FARM MACHINERY

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Summary

Resources are currently available for agriculture and it's management beyond those from the human body. These resources include energy from draft animals, engines, electric motors, windmills and water wheels. Other resources are special devices such as winnowing machines and cotton gins that can perform operations at a high rate which would otherwise require slow, decide-and-manipulate sequences. Currently, electronic technology is available to achieve rapid and low-cost sensing, and decide-and-control of many phenomena in agricultural operations. The energy delivery rate of the human body is perhaps the most critical limitation for manual agriculture. Thus the first applications of external resources to agriculture are those in which non-human energy is used for the high-energy or high-energy-flow-rate operations such as transportation, water lifting, tillage, threshing or crop processing. Once high-energy-flow-rate operations can be managed with external energy resources, operations involving detail in manipulation (even though very little energy may be involved) become candidates for the applications of machines in agriculture. Some of these operations are those of seeding, planting, weeding, insect control, harvesting and crop grading.

The processes of applying mechanical resources to agricultural operations are initially focused on the objective of supplying sufficient food for the farm family, the village, the region and the country. In approaching this objective, farm machines that help bring more land into production, more water to dry-season production, provide for

accommodation of intensively-managed crops etc. are usually given priority. Once food sufficiency has been achieved, the focus of farm machinery tends to become the improvement of the efficiency of food production. In this context technologies that reduce costs, save on scarce resources, meet market demand for high-value products, reduce environmental stresses, etc. are frequently found to receive particular attention. Most applications of mechanical technologies to agriculture involve the use of capital-intensive items, both for annual inputs as well as for long-term facilities. This is one of the primary constraints on the extent to which farm machines are used. As the economy develops, the value of human resources tends to become related to the utility of these resources in off-farm economic activity. This impacts on both the physical availability of human resources for agricultural endeavors as well as the economic costs of the use of human resources in agriculture—in both cases irrespective of the situation of the farming operation. In such circumstances, farm machinery can provide the means by which full-productivity equilibrium may be maintained in concert with changed off-farm utility levels for human resources.

1. Introduction

Farm machinery refers to hand tools, animal drawn implements and power-operated equipment used for performing various field operations in the production of agricultural crops. For a machine to function, it must be provided with an input of physical work by a source of power: human, animal or mechanical power. Human labor is characterized by a limited power output counterbalanced by versatility and judgement. Animal power is of enormous importance in Asia, Africa and South America. The use of farm machinery helps to achieve improved timeliness of farm operations and efficient use of inputs such as HYV seeds, fertilizers, chemicals and irrigation water to enhance productivity of land and labor. The use of farm machinery also reduces drudgery on the farm.

Agriculture is the human management of photosynthesis-based solar energy collection and conversion processes. Historically, throughout the world, all agricultural operations were performed manually using simple hand tools. Even at present there are large areas of Sub-Saharan Africa and Latin America and limited areas in Asia where human labor is still the only power source used in field operations, especially in hilly areas. These regions practice shifting cultivation, which was prevalent many centuries ago in Europe and Asia. The shifting cultivation has a very low labor requirement per unit of output. Population growth gradually forces a reduction in the period of fallow. As population density increases, fallow is entirely eliminated, and annual cropping systems emerge. With suitable climate and the availability of water (from rainfall and/or irrigation) these systems develop into multi-cropping systems.

There are limitations on the work and operational capabilities of persons engaged in farming. These limitations are on the physical energy output rate as well as on the number of decisions that can be made with resulting manipulations. Labor input in annual or multi-cropping systems is higher than in shifting cultivation and labor input per hectare rises as cropping intensifies. The labor input increases occur because certain operations have to be performed more often and more thoroughly, i.e. land preparation and weeding and some new operations need to be performed, i.e. manuring and irrigation.

As population increases, so does pressure for intensification of agriculture. Intensification is always associated with greater requirements for labor or power or both. When demand for additional power rises above the level that the agricultural labor force is capable of providing, animal drawn implements supplement or replace hand cultivation. Similarly, when animal draft power and human labor are not capable of meeting the power demands, mechanical power sources supplement or replace these animate sources of power. The mix of power sources and machines used are determined by the demand for agricultural output, the price of agricultural produce, the supply of labor, the level of wages, the availability and cost of capital, and the cost of machine operations themselves. The cost of animal draft includes the cost of raising and training animals, and feeding and maintaining animals. The speed of adoption of animals for draft power will be influenced by the value of products like manure, meat and hides.

Tractor prices have been reported in terms of the number of kg of unhusked rice that needed to be sold to equal the average cost per kW of the rated power for a tractor (Table 1). It was found that there were great differences among data for individual countries. It is relatively easier for a Japanese, Korean or Chinese farmer to purchase a new power tiller than it is for a Nepalese farmer to do so. The effect of prices is reflected in the number of power tillers owned by farmers in these countries. In spite of very small holdings there are a large number of power tillers in Japan, Korea and China. Similarly Japanese farmers also own a very large number of four-wheel tractors. Table 1 also shows that tractor power costs in terms of unhusked rice equivalents had decreased from 1980 to 1995, with a slightly greater decrease taking place for four-wheel tractors than for two wheel tractors, although these trends vary from country to country.

