Chapter 17

RESEARCH AND DEVELOPMENT

Over the past few decades major technical changes have occurred in the farm machinery used on Canadian farms, and these changes have had far-reaching effects on the productivity, structure, and organization of Canadian farming. The self-propelled combine and 100 HP tractor of 1969 are a far cry in sophistication and productivity from the binders and threshing machines of the twenties and thirties. What has been the source of these changes? How much do they owe to the individual farmer-inventor; how much to the research laboratories of industry, universities or government; how much to the genius of gifted inventors; how much to research carried out in other industries? Throughout the world there has been increasing emphasis on research and development. In many Canadian industries the first formal R&D units were set up within the past few years. What is the situation in the farm machinery industry? Is the industry's R&D expenditure adequate? Is an appropriate amount of the research expenditure taking place in Canada? Are Canadian governments and universities fulfilling a proper role? Does the individual farmer-inventor receive enough encouragement and protection in an age of large-scale industrial research? How does one decide on the amount of money that should be devoted to research? This chapter will attempt to answer some of these questions and in doing so will examine in some detail the role of research and development in the farm machinery area.

In assessing the significance of these R&D expenditures, three rather different considerations must be kept in mind. First, what effects do they have on the location of farm machinery manufacturing facilities? Would an increase in Canadian expenditures on research lead to a significant growth in the Canadian industry? Or is there little relation between the location of research and the location of manufacturing? In respect to these questions, does it matter whether these increased expenditures are made by industry, by government, or by universities? Second, what effect does R&D expenditure have on the pattern of competition in the industry? Do the large research programs of the major firms give them competitive advantages over smaller firms, with the result that the whole industry is made less competitive? Would additional government or university research help offset the advantage gained by the dominant firms and thus

contribute to the maintenance of a competitive industry? Third, what contribution can R&D expenditures make to improving the economic position of Canadian agriculture? Are industry research expenditures adequate for this purpose, or should they be supplemented by university and government expenditures? The first and third points will be examined in this section. The second point is considered in Part II of this Report, where the pattern of competition in the farm machinery industry is examined in some detail. Before proceeding to examine these questions, the present pattern of research expenditures on farm machinery in Canada, and to some degree throughout the world, will be outlined.[1]

The Present Pattern of Farm Machinery Research

While information on R&D expenditures on farm machinery in the past is sketchy and incomplete, evidence suggests that prior to 1945 most of the expenditures in this area were carried out by industry, and these expenditures were relatively modest in size. Massey-Harris is reported to have spent an annual average of $361,000 for research from 1925 to 1929, or about 1 per cent of sales. Despite the sharp decline in sales during the thirties, expenditures were increased to a level of $510,000. It was during this period that Massey started the research that led in a few years to their highly successful self-propelled combine. Research expenditures on farm machinery by Canadian governments or universities in this period were virtually non-existent.

In the North American industry's early history—say, prior to 1920—most of the major new developments were the result of the efforts of farmers or other individuals. In some cases, as was true of Deere and McCormick, the individual began to manufacture and sell his invention and thus formed the basis of a highly successful business. Other individuals patented their inventions and sold them or licensed them to someone else to manufacture. Rarely were these inventions completely new. Both the McCormick reaper and Deere's steel plow had been preceded by a long series of experiments on the part of many different individuals. In this early period, too, patent suits between competing companies were a common feature of the industry.

In the period between the two world wars, the inventions of individual farmers continued to be important, but the R&D expenditures of the major firms gradually increased in importance. International Harvester's success in recapturing a large share of the U.S. tractor market in the mid-twenties was based on its development of the all-purpose tractor. However, very little data are available on the size of these R&D expenditures. Brilliant individuals also made important contributions in this period, the most notable example being Harry Ferguson, who

[1] A detailed study of the subject, *Research and Development in the Farm Machinery Industry* by A. G. Vicas, was published in 1970 by the Royal Commission on Farm Machinery, Study No. 7 (Ottawa: Queen's Printer, 1970).

developed the three-point linkage which made it possible for a lighter, less expensive tractor to perform the work of a much heavier and more costly machine. Now called the Ferguson system, this development was eventually adopted by almost all manufacturers.

