AGRICULTURAL MECHANIZATION AND AUTOMATION

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Summary

The mechanization of farming practices throughout the world has revolutionized food production, enabling it to maintain pace with population growth except in some less-developed countries, most notably in Africa. Agricultural mechanization has involved the partial or full replacement of human energy and animal-powered equipment (e.g. plows, seeders and harvesters) by engine-driven equipment. Most of this is tractor driven and to a lesser extent self-propelled equipment (including harvesters, sprayers, fertilizer applicators, planters and seeders). Agricultural mechanization has been pioneered in North America and Europe and more recently in Japan, and is now spreading rapidly throughout the world. Notwithstanding such progress, a significant element of human and animal powered mechanization remains, particularly in the poorer regions of the world. The importance of enhancing and upgrading such mechanization practices prior to the almost inevitable transition to engine-driven equipment is now well recognized. Automation of agricultural mechanization is an intensive area of research and development with emphasis on enhancement of food quality, preservation of operator comfort and safety, precision application of agrochemicals, energy conservation and environmental control. Automation applications will be orientated towards and assist in the attainment of environmentally friendly and sustainable systems of agricultural and food production. However, the difficulties in matching environmental concerns and sustainability with an ever-increasing world population cannot be underestimated especially in the developing countries. Thus, there may be a tension between maximizing food production on the one hand and implementing sustainable development and environmental protection systems (e.g. erosion control) especially, in poorer regions, where the demand for increased food production follows logically from an increasing population.

1. Technology and Power

Advances in technology have been central to the dramatic progress in the mechanization of farming practices throughout the world. Of greatest importance has been the development of the internal combustion engine and its utilization in farm tractors, combine harvesters and other self-propelled agricultural machinery. Such machinery has facilitated the full or partial replacement of human- and animal-powered equipment in developed countries and increasingly in developing countries as well. The net result has been higher productivity and the welcome elimination of much of the drudgery of manual farm labor. For example, one person involved in agricultural production can now provide enough food and fiber for 128 others whereas only a century ago one person could provide food and fiber for only eight others (see also *Technology and Power in Agriculture*, EOLSS on-line). However, the social impact of the consequential rural depopulation has not been adequately addressed.

The second most important advance in technology has been the ready availability of rural electricity to power a multiplicity of items of farm equipment including lighting, heating, ventilation, milking, pumping, drying, milling, conveying and mixing. Furthermore, the automation of both mechanically and electrically powered equipment is now a dominant feature of mechanization developments in the developed regions and will inevitably impact to an increasing extent on the developing regions as labor costs increase. The rapid penetration of telecommunication and information technologies will provide a further layer of sophistication to the mechanization capability and strategies in agriculture.

All of the foregoing technological advances have been critically dependent on the availability of an abundant and economic supply of fossil fuels including diesel fuel for on-farm tractors and self-propelled machines; and natural gas, heavy fuel oil and coal for off-farm electricity generation. With a decline in fossil fuel supply (inevitable in the medium to long term) the attention will switch to renewable sources for on-farm fuel use and to renewable and/or nuclear for off-farm electricity generation. The renewable fuel that is most likely to be suitable for use in tractors and other self-propelled machines is esterified oil from oilseeds. Even though bioethanol is an outstanding renewable engine fuel, it is more suited to Otto gasoline (petrol) than to farm diesel engines. Electricity may be generated from a range of renewable sources including wind, wave, hydro and biomass, but on-farm generation is unlikely except on a small-scale or on the basis of specialized energy or wind-power farms. The projected gradual increase in the use of renewable fuels coupled with state-of-the-art advances in mechanization, such as precision farming, means that the goal of high productivity may be coupled with sustainable strategies and environmental protection. How the economics of such an approach evolve depends on the commitment of the international community to attain such sustainable and environmental goals.

1.1 Investment in Mechanization

There has been a substantial global investment in agricultural mechanization and automation by governments, industry, farmers and international agencies. In general, the return on investment has been spectacular. In North America and Europe, the combination of advanced mechanization systems, agrochemical inputs and plant breeding has produced an increase in farm production of such proportions that ultimately quotas on production had to be imposed to prevent the accumulation of massive food surpluses.

