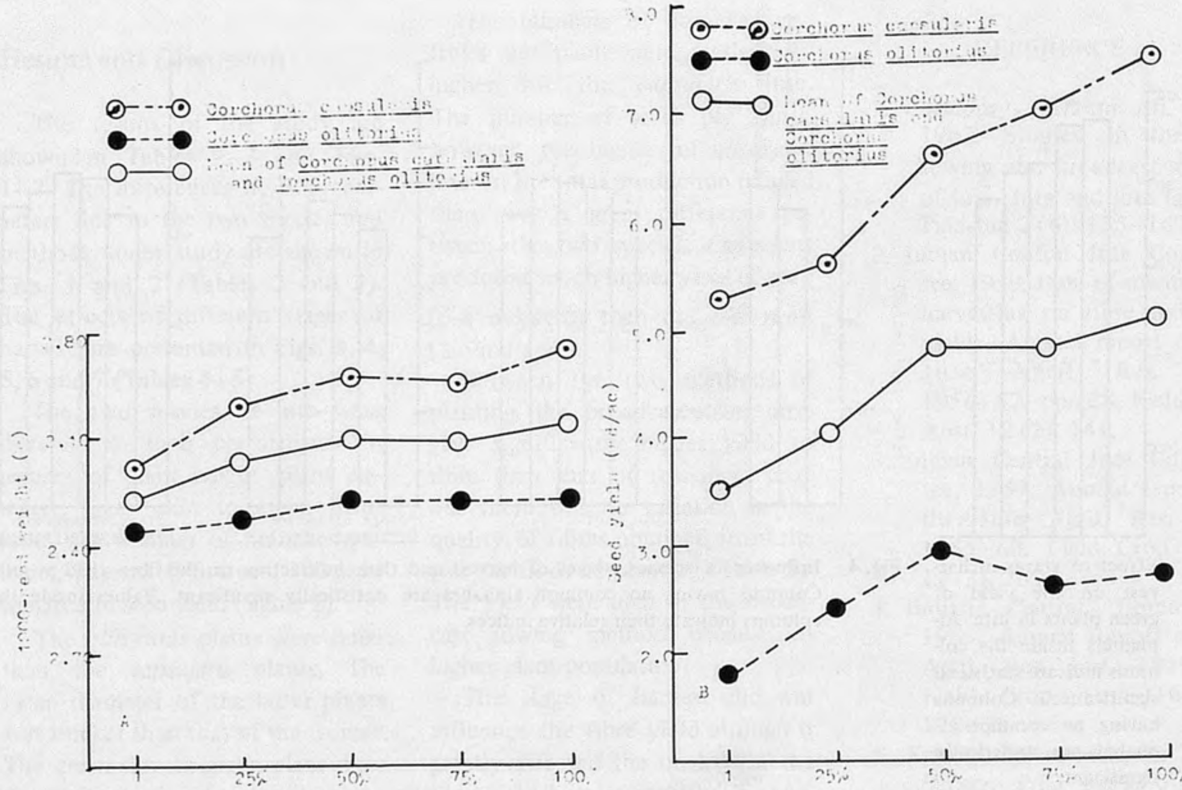

Fig. 6 Effect of stages of harvest and their interaction on the weight of 1000-seed (A) and the seed yield (B) in jute.

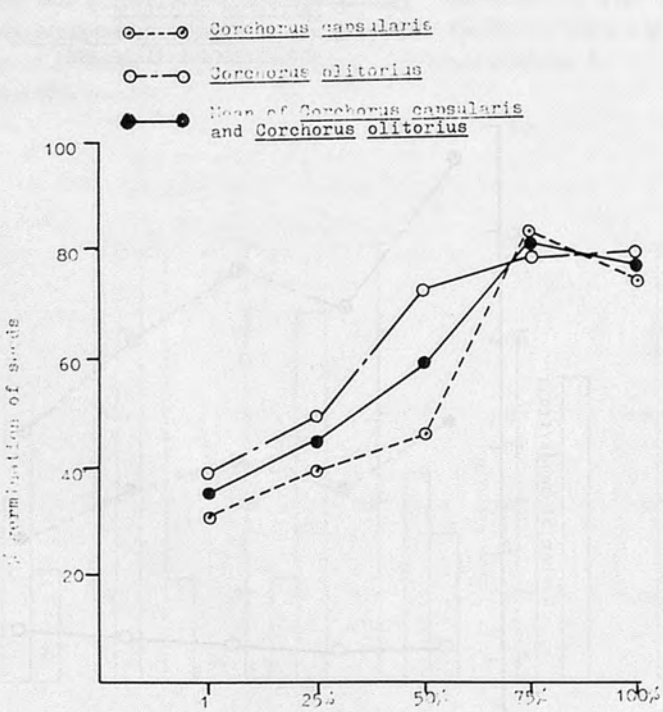

Fig. 7 Effect of stages of harvest on the percentage of germination in jute seeds.

Status of Post-Harvest Handling Operations for Food Grains and Proposed Mechanization of Grain Markets in India

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Introduction

India's record production of food grains in 1977–78 was 126 million mt. The increased production coupled with stable prices of grains, fixed by the Government, have aggravated the problem of receival, precessing, handling, marketing and storage in the grain markets. In India, about 40–50 of percent total production is marketable surplus, and the balance is retained by farmers for food, seed and feed.

The benefit of high production can be utilized by minimizing the losses of food grains from production to comsumption. The post harvest losses as estimated by an expert committee appointed by the government of India is shown in **Table 1**.

Table 1 Post-Harvest Losses

Stage	Loss of good grains (%)
Processing	0.92
Threshing yard	1.68
Transport	0.15
Storage	6.58
Total	9.33

In most of India food grain is harvested manually with the use of a sickle, (a curved, serrated blade about 25 cm long) the size and design of which vary from place to place. Threshing is done by power-operated threshers, animal treading or flailing by hand. Over the past 10 years the pull type combine and self-propelled combine harvesters have been introduced into the country. **Figs. 1, 2, 3** show the harvesting operations of wheat crop in Punjab by pull type combine and self-propelled combines. **Table 2** shows the comparative costs of harvesting and threshing of wheat using different systems.

The production of wheat has increased from 12–31 million mt. over the last ten years. Paddy production has also increased to 53 million tonnes in 1977–78 as well as other food grains (**Table 3**).

The yield per hectare of various food gains in different states is shown in **Table 4**.

Increased foodgrain productivity has recently affected the markets. The marketable surplus is brought by farmers soon after harvest to the grain markets which were primarily designed to handle comparatively small volumes of grains manually. The periods of grain arrivals has been shortened to 6–7 weeks in April, May and June and resulting in complete glut of food grains during peak arrivals, particularly in wheat markets of Punjab, Haryana, Uttar Pradesh and Rajasthan. Congestion and traffic jams are regular feature in these markets, the delay marketing operations from unloading to despatch of grains. **Fig. 4**

Fig. 1 Indigenous pull-type Combine "Vicon"

Fig. 2 Self-propelled Combine

Fig. 3 Harvesting operations – Self-propelled Combine

Table 2. Comparative Cost of Harvesting and Threshing Wheat

Annual Use (hours)	Manual Harvesting & Power Threshing (Rs./acre)		Reaper Harvesting & Power Threshing (Rs./acre)		Tractor-operated Combine (1.5 m) (Rs./acre)	Self pro-pelled Combine (4 m) (Rs./acre)
	Tractor	Electric* Motor	Tractor	Electric* Motor		
100	178.56	147.40	141.32	110.16	117.90	115.68
200	161.36	130.20	129.64	98.48	72.45	88.83
300	155.64	124.48	122.44	91.28	57.30	67.80
400	152.76	121.60	118.80	87.64	49.70	56.90
500	151.04	119.88	116.64	85.48	45.15	50.32
600	149.48	118.72	115.16	84.00	42.10	45.93
700	149.08	117.92	114.16	83.00	39.95	42.79
800	148.52	117.36	133.44	82.28	38.33	40.44
900	147.96	116.80	112.76	81.64	37.05	38.61
1000	147.60	116.40	112.32	81.16	36.05	37.15

*Either a tractor or electric motor operates the thresher.

Source: Post-Harvest Technology of Cereals and Pulses, Proceedings of Seminar held in New Delhi, 1972, p. 19.