Country	**Two-wheel tractors**		**Four-wheel tractors**	
	1980	**1995**	**1980**	**1995**
Japan	374	n.a.	303	n.a.
P. R. of China	701	442	564	898
Republic of Korea	539	183	662	628
Malaysia	1829	1489	2319	1327
Nepal	3444	3192	1394	2382
Philippines	1271	521	2590	2515
Sri Lanka	1541	n.a.	2316	n.a.
Thailand	1051	1775	2154	1091(used)
Median	1161	1005	1724	1209
Source: Chancellor (1997)				
n.a.: not available				

Table 1. Relative tractor prices: kg of unhusked rice per unit rated power (kW).

A particular combination of power source and machinery tends to be used for tasks for which it has the greatest comparative advantage. Thus, various combinations of power sources and machines operate side by side. FAO estimates that 52% of the cultivated land in developing countries, excluding China, is farmed with oxen, buffalo, horses and other draught animals, while 82% of the cultivated land in developed countries is farmed with tractors (Table 2).

Cultivated land farmed with	Developing countries	Developed countries
Hand labor	26	7
Draft animal power	52	11
Tractor	22	82
Cultivated land	479 million ha	644 million ha
Source: FAO (1999)		

Table 2. Percentage of the cultivated land farmed with various sources of power.

2. Trends in Farm Machinery Adoption

In order to understand recent patterns of mechanization, operations must be distinguished as those primarily dependent on the application of power and those that require primarily the control or judgement of the human mind (Table 3). Both types of operations may use either mobile or stationary power sources. Operations such as land preparation, transport, milling, grinding and threshing are energy-intensive and are mechanized first using animal draft and later using mechanical power. Seeding and harvesting of grain crops encompass intermediate levels of power and control intensity and are mechanized second. Operations like weeding, transplanting, cotton harvesting and harvesting of tree crops, fruits and vegetables are examples of control-intensive operations and are last to be mechanized.

Type of operation	High power and low control intensity	Intermediate power and control intensity	High control and low power intensity
Stationary	Grinding, milling, crushing, threshing	Sieving and grading on a size basis	Grading on a quality basis
	Water pumping		
Mobile	Land preparation	Seeding grain crops Harvesting grain and root crops	Weeding, transplanting
	Transport		Harvesting tree crops, fruits and vegetables
Source: Biswanger and Donovan (1987)			

Table 3. The power and control intensity of agricultural operations.

In industrialized countries, tractors and self-propelled machines are used for all but the most delicate operations. In developing countries farmers generally use mechanical power sources for the tedious and energy-intensive operations first. The large quantity of animal or human labor that can be saved provides a strong incentive to mechanize such operations even when labor has a low opportunity cost or fodder is abundant. Many of the power-intensive operations are performed by simple and low-cost stationary machines such as irrigation pumps and threshers. Tractors are used for power-intensive operations like tillage and transport. Generally control-intensive operations like weeding and transplanting are performed by draft animals or hand labor.

In general, the work that one person can supply to an energy-intensive task in one day is equivalent to the work that can be obtained from 1/4 liter of fuel by a diesel engine. The work that can be supplied by a large draft animal in one day is equivalent to the work that can be obtained from 8 worker-days or from 2 liters of diesel fuel. The capital costs associated with engine-powered equipment are approximately equivalent to (and in addition to) the cost of the fuel consumed. These ratios provide some basis for understanding the economic circumstances in which it becomes advantageous to substitute draft-animal or engine/motor energy for worker energy or substitute engine/motor energy for draft-animal energy in energy-intensive agricultural operations.

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Biographical Sketch

Gajendra Singh was born in a farmer's family of a small village in Bulandshahr District of Uttar Pradesh, India. He graduated in Agricultural Engineering & Technology in 1966 from the G B Pant University of Agriculture & Technology, Pantnagar in India. He received his Master's degree from

Rutgers University, New Jersey, USA in 1968 and a Ph.D. from the University of California, Davis in 1973. Prof. Singh joined the Asian institute of technology (AIT) in 1975. During 1977 to 1984, he served as Chairman of the Division of Agricultural & Food Engineering. He served on the faculty of the Rutgers University, USA from 1984 to 1986. During 1986 to 1988 he served as Vice President for Academic Affairs of AIT. He served the Indian Council of Agricultural Research (ICAR) as Deputy Director General (Engineering) from 1994 to 1997 and was responsible for the policy and the planning of Agricultural Engineering research and education at national level. He was also the in-charge of the Agricultural Research Information System (ARIS) Network of the ICAR. Prof. Singh's fields of interest are agricultural development, mechanization and soil & water management and development of management information systems for agriculture. He has published more than 70 papers on these topics in international and national journals. He is on the editorial board of four journals. Prof. Singh is a fellow of the National Academy of Agricultural Sciences (India), the American Society of Agricultural Engineers, the Indian Society of Agricultural Engineers and the Institution of Engineers (India). He is the founding President of the Asian Association for Agricultural Engineering and Executive Committee member of the Club of Bologna. He has served as a consultant to the Asian Development Bank, ICRISAT, IRRI, UNDP, FAO and the European Economic Community. He is the recipient of the 1990 American Society of Agricultural Engineer's KISHIDA INTERNATIONAL AWARD, 1991 EMIL MRAK INTERNATIONAL AWARD by the University of California, Davis and the 1994–95 GOLD MEDAL by the Indian Society of Agricultural Engineers.