The lesson from this experience is abundantly clear. Food production can be increased if the primary producer or farmer is provided with a guaranteed profitable income for the farm produce. With such guarantees the farmer can invest in the necessary inputs including mechanization to increase productivity, secure in the knowledge that, as productivity increases, income will increase enabling payback and facilitating further investment as required.

The scale of the investment required may be determined from comprehensive data on farm mechanization costs (see also *Expenditures and Returns*, EOLSS on-line). For instance, the current cost of mechanization in the UK is about 20 % of total farm input costs (Table 1).

	1997	**1985**
Livestock inputs	23	30
Crop inputs	12	11
Labor	21	18
Power & machinery	19	18
Buildings	8	7
Rent	1	1
Interest	4	5
Miscellaneous	12	10
Total input	100	100

Table 1. Breakdown of farm input costs (UK inputs) (see also *Expenditures and Returns*, EOLSS on-line).

Provision of a guaranteed profitable income to primary producers is a powerful but expensive food policy instrument. The poorest countries that typically have the highest population growth and the greatest need to produce more food are least well placed to afford such a policy. As such, the international community and its agencies could make a huge contribution to food security by investing heavily in a program of guaranteed profitable income for farmers based on food production. Such a policy presupposes individual ownership of the land or a tenancy beneficially linked to productivity increase. State farms in centrally planned economies could also participate where beneficial tenancy arrangements can be incorporated. While such or related arrangements are being put in place, the transference of food surpluses as food aid to regions in need will continue for quite some time. Special care needs to be taken that such measures are complementary to, rather than in conflict with, local policies designed to enhance food security.

1.2 Selection and Operation of Equipment

The choice or selection of agricultural equipment is dictated by a multiplicity of factors including the nature and size of the enterprise, the profitability and access to finance, the economic status of the region, the accessibility to a range of equipment options at local level, the ownership (individual, shared or cooperative) of equipment and access to mechanization contractors. For individual farmers in the developed world, a tractor is likely to be the key item of equipment as it provides power and mobility for a wide range of mechanical farm operations including tillage, spraying, fertilizing, harvesting, milking and feeding. The size and number of tractors is dictated by the size, nature and profitability of the farming enterprise as well as by how many (if any) operations (e.g. plowing, planting, spraying, harvesting) will be serviced by local contractors. For example, the capital cost of purchasing a harvester to harvest a small area of a moderate value crop is often prohibitive. On the other hand, a contractor servicing many small growers in a local region can spread the capital cost accordingly and provide a service at an affordable price. For individual farmers who cannot afford a new and expensive item of equipment and who prefer not to depend on contractor availability, purchase of second hand equipment is an option where the support of a local finance agency may be required. Leasing of expensive equipment is also an option but generally is less popular except with larger producers.

In the developing countries, the trend towards adoption of the tractor as the fundamental unit of agricultural mechanization systems is sure to continue. However, for many small farmers in deprived regions the transition to tractor-based mechanization is not a realistic option due to the lack of finance and basic infrastructure. In this situation, a continued reliance on human energy and animal-powered equipment for tillage, planting and harvesting will prevail for the foreseeable future. As a consequence, the design and operation of such equipment requires increased investment in research and development to enhance their operational and performance characteristics (see also *Human and Animal Powered Machinery*, EOLSS on-line).

It is well recognized that the selection of equipment is only the beginning of appropriate machinery management (see also *Agricultural Equipment: Choice and Operation*, EOLSS on-line). For example, the operation of the individual pieces of equipment must be coordinated properly in order to enhance productivity and efficiency. Another trend is precision agriculture (Figure 1), where state-of-the-art control and automation technology can be used to apply the optimum amount of seeds, water, fertilizers and pesticides to maximize economic return and minimize environmental damage.

1.3 Performance of Agricultural Equipment

Maintaining working conditions and optimal performance of agricultural equipment is of vital importance in agricultural and food production due to the timeliness factor. The concept of timeliness recognizes that there is an optimum time to perform certain crop production operations from planting through to harvesting. If one or more of these operations is performed too early or too late, a timeliness penalty is likely to accrue, that is, yield and/or the quality of the crop is diminished, yielding a lower price to the farmer.