Table 3. All India Foodgrain Production, 1949–50 to 1974–75

(Unit: million mt)

Crop year	Food grains						Pulses		Total
	Rice	Wheat	Jowar	Bazra	Other	Total	Gram	Total	
1949–50	25.1	6.8	7.0	3.2	8.6	50.7	3.9	10.0	60.7
1950–51	22.1	6.8	6.3	2.7	8.0	45.7	3.8	9.2	54.9
1955–50	28.7	8.9	6.7	3.5	9.8	57.5	5.4	12.0	69.2
1960–61	34.6	11.0	9.8	3.3	10.7	69.3	6.3	12.7	82.0
1961–62	35.7	12.1	8.0	3.7	11.5	71.0	5.8	11.8	82.7
1962–63	33.2	10.8	9.8	4.0	10.9	68.6	5.4	11.5	80.2
1963–64	37.0	9.9	9.2	3.9	10.6	70.6	4.5	10.0	80.6
1964–65	39.3	12.3	9.7	4.5	11.2	76.9	5.8	12.4	89.4
1965–66	30.7	10.4	7.5	3.7	10.0	62.2	4.2	9.8	72.0
1966–67	30.4	11.4	9.2	4.5	10.4	65.9	3.6	8.4	74.2
1967–68	37.6	16.5	10.0	5.2	13.6	83.0	6.0	12.1	95.1
1968–69	39.8	18.7	9.8	3.8	11.6	83.6	4.3	10.4	94.0
1969–70	40.4	20.1	9.7	5.3	12.2	87.8	5.6	11.7	99.5
1971–72	43.0	26.4	7.7	5.3	11.6	94.0	5.1	11.1	105.1
1972–73	39.2	24.7	6.9	3.9	12.0	86.7	4.5	9.9	97.0
1973–74	44.0	21.8	9.0	7.6	12.2	94.6	4.1	10.0	104.6
1974–75	40.2	24.2	10.2	8.2	12.8	90.6	4.0	10.3	101.0

Total may not equal sum of parts due to rounding.
Source: Government of India, Economic Survey, 1970–71 New Delhi p.83 and Indian Agriculture in Brief, 15th edition p.88 respectively.

Table 4. Yield of Various Food Grains, 1976–77

(Unit: Quintal/ha)

State	Wheat	Rice	Bajra	Maize	Jowar
All India average	13.94	11.08	5.34	10.33	6.59
Andhra Pradesh	–	13.78	4.40	10.15	4.93
Assam	–	9.33	–	–	–
Bihar	12.70	8.95	–	10.17	–
Gujarat	14.75	12.18	8.08	7.94	5.56
Haryana	20.24	24.68	5.74	10.08	–
Himachal Pradesh	13.81	11.17	–	17.88	–
Jumm & Kashimir	8.75	13.71	–	13.81	–
Karnataka	7.08	15.37	5.79	26.17	6.83
Kerala	–	14.71	–	–	–
Madhya Pradesh	7.41	6.20	6.25	11.01	6.67
Maharashtra	7.90	13.51	3.85	–	7.31
Orissa	–	7.35	–	6.04	–
Punjab	24.32	25.83	9.24	11.44	–
Rajasthan	12.80	13.41	3.66	7.60	4.28
Tamil Nadu	–	21.29	8.61	–	9.09
Uttar Pradesh	13.24	9.16	7.49	7.75	6.82
West Bengal	21.01	11.38	–	–	–

shows the marketing operation of wheat crop in Punjab.

Mechanized handling of grains seems a viable solution for facilitating these large grain arrivals in the large markets of India. Such mechanized process needs to introduce a new system of grain handling efficiently and economically.

Grain Markets in Punjab

A survey of 8 grain markets (Mullanpur, Jagraon, Khanna, Moga, Ludhiana, Samrala, Doraha and Phillaur) was carried out to study the present grain handling procedures in Punjab in respect of cleaning, bagging, weighing and sewing and to examine the extent to which these operations can be mechanized.

Fig. 4 Grain handling and marketing operations in the grain markets

The costs of different marketing operations 1972 at Khanna Grain Market are shown in **Table 5**. The figures is based on the studies conducted biggest market in Punjab.

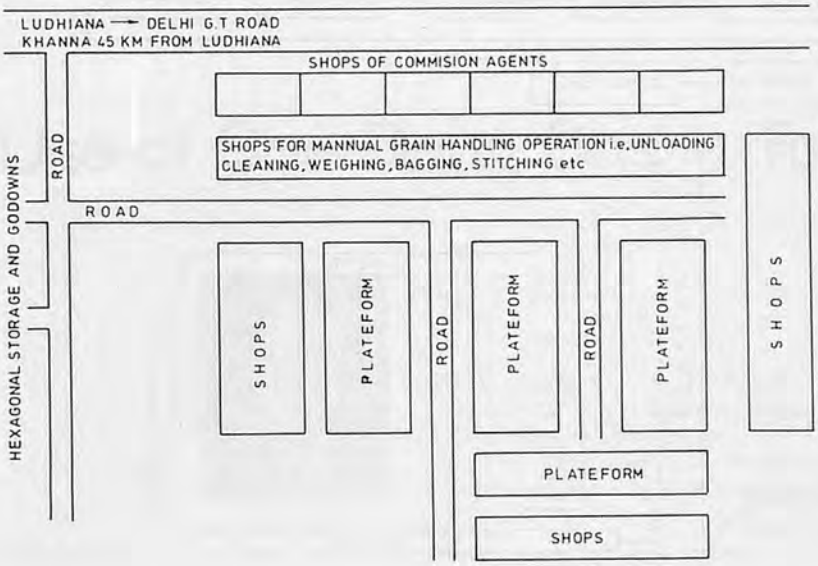
Table 5. Food Grain Handling Costs, Khanna Market

Operation	Operation Charges Rs./quintal	Source of Payment
Unloading	0.08	Farmer
Cleaning	0.20	Farmer
Weighing	0.12	Farmer
Filling	0.05	Farmer
Stitching	0.06	Purchasing agent
Marketing	0.01	Purchasing agent
Transporation to godown (depending on distance)	0.20	Purchasing agent
Stacking in godown	0.05	Purchasing agent
Total	0.71	

Process involved in present method of handling

Under the present market operations the grain is unloaded manually. Cleaning is done manually through small sieves or using hand-operated winnowing machines and power-operated cleaners. The bags are loaded manually from bullock cart or trucks. Unloading and stacking of bags is also done manually **(Fig. 5)**

With the present financial arrangement between the commission agents and farmers it is not possible to mechanize completely the handling of grains in individual lots for individual farmers unless a drastic change is made in the marketing



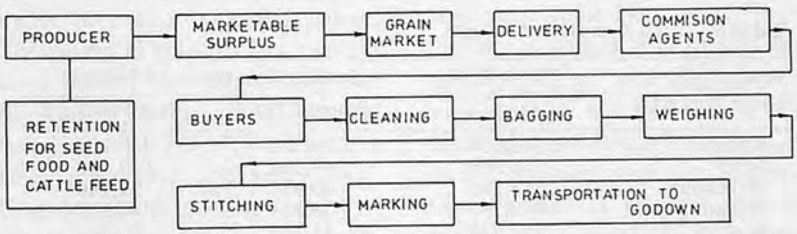


Fig. 5 Flow process diagram of present marketing procedures at Khanna Grain Market (Punjab)

structure. However, a partially mechanized and fully mechanized systems are considered for investigation in order to determine suitability and acceptibility based on performance, economy and efficiency.

Proposed partially mechanized system

A small cleaner of 10–15 mt./hr capacity mounted on a tractor trolley to move from heap to heap should be used. A portable auger conveyer to feed the cleaner may be used along with the fixed bucket elevator to elevate the cleaned grain to the bagging off spout. An automatic weigher to weigh the bagged grain is also provided. The equipment is fitted on the mobile trolley, and could be run by an electric motor or tractor P.T.O. or diesel engine. The advantages of the system are shown below.

Advantage
Mobility
Lots retain identity
Uniformity in quality
Some labour still in use

Disadvantage
Small output
Ties up a tractor for hauling and power

The operating cost analysis for partially mechanized system are given below.

Capital Cost

Equipment
Auger conveyor (15 mt/hr) – Rs. 3,500
Precleaner (15 mt/hr) – Rs. 7,000
Automatic bag weigher (100 kg) – Rs. 7,000
Elevator (15 mt/hr) – Rs.10,000
Tractor, trolley – Rs.60,000
Total equipment cost – Rs.87,500
Average hourly rate – 10 mt/hour
Daily output per 20 hrs. (3 shift 8 hours each with effective 20 working hours) – 200 mt/day
Operational season for wheat, paddy and maize
Total – 100 days.
Total quantity of grains to be handled – 20,000 mt

Running cost
Depreciation (10% of capital cost/year) – Rs. 8,750
Interest on capital (@9%/year) – Rs. 7,875
Cost of fuel, electricity – Rs.15,000
Labour (12 men @Es.8/day (4 men in one shift) – Rs. 9,600
3 mechanic-cum-operator for 100 days one man in each shift (@Rs.10 per day) – Rs. 3,000
Maintenance (5% of capital cost) – Rs. 4,375
Rs.48,600

Cost per quintal Rs.48,600 / 200,000
= Rs.0.243/quintal
Say, Rs.0.25 or 25 paise/quintal.