The postwar period has seen a rapid growth in R&D expenditures by the major manufacturing firms. The three largest firms on a worldwide basis reported expenditures in 1969 as follows: Deere & Company, $48 million–4.6 per cent of sales; International Harvester, $85 million–3.2 per cent of sales; and Massey-Ferguson, $26 million–2.5 per cent of sales. It is clear that in absolute amount these expenditures are now very large. Much of this growth has been relatively recent. Deere & Company reported that its R&D expenditures had increased almost four times between 1955 and 1965. While most of the industry's research is applied research and oriented to fairly short-term developments, within recent years the industry has begun to devote some resources to more basic research. In 1963, Deere & Company set up a basic research unit to explore some of the principles underlying the operation of farm machines. At the time the Commission visited this unit in 1967, it employed 170 people, of whom some 70 were professionally trained–17 with doctorates. Some examples of the type of research then under way were as follows: an aerodynamic study of air flows in a combine, the influence of the earth's magnetism on plant growth, and precision planting of vegetable seeds to eliminate the need for thinning. Some further data on R&D expenditures, related to all products, by each of the three major international companies are given in Table 17.1.

One survey of research and development expenditures in the United States ranked farm machinery and equipment thirteenth among the manufacturing industries in terms of the ratio of its R&D to value added.[2] However, almost half of the industries that ranked above it were heavily involved in defence or space programs, with R&D strongly supported by the federal government. If the ranking had been based on privately financed R&D expenditures, the farm machinery industry undoubtedly would have placed much higher. The farm machinery industry's total research and development expenditure was reported as $75 million in 1960. If the industry total increased at the same rate as that reported by the three major firms listed in Table 17.1, this figure would have reached $130 million by 1967. No data are available which would indicate how much of the industry expenditure in this field is research as opposed to development. Given the very limited amount of basic research carried on by the industry, it seems likely that the total program is strongly oriented to development.

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[2]N. E. Terleckyj, *Research and Development: Its Composition and Growth*, National Industrial Conference Board, New York, 1963, p. 85.

TABLE 17.1–RESEARCH AND DEVELOPMENT EXPENDITURES AS PERCENTAGE OF SALES OF ALL PRODUCTS, MAJOR FARM MACHINERY MANUFACTURERS, 1960-69

(Millions of dollars)

	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969
					(U.S. dollars)					
Deere & Company										
Net sales	511.9	561.6	572.8	688.9	816.6	886.6	1,062.1	1,086.4	1,030.5	1,043.3
R&D expenditures	22.9	21.6	25.5	27.0	n.a	39.0	42.0	46.0	49.0	48.0
Percentage of sales	4.5	3.8	4.4	3.9	n.a	4.4	4.0	4.2	4.7	4.6
					(Canadian dollars)					
Massey-Ferguson Limited										
Net sales	490.4	519.3	596.1	685.7	772.0	808.5	932.1	913.3	916.8	1,043.4
R&D expenditures	11.7	13.1	14.0	16.1	17.4	19.1	21.3	24.7	23.8	26.4
Percentage of sales	2.4	2.5	2.3	2.3	2.3	2.4	2.3	2.7	2.5	2.5
					(U.S. dollars)					
International Harvester Company										
Net sales	1,683.2	1,611.9	1,837.2	1,957.4	2,190.4	2,336.7	2,583.0	2,541.9	2,540.0	2,653.0
R&D expenditures	52.0	55.4	54.4	58.0	58.4	63.8	71.0	78.0	80.5	85.0
Percentage of sales	3.1	3.4	3.0	3.0	2.7	2.7	2.7	3.1	3.2	3.2

Note: In addition, Allis-Chalmers reported R&D expenditures of U.S. $25 million in 1961 or 5.0 per cent of total net sales; White Motor reported R&D expenditures of U.S. $9 million in 1967 or 1.2 per cent of net sales. Massey-Ferguson's R&D expenditures averaged Can. $7.6 million for the years 1957 to 1959 or 1.8 per cent of net sales.

Source: *Annual Reports* of companies.

In order to provide data on the pattern of farm machinery research in Canada the Commission surveyed the major firms in the industry, as well as universities with agricultural engineering departments. The results of this survey are summarized below.

Research and Development in Canada: The Industry

Research and development facilities in the Canadian farm machinery industry go back more than 60 years. International Harvester established an engineering department in Hamilton in 1906, and Massey-Harris set up a permanent R&D unit in 1918. Even before that time, Massey had been responsible for a number of important developments, particularly in binders and combines, and these had helped it establish its large export business. John Deere set up an experimental engineering department at its Welland works in 1948. Less is known about the old Cockshutt company, although it is clear that it had a significant research effort. Two of its more notable contributions were the "tiller combine" developed in the twenties and the continuously running power-take-off introduced shortly after the Second World War.