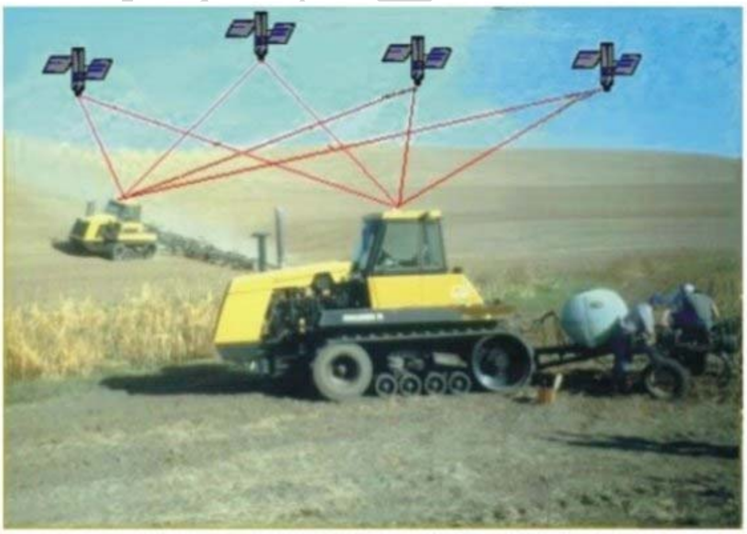

Figure 1. Precision farming relies on signals from at least four satellites to determine the position of a machine in the field. An on-board computer can change application rates or collect data on the go based on the machine position and a pre-determined data file. (Photo courtesy of the University of Idaho, Department of Biological and Agricultural Engineering.) (see also *Technology and Power in Agriculture*, EOLSS on-line).

For example, the ideal time to harvest grain is when the crop is ripe and the moisture is low (see also *Maintaining Working Conditions and Operation of Machinery*, EOLSS on-line). However, if the weather is bad and the quality of the grain is in danger, it may be more economical to protect quality by harvesting early (before ripeness) even if an increased post-harvest drying cost is incurred.

Due to the timeliness factor, machinery of a somewhat higher capacity is often employed to avoid timeliness penalties that may accrue due to the use of a contractor, machine breakdown and repair, bad weather or operator illness.

Likewise, the use of preventive maintenance protocols are desirable in the off-season e.g. replacing parts (such as bearings or soil engaging elements) that may break or wear out before they need repair or replacement.

The use of highly skilled and competent operators is also desirable to ensure optimal performance of equipment that is generally getting bigger, working faster and becoming more complex despite the welcome introduction of more automated control and ergonomic systems designed to assist and enhance performance.

The training of operatives involves a partnership between equipment users, equipment suppliers, maintenance and repair services, extension services (where available), research and educational institutions, and the communications media (farming press, radio, TV, Internet).

Farm relief services are an integral part of a back-up system where illness or other difficulties prevent a farmer from operating equipment effectively.

1.4 Human and Animal Power

There is a long history of agricultural mechanization that has been human and animal powered rather than engine powered. The difference in scale is quite staggering and is a measure of the economic gulf between the rich and the poor on this planet. For example, an average horse plowing the soil at an average rate will perform work at a rate of one horsepower (hp).

In contrast, a 100 hp (75 kW) tractor could work (e.g. plowing the soil) at a rate one hundred times faster than the horse. Thus, huge savings in labor have accrued from engine-driven mechanization systems in the developed world, which in turn have been rapidly followed by rural depopulation.

The societal impact of rural depopulation has not been adequately addressed (see also *Technology and Power in Agriculture*, EOLSS on-line).

Human and animal powered mechanization systems (Figures 2 and 3) are described in detail in *Human and Animal Powered Machinery*, EOLSS on-line.