Thus the cost per quintal for cleaning, weighing, filling and bagging = Rs.0.25/quintal
Present cost for these operations = Rs.0.37
Net saving=37–25=12 paise/quintal.

Proposed fully mechanized system

i) On arrival of the grain loads in the market, the samples for moisture control hecto-litre weight, insect infestation, etc. will be drawn and analyzed quickly in the quality control laboroatory for acceptance. Payment will be based on the quality standards which are published well in advance (**Fig. 6**).

ii) The grain load would be weighed over a weigh bridge and be emptied into an intake pit and the conveyance again would be weighed for tare weight.

iii) The grain will be pre-cleaned at the rate of mt/hr and stored in the bins. If necessary the drying system may be incroporated.

iv) For despatching the grain an under storage conveyor, an elevator and a over-head conveyor will be provided for delivery to the vehicle.

The operational cost analysis for

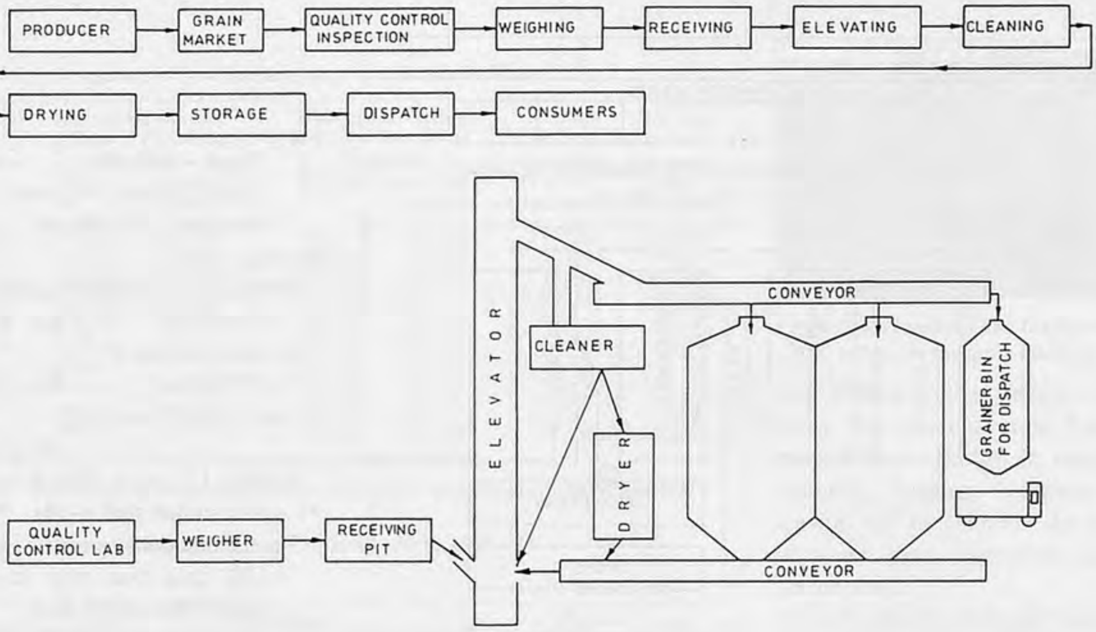


Fig. 6 Flow process diagram for proposed mechanized grain handling operations at Khanna Mandi (Punjub)

the fully mechanized system of 40 mt/hr capacity is given below.

Capital Cost

Equipment

Bucket elevator (10 m high, 50 mt/hr) – Rs. 35,000
Pre-cleaner (40–50 mt/hr) – Rs. 30,000
Conveyors (2 units) – Rs. 20,000
Weight bridge – Rs. 10,000
Civil and steel works for storage bins and supporting frames – Rs.140,000
Contingency – Rs. 20,000
Rs.255,000

Running cost

Depreciation (10% of capital cost) – Rs. 25,500
Interest on capital (@%/yen) – Rs. 22,950
Cost of energy – Rs. 9,000
Maintenance (@5% of total capital) – Rs. 12,750
Total Cost Rs. 80,200

Average hourly output= 40 mt (total output per day 3 shifts of 8 hours each with 20 effective working hour) = 800 mt per day
Again taking 100 working day = 80,000 mt
Cost of grain handling per quintal = 80,200/80,000 =Rs.0.10 or 10 paise/quintal
Present cost = 37 paise/quintal
Net saving = 37–10 = 27 paise/quintal.

Table 6. Total Arrivals and Savings

Location of Grain Markets	Total Arrivals of Wheat in 1972 (quintals)	Savings from Proposed Systems	
		Proposal No. 1	Proposal No. 2
Khanna	1,002,856	120,342	270,771
Moga	516,306	61,966	139,402
Mullanpur	341,285	40,954	92,146
Phillaur	149,287	17,914	40,307
Boroha	342,828	41,139	92,563
Samrala	282,073	33,848	76,159
Jagraon	684,253	82,107	184,742

Conclusion

The savings from the proposed systems No. 1 & 2 in Khanna, Jagraon and Moga are considerable and the savings of this high magnitude can not be ignored. The cost of all equipment, including storage structure can be recovered within a period of 4 to 5 years out of the savings. The total quantity of grain handled and savings from the proposed mechanized systems are shown in **Table 6**.

Acknowledgement

The author is grateful to the authorities of the Marketing Board, Department of Food & Civil Supplies, Govt. of Punjab, Food Corporation of India for giving an insight to their marketing and grain handling operations. The author is thankful to Mr. Frigaard, F.A.O. engineer, for his valuable suggestions and help in carrying out the survey work.

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Use of Cow Dung Gas in Tobacco Curing

by

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Abstract

Tobacco is one of the most important cash crops in Bangladesh. The curing of tobacco at present is done mostly by sun drying and flue-curing. In flue-curing, coal and wood are used as fuel, but these are becoming scarce and very costly. Considering the growing scarcity of wood and coal, the use gobar (cowdung) gas in tobacco curing is recommended.

Tobacco Production

The importance of tobacco in raising the gross domestic product in Bangladesh can not be overemphasized. The yield rate of tobacco per year increased from 39,000 mt in 1974–75 to 63,000 mt in 1076–77 (1). Tobacco plays very vital role both in large and small scale industries in the country. The annual average production of cigarettes is about 11,500 million sticks from 1971–72 to 1976–77 (1) and the average daily employment by the tobacco industries was 5,984 (1). The total value was Tk. 1,653,719 in the same year (**Table 1**).

Table 1. Gross Value of Tobacco Production

(Unit: Thousand taka)

1969–70	363,575
1970–71	323,614
1971–72	303,067
1972–73	405,259
1973–74	1,276,114
1974–75	1,255,503
1975–76	1,653,719

Source: Statistical Pocket Book of Bangladesh (1978), Bangladesh Bureau of Statistics, Statistics Division, Ministry of Planning.

The above data indicate that any contribution to raise the quantity and quality of tobacco is undoubtedly valuable for the economic prosperity of the country. Concern here is given to the improvement of quality since quantity is largely a question of agronomy. Curing is the very factor that governs the quality of tobacco. Curing is nothing but the drying of green tobacco leaves to a state most suitable for smoking.

Tobacco, is cultivated in almost all districts of Bangladesh. But the district of Rangpur alone produces more than one-half of the total production in the country. Other major producers are Dinajpur, Kushtia and Jessore. Tobacco growers have since been using natural source of energy, i.e., sun ray and air for tobacco curing (**Fig. 1**) This crude system lead only to inferior quality of cigarettes and tobacco so cured are mostly consumed by the natives through "Hukka"* and "Biri"** which are very much unhygenic. It was not until 1972–73 when artificial curing was started using a system of smoke pipes (2). This method may be better called flue-curing. Now, Virginia tobacco, the best variety for cigarettes, raised in Kushtia and Jessore districts are generally flue-cured using coal and/or firewood as fuel (**Fig. 2**) Air curing still practised in the districts of Rangpur and Dinajpur.

*A device for smoking tobacco through. It is made from coconut hard shell and wooden stick with hole through its longitudinal axis and an earthen cup to hold tobacco.

** It resembles cigarette with the exception that it is mannually made with non-refined tobacco and sometimes uses other leaves instead of paper.

The scarcity of coal and firewood and the heavy cost involved discourage tobacco farmers from improving their method of drying. Electricity and natural gas are not within reach of most tobacco growers. Jute stick would have found a better economic position had it not been a means of fencing and roofing the cottages of village people and as a source of domestic heat requirements. Besides, pulp industries have found the jute stick suitable for raw materials.

An alternative source of heat for flue-curing is methane gas from cow manure because it has a very flammable gas which generally goes unused in every farmer's home. Also, the by-product of the gobar gas extraction plant, i.e., the slurry is available as improved organic fertilizer as it contains over 2.5% N_2 (by weight) as against .75% only in ordinary state (3). Moreover, cattle manure is free from weeds. Methane gas plants are not complicated and requires simple knowledge for construction, operation and maintenance.

Fig. 1 Sun drying

Fig. 2 Flue-curing barn

Gas can be made available at every farmer's home by teaching them the procedure of construction and installation of the gas-extraction plant of sizes depending on their capacities and ability to collect cow dung.

One mt of wet cow dung produces 3,122 SCFT of gas (3). This can replace 206 lbs of bituminous coal or 445 lbs of firewood assuming:

Calorific value of gobar gas = 2/3 calorific value of natural gas.

Calorific value of N.G. = 1004/-BTU/SCFT (1)

Calorific value of firewood = 6500/-BTU/lb (1)

Calorific value of bituminous coal = 14,100 BTU/lb (4).

Table 2. Approximate Composition (by volume) of Cow Dung Gas

Methane (CH_4)	50–60%
Carbon-di-oxide (CO_2)	30–40%
Hydrogen (H_2)	1%
Nitrogen (N_2)	1%
Hydrogen Sulphide (H_2S)	Traces.

Source: Bio-gas from Animal Wastes, Volume II, No.II (1977), Asian Livestock, Bangkok, Thailand.

Table 3. Percentage Composition (by Volume) of Natural Gas, Chatak, Bangladesh

Methane	99.05%	Gross calorific
Ethane	0.24%	value 1004
Nitrogen	0.67%	BTU/SCFT.
Carbon-di-oxide	0.04%	

Source: Statistical Pocket Book of Bangladesh Bureau of Statistics, Statistics Division, Ministry of Planning.

Table 2. shows the chemical properties that can be extracted from cow dung.

Methane gas is a clean fuel and its use does not contribute to environment pollution.

The minimum number of heads of cattle necessary for the operation of the smallest size of cow-dung gas plant is two (3). This means even a poor farmer may use this plant benefically and economically for his tobacco barn.

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Soybean Production and Processing in the Developing Countries*

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Introduction

Soybeans can be grown in tropical as well as temperate climates. The crop might first be introduced in tropical countries as a secondary crop. Soybeans are adaptable to being planted and grown after a rice crop has been harvested. The cooler season if any would be quite suitable for soybeans.

World soybean production has increased nearly two-thirds in the past 7 to 8 years, as shown in **Table 1** (1). Brazil, which has increased production 7 to 8 fold in that same period of time, is giving special attention to the development of the soybean crop and processing industry (9). Indonesia, even in the tropics, is producing soybeans commercially at locations near the equator. Subtropical and tropical regions are thus being shown to have a great potential for soybean production. That potential will no doubt increase as new adaptable cultivars are made available. The improvement of soybeans is still, however, in an early stage; thus, there is much room for development (12). Technological innovation for higher production and better preservation of soybeans must be implemented to meet diversified regional conditions and requirements.

Soybeans have been grown and utilized for many years in the Oriental countries. Soybeans in Japan and China have played an important role as a source of protein, fat and vitamins. The soybean may prove to be one of the most practical and least expensive solutions to the predicted coming shortage of protein for human food especially in the highly populated developing countries.

For the past several years soybean characteristics have been studied quite extensively with the possible exception of the engineering properties (2,3,13,14,15). More extensive and applicable data related to mechanical, hygroscopic and thermal properties of soybeans are necessary for a quality improvement during post-production, preservation and marketing operations (7).

Technology and Losses

Production and post-production methods and techniques for soybeans have evolved in the less developed countries without extensive knowledge or consideration of the effect on the quality of the final harvested product.

Some non-mechanized operations which have been safely used for rice can be quite harmful to soybean seeds. For example, threshing by beating or treading provides impacts sufficient to damage many seeds. Physical property data for soybean seeds show they have less mechanical strength than rice. **Table 2**, shows the compressive strength of soybeans was 1/6 or 1/7 of that for rice in the moisture ranges tested. Conventional combines have similar difficulties in minimizing damage to soybean seeds as they were originally designed for small grains with higher resistance to mechanical impact.

Considerable effort has, however, been put into the development of large "modern" bean harvesting machines. The problem is how to focus attention on the

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* The article is based upon the authors' paper on MECHANIZATION ALTERNATIVES FOR SMALL ACREAGES IN LESS-DEVELOPED COUNTRIES presented at World Soybean Research Conference-II held at North Carolina State University on March 26–29, 1979.

** On sabbatical leave from Mie University, Tsu 514, Japan from December 1, 1978 to March 31, 1979.

Table 1. Soybean Production Data for Selected Major Producer Countries

	1969–71			1977		
	Hectares (1000 HA)	Production (1000 MT)	Ave. Yield (KG/HA)	Hectares (1000 HA)	Production (1000 MT)	Ave. Yield (KG/HA)
World	35,314	46,747	1,324	49,426	77,502	1,568
USA	17,036	31,174	1,830	23,435	46,712	1,993
Brazil	1,314	1,547	1,178	7,059	12,100	1,714
China	13,859	11,398	822	14,236	12,955	910
Indonesia	643	468	728	663	527	795

Source = FAO Agricultural Statistics, 1978

Table 2. Ultimate Compressive Strength of Soybeans and Rice

M.C. (% w.b.)	Soybean 1) (kg/mm²)	Rice 2) (kg/mm²)
8	2.5	16.0
13	1.1	8.1
17	0.6	4.5

Source = 1) Hoki and Tomita, 1976
2) Lee and Kunze, 1972

post production quality loss problems in the less developed countries. Engineers like to think of themselves as doing research at the forefront of knowledge. The results of such new and basic research is then quite naturally applied to the largest and most expensive machinery. The cost of research can no doubt be recovered most quickly by including it as a small part of the sale price of the high priced machines. Unfortunately these research and design procedures do not help the less developed countries that can only afford low cost hand and animal technology. Creating something other than the largest, most complex machine has not been considered very exciting or even worthwhile. Intermediate technology seems only to be interpreted as some routine adoption of a long ago discarded machine from the "advanced" countries. Occasionally such as application might work but generally not.

Appropriate Technology

Appropriate technology must take on increased meaning even in the "developed" USA. For the first time ever engineers must begin to consider energy dfficiency. Technology just for the sake of technology is being questioned. Is bigger always better? Do new designs always have to be more expensive and more complex? Is labor efficiency the only index cor innovation and mechanization? Can various product quality losses be arbitrarily sacrificed for mechanization? Does mechanization have to be more and more automated? Will technology that makes possible the concentration of the population masses in a few large cities be forever justified?

Appropriate technology for a primitive society may mean the design of a better club for beating the soybean vines for threshing. Possibly a wider, softer club would separate more bean seeds easier and without the sharp impact responsible for damage. But, who wants to work on such a mundane problem? It would be argued, I am sure, that engineering skills are not needed for such simple improvements. But why not? Cannot the same laboratory physical property results be applied to solving the threshing by beating problem as for a complex threshing machine? The problems may in fact be more complex than threshing with a machine. For example, uneven maturity at time of harvest is often encountered. This may be partly due to the mixed varieties and partly the varying conditions of tillage, water management, fertilizer and pesticide application. As these unpredictable conditions may remain for some time, along with the susceptibility to mechanical damage of soybeans, a device for selective harvesting may be justified in some areas. A good example is "Ketap or ani ani" for rice. This is a selective harvesting tool still widely used because of its simplicity and ingenuity incorporated with labor intensity (5). Many people would benefit from improvement of the hand bean threshing operation or the development of a simple selective harvesting device unless the "improved" technology removed itself from their reach by its high cost and/or put them out of a job because of undesirable labor efficiency.

Solar Drying

Pride, recognition and compensation must be promoted for designs that are truly appropriate for given situations under specific conditions. The social and public costs and returns must be considered as well as the private cost and returns. Another example of a need for an appropriate technology is for drying of beans and grain crops. Sun drying has been used for centuries. It is a use of free solar energy, but there are problems. Sun drying as generally practiced is an uncontrolled process. Some seeds, due to the random exposure, are overheated and dried too fast and too much, while others are underdried. High temperatures and overdrying cause quality deterioration.

There is a need for a simple, low cost, non-mechanical solar dryer with an essentially self-controlling temperature. The dryer would require no outside mechanical power source, which is always expensive and also burns expensive fossil fuels. The design of such a solar dryer requires the careful and skillful application of some basic engineering concepts of heat transfer and fluid flow; however, few engineers are interested. Comparatively, it takes little engineering expertise to assemble mechanical components to force heated air through a fixed bed of beans or grain. The design of a successful low-cost solar grain dryer with clear and black polyethylene plastic and some wood framing material requires the application of the basic engineering concepts of thermal convection drying theory, solar radiation and product physical properties. The thermal convection and temperature must be balanced in such a way that during intense solar radiation the dryer does not overheat the product. If designed properly, the air will merely flow through the product faster rather than increasing appreciably in temperature. When clouds shield the sun or during a rain shower air movement and drying would cease because of a lack of thermal convective forces. As compared to open sun drying the solar dryer would have two important advantages; one would be temperature control, which can eliminate overdrying and much seed checking and cracking; and two, protection from rain showers and rewetting.