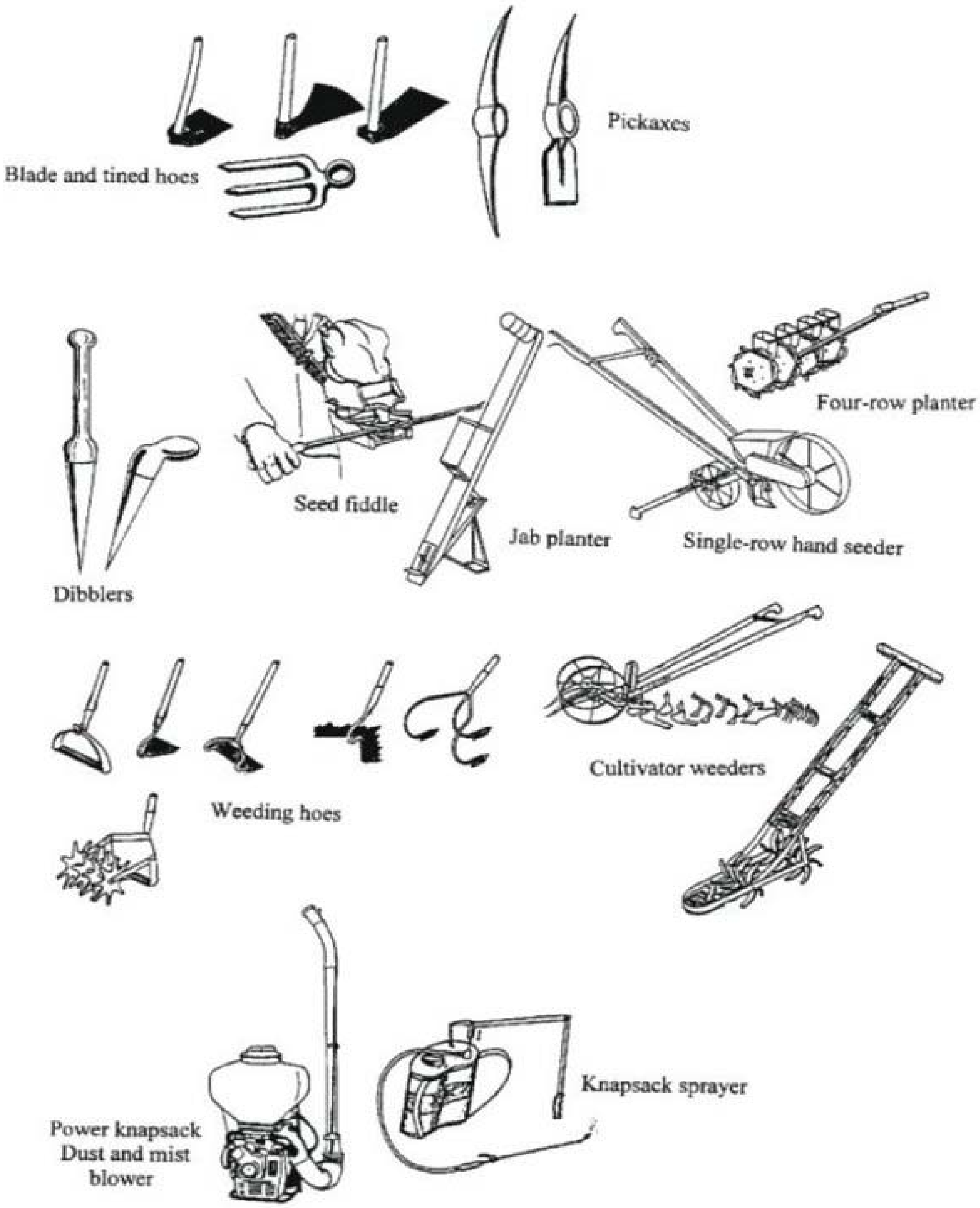

Figure 2. Human powered equipment for land preparation, planting, weeding and crop protection (see also *Human and Animal Powered Machinery*, EOLSS on-line).

The drudgery, long hours and low pay typically associated with these systems make rural life in the developing countries an unattractive career for young men and women. As a consequence, the transition to engine powered mechanization is likely to occur sooner rather than later in the poorer regions unless rural life (especially for females) can be made more attractive.