Research Needs

The hygroscopic and thermal properties of many grains have been studied although less attention has been given to soybeans. The recent rapid increase in production with the associated problems accelerates the need for research on the processing and storage of soybeans (10, 11 & 8).

Soybeans are a high value, high protein crop. Thus, countries around the world are promoting production. Many countries, particularly in Asia, are mainly concerned with supplying their own consumption demands, while others such as Brazil are interested in expanding soybeans into a major export commodity. Bean production in most Asian countries is labor intensive and on small farms with field sizes that average less than one acre in size. In many of the rice producing tropical countries soybean production is an off-season crop following one or two crops of rice. Since labor is adequate and yield levels low considerable increase in land productivity is necessary. Soybean production may be totally a hand operation in many of these countries. The only tools used would be a hoe-type device for primary tillage and a sickle for cutting the crop. This does not necessarily mean that improved seed varieties are not used. Higher yielding varieties are often planted and plant protection chemicals applied.

The international Crop Research Institute for the Semi-Arid Tropics (ICRISAT) in India is developing a farming system for beans, peas and sorghums utilizing animal power. A permanent ridge and ditch cultivation approach is being tried. The narrow ditches are 1-1/2 meters on center and serve as paths for the animals and implement wheels in order to prevent soil compaction in the plant growing ridge area. The ditches may also serve for irrigation.

Conclusions

1. Soybean production in most developing countries is labor intensive and on small farms with low land productivity.
2. There is a great potential of production by increase of land productivity through the careful utilization of labor and adoption of selected new varieties and cultural practices.
3. Appropriate mechanization and technological improvements for the post-production operations are prerequisites for minimizing losses and preserving quality soybeans.
4. The physical properties of soybeans are needed for the design of improved tools and machines for post-production operations.
5. Mechanization or technological improvement in post-production operation improve quality, storability and marketability of soybeans without replacing laborers which might induce unemployment problem.

Recommendations

The introduction of soybeans in developing countries should be done through a package program. Acceptable high yielding and disease and insect resistant varieties must be selected. Adequate cultural and weed control practices need to be developed and followed. Harvesting and post-harvest operations must be carried out in such a way to minimize losses and maintain quality. Utilization of the crop may need to be developed in order that adequate demand for human consumption exists for the establishment of an effective marketing system.

1. Greater attention must be given to the design and development of technology that is appropriately simple, low cost and energy efficient for small producers with little capital.
2. The first step to be taken for increased soybean production is to increase the yield per hectare. This should be done with the effective utilization of manual labor and the gradual introduction of appropriate mechanical power for selected areas in the soybean growing countries. Mechanical power for selected areas in the soybean growing countries.
3. Better weed control and management techniques incorporated with simple mechanical device will be desirable especially under tropical and subtropical regions where the vigorous growth of weed is prevailing and frequent use of chemicals are not justified from the point of cost and environmental protection.

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EIMA 1979
Nov.14–18, 1979, Bologna/Italy

In november will be opened in Bologna (Italy) the tenth edition of EIMA.

EIMA – which stands for International Exhibition of Farm Machinery Industry – has been organized in order to foster the interests of agricultural machinery manufactures all over the world and it is promoted by UNACOMA, the italian national association of agricultural machines manufacturers. It represents the ideal platform for the presentation of the world's new machinery and equipment, developed to facilitate and rationalize farm work and to accelerate the restructuring of agricultural activities by raising productivity.

As it has been confirmed by all previous editions, EIMA, by virtue of the choice of its timing, represents the ideal meeting point for distributors, users and machinery manufacturers, enabling them to formulate their production programmes on the basis of the requirements which emerge from contacts with representatives of all interested categories.

In addition, 13 separate production sectors and absence of any form of advertising facilitate the comparison of technical characteristics and the choice of the machine which meets more closely farmer's needs and the ecological conditions in which it has to operate.

Bologna's exhibition quarter has an overall surface of 500.000 square metres of which 70.000 square metres composed by covered and heated stands. Motorway intersections at 500 metres, railway and city centre at 2.000 metres and the international airport at 6.000 metres enable rapid access to EIMA.

Conference rooms of various sizes, logistic and interpreter services provide the exhibitor with the opportunity of arranging, within the EIMA framework, meetings with distributors and customers.

The X° edition of EIMA will take place 14/18 november 1979: as usual the first three days will be reserved for visitors invited by the exhibiting firms while saturday 17 and sunday 18 the exhibition will be opened to the general public (more than 100.000 visitors in the last two days of EIMA 1978).

IRRI Engineer Recommends Improved Rice Huller

Of special interest to the rice milling industry is a recommendation by Dr. C.J. Moss, head of IRRI's agricultural engineering Department that the use of an abrasive stone roller with another rubber roller (instead of the conventional pair of rubber rollers) in rice hullers prolongs the life of the hulling mechanism and, therefore, reduces running costs. The ordinary twin rubber rollers are known to have superior performance to the older designs of rice hullers but are costly and do not last long. On the other hand, abrasive stone rollers of suitable width and diameter are not always readily available in some Asian countries.

According to Dr. Moss, a Filipino rice miller discovered that with the use of a hardened, knurled steel roller running alongside a standard rubber roller can hull 30 tons of paddy with minimum wear and tear for either stone roller or rubber roller. This is indeed good news for rice mill owners with rubber rollers and an incentive for those with older rice mills to modernise their hulling operations.

BIO-Energy '80
April 21-24, 1980, Atlanta/USA

BIO-Energy '80 will take place at the Georgia World Congress Center, USA from 21 to 24 April 1980. It is sponsored by U.S. Government, United Nations, Organization of American States, Inter-American Development Bank, and International Solar Energy Society.

Bio-energy is solar energy stored in plant matter through photosynthesis.

Bio-energy provides: 14% of the energy used worldwide, 45% of the energy used in developing countries, 2.3% of the energy used in USA (equivalent to 9.8% of fuels imported).

BIO-ENERGY '80, the World Congress, will highlight the potential for much greater use.

ADDITIONAL FEATURES

Post Conference Trips: A variety of one-day to one-week inspection trips to industrial, academic and government bio-energy installations will be available at reasonable cost.

Poster Sessions: There will be poster presentations of pre-commercial and R&D projects.

Resource Book: Summary descriptions of bio-energy projects in any stage of development in any part of the world will be published as resource material. Contributors will receive complimentary copies.

Audio and Video Tapes: Replays of conference sessions will be available to expand possible coverage of concurrent meetings.

Programs are as follows:

Monday ... April 21, 1980
- Global Overview
- Exposition Opens
- Biomass Sources seminars
- Reception

Tuesday ... April 22, 1980
- Conversion Processes Seminars
- Major Luncheon Speaker

Products and Uses Seminars
Reception
Wednesday ... April 23, 1980
Total Systems Seminars
Exposition Closes
Major Luncheon Speaker
Total Systems Seminars (continued)
Thursday ... April 24, 1980
Special Topics Seminars
Major Luncheon Speaker
Summary and Conclusions

Obtaining Information

For further World Congress Information, contact:

The Bio-Energy council
1625 Eye Street, N.W.
Suite 825A
Washington, D.C. 20006, U.S.A.

For further Exposition Information, contact:

Bio-Energy Expo Headquarters
P.O. Box 17413
Washington, D.C. 20041, U.S.A.

AMA Chief Editor Joins FAO Experts' Panel

AMA's chief editor, Mr. Yoshisuke Kishida, was recently appointed as member of the Food and Agriculture Organization's (FAO) Panel of Experts on Agricultural Mechanization for a four-year period effective May 1, 1979.

The Panel was organized during an informal meeting of experts in Rome on December 14-15, 1979 as a result of a proposal by the FAO Director-General. It is composed of leading experts on agricultural mecanization from various FAO member countries. The Panel was formally organized on February 6, 1979 as a consultant board under the direct control of the FAO Director-General. Its main objective is to promote agricultural mechanization. Members of the Panel are appointed on a personal capacity and not as representatives of their governments nor FAO employees. Their tenure convers a four-year period each.

The initial panel meeting will be held in Nakaru, Kenya on June 24, 1979 in order to examine and advise the FAO Director-General on three main issues: a) Testing and evaluation of farm machineries in tropical countries; b) Soil preparation and soil conservation; and c) Mechanization of small farms. ■■

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Soybean Production and Processing in the Developing Countries

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NEW PRODUCTS

Iseki TX1300 Tractor

The Iseki TX Series – either the 2-wheel or 4-wheel drive versions – are versatile performers that can best suit your farming needs.

The water-cooled diesel engines are powerful, economical, reliable and durable. And they are relatively vibration-free and quiet-operating units so you can work with them for hours without undue fatigue. They start at a touch of a button, are completely waterproofed to work in wet conditions and, unlike some engines which tend to "race", they respond with precision accuracy to the throttle and are entirely safe and controllable.

[Main specifications]
Dimensions: 1,900 x 980 x 1,200 (L x W x H), Weight: 480kg, Engine: 13 ps/2,700 rpm 4-cycle 2-cylinder, Speed: 6 forward 2 reverse, PTO(1/2/3): 472/752/1,177 rpm, Implement lifting device: hydraulic 3 point, wheel tread: front 700mm rear 740·840mm.

(Iseki & Co., Ltd.: 3, Kioi-cho, Chiyoda-ku, Tokyo, 102 Japan)

The Gutbrod 22 SSFT

Dubbed as the most versatile diesel tractor with the small farmer in mind, GUTBROD of W. Germany is marketing this 22hp tractor called GUTBROD 22 DIESEL SSFT (small-scale farm tractor)

The GUTBROD 22 SSFT is different in all aspects and performances. It was tested by several machinery testing units in Africa, Asia and Europe and was especially manufactured to suit hard soil conditions, can be used for farm work, is durable and simple enough to stand up under severe operating conditions, with a minimum in maintenance and care.

A wide range of equipment is available for the tractor which includes: double mouldboard plough, reversible mouldboard plough, tiller, seeder, harrow, cutter bar, cultivator, disc harrow, trailer and fertilizer spreader.

The mechanical and technical data of GUTBROD 22 SSFT are as follows:

Engine: 2-cylinder, 4-stroke water-cooled diesel engine, 22 HP at 2,900 rpm, 743 cc, Bosch injection pump, alternator key ignition start

Transmission: 5-speed toothed-wheel transmission with 4 forward and 1 reverse speed, with differential and differential lock

Clutch: Single-disc dry clutch

Wheels: Agricultural tires, rear 7.5 L-15 AS, on turnable rims front 4.00–12 AM, with extendable axle

Steering: Automotive type worm gear steering

Hydraulic: Bosch high pressure hydraulic system

Power lift: 3-point hitch with individually adjustable upper and lower linkage

PTO: Rear transmission PTO 1,000 upm, standard 1 1/8" spline

Axles: Rear – rigid axle with sturdy axle hubs
Front – pivoted ball bearing axle, adjustable in width

Hitch: Turnable trailer coupling

Dimensions: Length – 2,025 mm, Height to seat – 900 mm, Height to steering wheel – 1,190 mm, Turning radius – 5.60 m, Weight – 610 kg

Interested parties may contact the Export Department, GUTBORD-WERKE GmbH, 6601 Saarbrücken, Bübingen, Postfach 60.

John Deere 8440 and 8640 Tractor

John Deere has introduced two new 4-wheel-drive tractors for the 1979 season. They are the 8440 with 215 engine horsepower/175 PTO horsepower and the 8640 with 275 engine/225 PTO horsepower.

The new 8640 has new pistons, rings, piston pins, rods, rod bearings and main bearings, new flange-type head bolts with increased load-bearing area, and a new turbocharger design that improves fuel economy. Both tractors boast larger radiators with more frontal area and a new dual-pressure system to minimize coolant loss, and new fans and water pumps for quieter 1800-rpm operation.

Operator comfort improvements include:

HydraCushioned™ seat suspension system with hydraulic vertical suspension and spring-dampened lateral suspension. A horizontal shock absorber reduces side-to-side motion characteristic of articulated 4-wheel-drive tractors.

A new Investigator™ warning system to monitor many critical tractor engine and power-train functions and warn of malfunctions both audibly and with indicator lights. A built-in computer logic system avoids many "false alarms" that could be triggered in an ordinary system.

Improved Sound-Gard® body with new headliner, insulated underbody, and more generous use of sound-deadening materials help seal out noise and dust.

(Deere & Company: John Deere Road, Moline, Illinois 61265, U.S.A.) ■■

NEW PUBLICATIONS

Can Japanese Agriculture Servive?
– A Historical Approach –
(Japan)

Agricultural Policy Research Center announces the publication, in August, of a new book: "Can Japanese Agriculture Survive? – A Historical Approach –" by Dr. Takekazu OGURA, President of the Agricultural Policy Research Center.

This book focuses on crucial points concerned with agricultural policy, agrarian problems, agricultural organizations, and food and agricultural policies in Japan: particularly, a historical review, analysis of the present situation, and some suggestions for the future. At the same time, Dr. OGURA makes a comprehensive survey of his past studies and deeply researches the subjects.

The main contents of this book are as follows: 1. Development of Basic Thoughts on Agricultural Policy, 2. From the Revision of the Feudal Land Tax to the Introduction of the Property Tax, 3. Vicissitudes of the Food Situation and Food Policy, 4. A Chronicle of the Agricultural, Rural and Administractive Organizations, 5. Agrarian Problems and Agricultural Policy, 6. Analysis of Agricultural Structure, 7. In Conclusion – Some Proposals on Japanese Agricultural Policy.

About 1,000 pages (18.0 cm x 25.5 cm) with 400 pages of statistics, photos and graphs and sells for ¥15,000 including postage.

Order may be placed with Agricultural Policy Research Center, Norinchukin-Yurakucho-Bldg., No. 202, 1-13-2, Yuraku-cho, Chiyoda-ku, Tokyo, 100 Japan.

The Blacksmith's Handbook
(Japan)

'The Blacksmith's Handbook' was written by the late Morio Sukigara (the ex-President of Sukigara Noki Co., Ltd., Okazaki-shi, Aichi, Japan) two times on September, 1932 and on June, 1933. This is composed of three parts for beginners, that is, methods of practical exercises for forge-welding, supplementary soldering and knowledge of cutlery, appendix. This has been appeared monthly in 'News Letter' from December, 1975 to November, 1977. Besides, this is a most valuable information translated into English.

Needless to say, our history of agricultural mechanization has developed from Blacksmith at villages, to Rural Industry and more to Agricultural Machinery Industry. It may safely be said that the development has its origin in Blacksmiths at villages. Taking this into consideration with the case in developing countries, it is most important to spread in every regions repair shops dealing with production techniques, supplementary repairing techniques, forging and so on in order to spread, operate favorably, maintain and charge agricultural machineries. In addition to these, farmers and repair shops in cooperation will bring forth designs, improvements and spreads of agricultural implements and machineries suitable for each regions. There is no doubt that the technique of forge welding should be a point of contact and play the most important part.

The book measures 21.0cm x 29.5cm, with soft cover. About 40 pages and sells for ¥2,000 (including sea mail postage).

Translated by Sumiko Enbutsu, Edited by Masayuki Kisu (Head, First Research Division, Institute of Agricultural Machinery)

FAO
Agricultural Services Bulletin 31
Rice-Husk Conversion to Energy
(Italy)

The focal point of this study is the pressing need to utilize rice husk as an energy source, especially in the developing countries. It surveys the available processes and equipment for burning rice husk for energy production, mainly inside rice mills, combined with high grade ash production and potential utilization. After reporting on studies and interviews at the principal research institutions, machinery suppliers, and companies that make use of ash, it puts forward suggestions for further research and development activities, with special emphasis on the requirements of the developing countries.

The main contents of this book are as follows:

Chapter 1: Introduction-Discussion
Chapter 2: General Energy Conversion
Considerations
Chapter 3: Physical and Chemical Characteristics of Rice Husk
Chapter 4: Use of Rice Husk as Fuel
Chapter 5: Processes Using Husk as an Energy Source
Chapter 6: Equipment and Machinery to convert Rice Husk to Energy and for Other Related Functions
Chapter 7: Conclusions

The book measures 21.5cm x 27.0cm and within its soft covers are 175 pages of useful reading.

Published by Food and Agriculture Organization of the United Nations, Via delle Terme di Caracalla, 00100 Rome, Italy.

Approved Practices in Swine Production

(U.S.A.)

The purpose of this book is to furnish a comprehensive list of activities in swine production which involve approved practices with information as to how they should be performed. An approved practice in swine production is a practice which has been tried and tested by State Agricultural Experiment Stations and/or successful farmers in the community and has been found to be desirable for the most efficient swine production. It is important that the producer know what these approved practices are and how to carry them successfully to completion.

The contents are covered under eleven chapters:
1. Opportunities in Raising Swine, 2. Selecting the Breeding Herd, 3. Managing the Breeding Herd, 4. Caring for the Brood Sow and Litter, 5. Feeding Swine, 6. Controlling Diseases and Parasites, 7. Marketing Swine, 8. Keeping and Analyzing Records, 9. Providing Housing and Equipment for Swine, 10. Butchering and Curing Pork on the Farm, 11. Essential Skills for the Swineman.