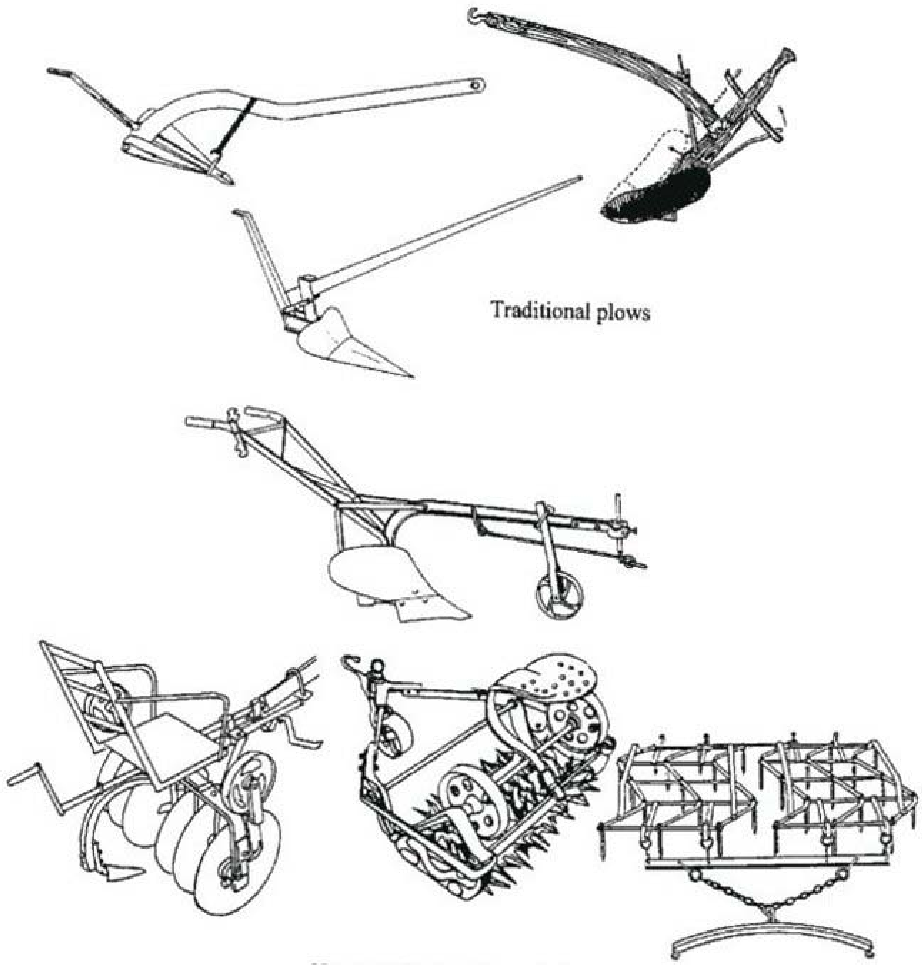

Figure 3. Equipment for tillage and harrowing with draft animal power (see also *Human and Animal Powered Machinery*, EOLSS on-line).

In the meantime, it is imperative that human and animal powered mechanization is made as efficient and attractive as possible to eliminate some of the drudgery associated with it. Substantial investment in research and development by governments, industry and international agencies is required to achieve this goal. For example, it has been proposed that state-of-the-art precision farming technologies could be integrated with animal powered mechanization to enhance land productivity through precise application of crop nutrients and environmentally sensitive tillage systems.

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Biographical Sketches

Dr Paul McNulty is Professor of Agricultural Engineering and Head of the Department of Agricultural and Food Engineering at University College Dublin, National University of Ireland since 1979. He is an authority on the physical properties of food and biological materials with particular reference to applications in food engineering and agricultural mechanization. In 1981, he received an ASAE Paper Award in recognition of authorship of a contribution to agricultural engineering literature of exceptional merit dealing with the mechanical and physical properties of grasses. He was a founder and first Chairman of the Agricultural and Food Engineering Division, Institution of Engineers of Ireland, 1977–1982. He was chairman of the Organizing Committee for the Sixth International Conference on the Mechanization of Field Experiments held in Dublin in 1984. He was appointed President of CIGR (International Commission on Agricultural Engineering) for the period 1989–1991.

Dr Patrick Grace is a Lecturer in the Department of Agricultural and Food Engineering at University College Dublin, National University of Ireland since 1983. He is an authority on grain drying with particular reference to mathematical modeling and numerical simulation in two dimensions. He has taken a particular interest in computer applications in food and environmental engineering and has employed this expertise to enrich his extensive teaching and research portfolios. He was a member of the Organizing Committee for the Eleventh (CIGR) International Congress on Agricultural Engineering held in Dublin in 1989. He co-edited the Proceedings of that Congress which were published by A.A. Balkema, Rotterdam in four volumes: Land and Water Use; Agricultural Buildings; Agricultural Mechanization; and Power, Processing and Systems.