The book measures 21.0 cm x 14.0 cm and within its hard covers are 430 pages of useful reading.

Published by The Interstate Printers & Publishers, Inc., 19-27 North Jackson Street, Danville, Illinois 61832, USA.

The Grain Harvesters

(USA)

The American Society of Agricultural Engineers announces the publication of a new book, The Grain Harvesters by Graeme Quick and Wesley Buchele. From the crude tools of pre-historic North Africa to the state-of-the-art in North America, The Grain Harvesters presents a methodical trek across 5500 years of agricultural history. The 24 chapters examine the men, ideas, technology, inventions and circumstances that shaped and continue to shape the harvest.

Hundreds of illustrations – from Egyptian tomb paintings to cross-sectional drawings of rotary combines – give this 280-page, hard-bound book value as either reference or casual reading. The authors have placed the emphasis on the last 150 years of harvest mechanization, a fact that should make equipment buffs quite happy.

Quick and Buchele have opened one avenue of controversy. They dispute Cyrus McCormick's claim to the invention of the reaper. The real inventor, they state, is one Patrick Bell. They make the case for Bell a very plausible one indeed.

The price of the book is $14.88 postpaid ($16.80 in Canadian dollars) from the American Society of Agricultural Engineers, P.O. Box 410, St. Joseph, Michigan 49085, USA.

Dictionary of Agricultural and Food Engineering

(USA)

This Book is designed to fill the need for a ready reference and source of technical know-how concerning terms and information encountered in the application of engineering to agriculture and food.

Agriculture today covers the production, processing and handling of food/feed and fiber products. Authorities state that 85 per cent of the problems of agriculture involve engineering in some degree, and it is claimed that more than one-third of all the jobs in the United States are in the food and fiber industries.

In this book will be found answers to hundreds of questions encountered by agricultural and food workers. The definitions and descriptions are simple and easy to understand.

In this revised volume, many hundreds of new words have been added dealing with food engineering, forestry engineering, waste disposal, safety and the metric system. Of course, the major areas covered in the previous edition have been updated. There are definitions related to power, machinery, electric apparatus, buildings, irrigation, drainage, soil conservation, materials handling, processing, storage and drying.

This book will be of help to engineers, technicians, salespeople, managers, advertising personnel and persons with financial interests. It will serve as a valuable aid to designers of agricultural and food equipment, teachers and students, research workers, county extension directors and specialists, vocational agriculture teachers, farmers, farm equipment dealers, librarians and secretarial personnel. Workers in the foreign agricultural field who deal with world food problems will find this volume to be of great assistance.

The book measures 23.5 cm x 15.5 cm and within its hard covers are 437 pages.

Published by The Interstate printers & Publishers, Inc., 19–27 North Jackson Street, Danville, Illinois 61832, USA. ■■

A NOTE TO AMA CONTRIBUTORS

The Editorial Staff of the AMA requests contributors of articles for publication to observe the following editorial policy and guidelines in order to improve communication and to facilitate the editorial process :

Criteria for Article Selection

Priority in the selection of articles for publication is given to those that —

a. are written in the English language ;
b. are relevant to the promotion of agricultural mechanization, particularly for the developing countries ;
c. have not been previously published elsewhere, or, if previously published are supported by a copyright permission ;
d. deal with practical and adoptable innovations by small farmers with a minimum of complicated formulas, theories and schematic diagrams ;
e. have a 50 to 100 word-abstract, preferably preceding the main body of the article ;
f. are typewritten, double-spaced, about 4,000 words (approximately equivalent to 8 pages of AMA-size paper) ; and those that
g. are supported by authentic sources, reference or bibliography.

Rejected/Accepted Articles

a. As a rule, articles that are not chosen for AMA publication are not returned unless the writer(s) asks for their return and are covered with adequate postage stamps. At the earliest time possible, the writer(s) is advised whether the article is rejected or accepted.
b. When an article is accepted but requires revision/modification, the details will be indicated in the return reply from the AMA Chief Editor in which case such revision/modification must be completed and returned to AMA within three months from the date of receipt from the Editorial Staff.
c. The AMA does not pay for articles published. However, the writer(s) is given 10 free copies of the AMA issue wherein the article appears, including 50 off-prints of the article so published.

Procedure

a. Articles for publication (original and one copy) must be sent to AMA through the Cooperating Editor in the country where the article originates. (Please refer to the names and addresses of Co-operating Editors in any issue of the AMA). However, in the absence of any Co-operating Editor, the article may be sent directly to the AMA Chief Editor in Tokyo.
b. Contributors of articles for the AMA for the first time are required to attach a passport-size ID photograph (black and white print preferred) to the article. The same applies to those who have contributed articles three years earlier. In either case, ID photographs taken within the last 6 months are preferred.
c. The article must bear the writer(s) name, title/designation, office/organzation, nationality and complete mailing address.

Format/Style Guidance

a. Whether the article is a technical or popular contribution, lecture, research result, thesis or special report, the format must contain the following features :
   i) a brief and appropriate title ;
   ii) the writer(s) name, designation/title, office/organization ; and mailing address ;
   iii) an abstract following ii) above ;.
   iv) body proper (text/discussion) ;
   v) conclusion/recommendation ; and a
   vi) bibliography
b. The pages must be numbered (Arabic numeral) successively at the top center. Tables, graphs and diagrams must likewise be numbered. Table numbers must precede table titles, e. g., "Table 1. Rate of Seeding per Hectare". Such table number and title must be typed at the top, center of the table. On the other hand, graphs, diagrams, maps and photographs are considered figures in which case the captions must be indicated below the figure and preceded by number, e. g., "Figure 1. View of the Farm Buildings".
c. Tables and figures must be preceded by texts or discussions. Inclusion of such tables and figures not otherwise referred to in the text/discussion must be avoided.
d. Tables must be typed clearly without vertical lines or partitions. Horizontal lines must be drawn only to contain the sub-title heads of columns and at the bottom of the table.
e. Express measurements in the metric system and crop yields in metric tons per hectare (mt/ha) and smaller units in kilogram or gram (kg/plot or g/row).
f. Indicate by footnotes or legends any abbreviations or symbols used in tables or figures.
g. Convert national currencies in US dollars and use the later consistently.
h. Round off numbers, if possible, to one or two decimal units, e. g., 45.5kg/ha instead of 45.4762kg/ha.
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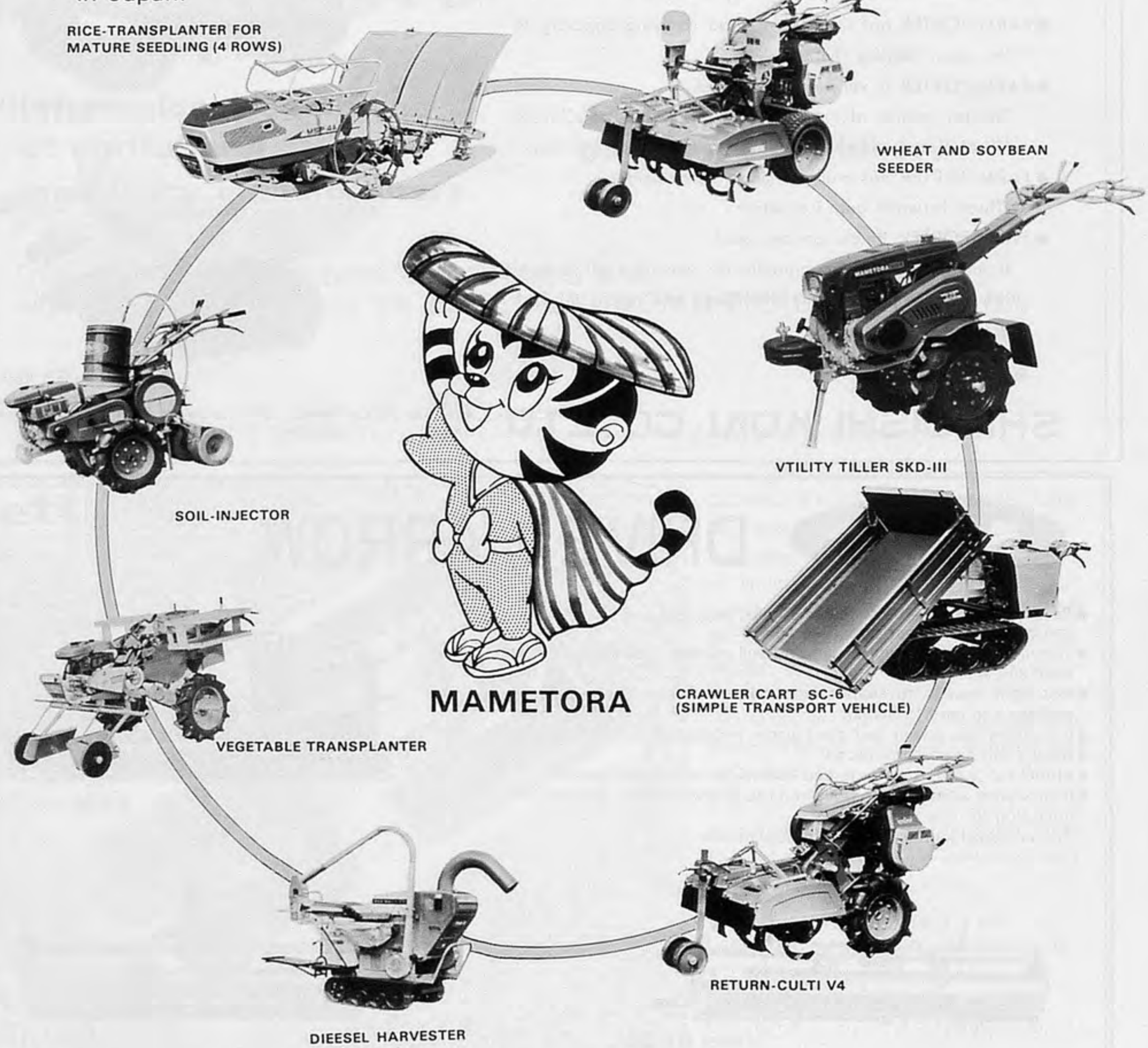
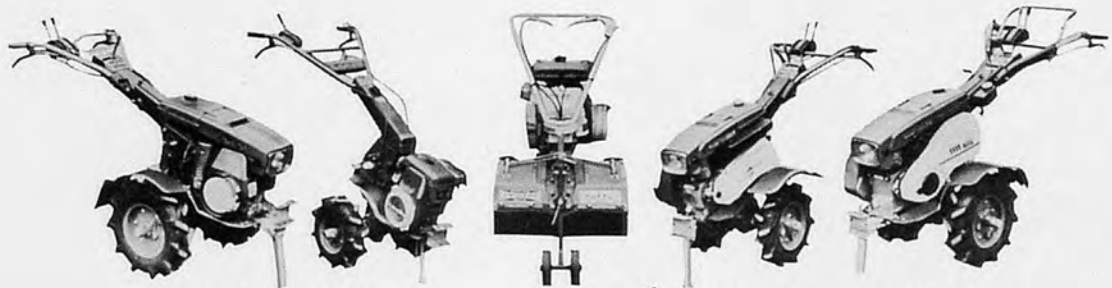
It is the motto of MAMETORA that we manufacture goods in order to meet customer's benefits with originality' trusty and hearty. In addition to the head office in Okegawa' Kisakata Factory has been established. Now that we have formed the much steadier basis as a comprehensive manufacturer. We are always making efforts to manufacture goobs of high quality and are pleased to devote ourselves to the food industry in the world as well as that in Japan.



MAMETORA AGRIC. MACHINERY CO., LTD.

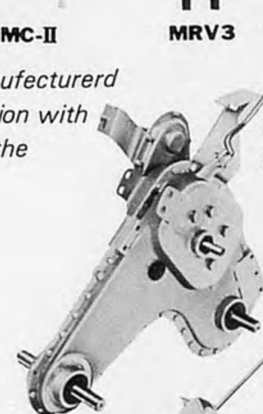
HEAD OFFICE ADD : 9-37, NISHI-2 CHOME, OKEGAWA-SHI, SAITAMA-KEN, JAPAN.
TELEPHONE : 0487-71-1181 TELEX : 2922561 MAMETO-J

CULTURE ALL OVER THE WORLD

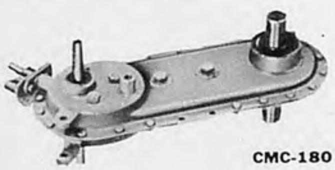


PM-350 DMC-II MRV3 SKD-II HMD-250

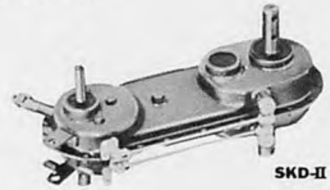
We are provided other Japanese manufacturerd with the transmission only.
We believe you can find the satisfaction with MAMETORA AGRICULTURAL MACHINERY.
We have not only the tiller but also the transmission under oder.



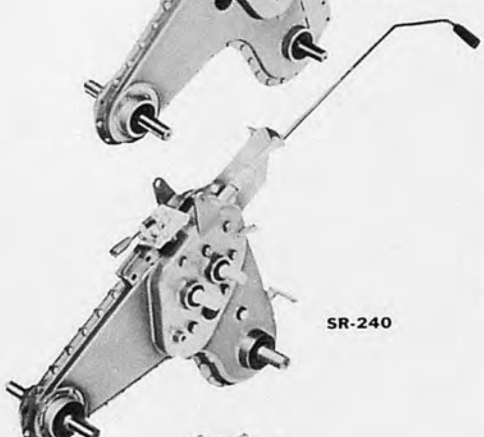
MRV3



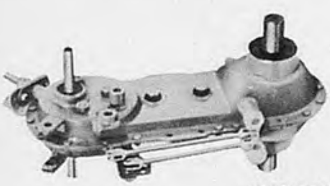
CMC-180



SKD-II

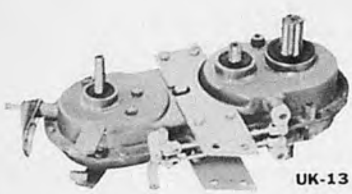


SR-240

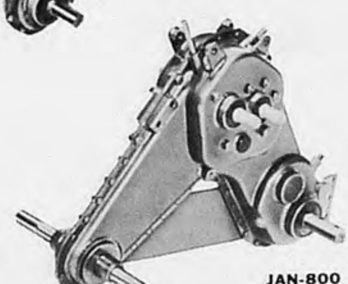


DMC-180

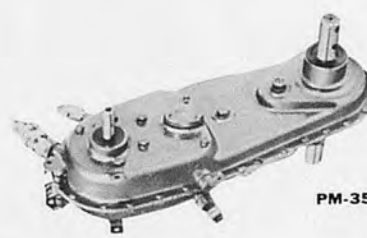
HMD-250



UK-13



JAN-800



PM-350

Model		MC-80	MCF-130K	CMC-180	DMC-180	DMC-II	SKD-18	SKD-II	SKD-III	HMD-250	PM-350	UK-13	MH-750	MT-40
Applications (PS)		1·8~2·5	2·0~3·5	3·0~4·5	3·0~4·5	3·0~4·5	3·0~4·5	4·5~6·0	4·5~6·0	5·0~7·0	6·0~8·0	3·0~4·5	3·0~4·5	3·0~4·5
Shifiting Stages		F1	F1, R1	F2, R1	F2, R1	F3, R1	F2, R1	F2, R1	F3, R1	F4, R2	F6, R2	F2, R1	F1, R2	F1, R2
Sidecluch		—	—	—	—	○	○	○	○	○	○	○	○	○ with Lock
Gear Ratios		F_1=1:21·71	F_1=1:18·16	F_1=1:25·41	F_1=1:25·41	F_1=1:41·31	F_1=1:21·21	F_1=1:31·06	F_1=1:66·07	F_1=1:70·03	F_1=1:53·97	F_1=1:32·13	F_1=1:25·54	F_1=1:37·62
			R_1=1:27·24	F_2=1:15·38	F_2=1:15·38	F_2=1:19·40	F_2=1:10·28	F_2=1:11·34	F_2=1:18·96	F_2=1:38·73	F_2=1:37·41	F_2=1:16·92	R_2=1:29·37	R_1=1:32·83
				R_1=1:35·58	R_1=1:35·58	F_3=1: 9·35	R_1=1:21·33	F_1=1:44·52	F_3=1:11·43	F_3=1:15·81	F_3=1:18·50	R_1=1:32·77	R_1=1:20·22	R_2=1:10·69
						R_1=1:49·91			R_1=1:81·09	F_4=1: 8·74	F_4=1:19·42			
										R_1 1:105·04	F_5=1:13·47			
										R_2 1:23·71	F_6=1: 6·66			
										:	R_1=1:66·67			
											R_2=1:24·0			
Dimensions	A	170	170	170	170	202	192	192	224	234	243·5	192	192	192
	B	434	434	434	435·5	532	492	492	545	578·5	603 3	467	467	467
	C	289·5	289·5	289·5	289·5	344·7	336·75	336·75	336·75	319·7	402·5	409·9	287	287
	D	15	15	15	15	16	16	17	19	19	19	16	16	16
	E	31	31	31	31	31	31	31	31	34·5	34·5	31	31	31