Although the industry's research and development activities have a long history in Canada, total expenditures are still comparatively small judged either in relation to total sales of farm machinery in Canada or in relation to the value of manufacturing shipments. In recent years R&D expenditures have been little more than 1 per cent of total industry sales and between 1 and 2 per cent of the value of manufacturing shipments (Table 17.2). In contrast, most of the major U.S. firms spend something in the range of 2.5 to 4.0 per cent of their annual sales on research and development. Further, in 1966, almost half of the industry's total expenditure in Canada, $4.7 million, was accounted for by one company, Massey-Ferguson. If Massey-Ferguson is excluded from the industry total, R&D expenditures by the industry in 1966 amounted to little more than one-half of 1 per cent of total sales. Another major firm, International Harvester of Canada, reported R&D expenditures covering their entire Canadian operation, which includes trucks and industrial equipment as well as farm machinery, at just under $2 million in 1966 or about 0.8 per cent of its annual sales. This contrasts with the average level of 2.9 per cent of sales reported by their parent company over the period 1960 to 1967. Even Massey-Ferguson, although its ratio of research expenditures to sales in 1966 was slightly higher in Canada (2.7 per cent) than in the United States (2.1 per cent) or the rest of the world (2.4 per cent), had a significantly lower ratio of R&D expenditures to manufacturing shipments in Canada than was true for the United States or all other countries. The number of people employed by the company in manufacturing and engineering is three times as large in Canada as in the United States; yet Massey-Ferguson spent only $2.6 million on research in Canada compared with $6.2 million in the United States.

When the research expenditures of the four major firms are examined, some support is given to the hypothesis that increased expenditures on research in Canada lead to a larger volume of manufacturing. In general, the data show that the larger the ratio of research expenditures to the value of manufacturing shipments in Canada, the larger the firm's total shipments.

TABLE 17.2–CURRENT EXPENDITURES ON RESEARCH AND DEVELOPMENT, FARM MACHINERY INDUSTRY, CANADA, 1955, AND 1960-66

		Ratio of Current Expenditures to:	
	Expenditures	Manufacturing Shipments	Wholesale Sales
	($'000)	(Per cent)	(Per cent)
1955	1,632	1.3	0.9
1960	3,005	1.7	1.2
1961	2,843	1.9	1.2
1962	3,202	2.0	1.1
1963	3,457	1.7	1.0
1964	4,057	1.6	1.1
1965	4,285	1.5	1.0
1966	4,702	1.4	1.0

Source: Commission survey. Data are approximate only; for earlier years, data had to be estimated for some companies, and the allocation of expenditures between farm machinery and other products was based in some instances on numbers of professional personnel.

Information on the research and development personnel employed by the Canadian companies suggests that their level of professional training is somewhat below that of comparable research units in the United States. In Canada, most professional research personnel had a bachelor's degree in engineering or its equivalent; no doctorates were reported, and there were only a very few masters' degrees. In contrast, in three U.S. companies for which data were available, 14 per cent of their research personnel had advanced degrees and 4 per cent had degrees outside the engineering field. In 1966 the Canadian industry employed the full-time equivalent of 39 professionals in a research and development capacity. In addition, there were 12 administrators with professional training, and 394 supporting personnel. Nearly all of these were in the large firms. Among the smaller firms, R&D is often carried on by people with practical experience but without professional training. For example, as of 1968, C.C.I.L. employed no graduate engineers, and Versatile employed only one. Yet both these firms have a substantial volume of production, and are continuously engaged in product development.

The industry's Canadian research has been heavily concentrated on combines in particular, and harvesting equipment in general. In 1966, combines accounted for 38 per cent of all R&D expenditures, other harvesting equipment for 28 per cent, and tillage equipment for 12 per cent.

Research and Development: The University Sector

Compared with the amount spent by private industry, R&D expenditures by Canadian universities have been very small indeed. As Table 17.3 shows, only in 1961-62 did total expenditures exceed $100,000, and in the latest year for which data are available, 1965-66, the total amounted to only $225,000–less than 5 per cent of the research effort of the Canadian farm machinery industry. More than half of this total represented a share of departmental budgets, judged to be for the support of research rather than teaching or extension. Research supported by a separate budget amounted to less than $100,000 in 1965-66, and more than half of this was at the University of Saskatchewan. Industry support to Canadian universities in the period covered was limited to one project at the University of Guelph, with an annual grant of only $2,500. In contrast, in the United States, the industry provides extensive support to university research.

TABLE 17.3 – CURRENT EXPENDITURES ON FARM MACHINERY RESEARCH AND DEVELOPMENT, CANADIAN UNIVERSITIES, SELECTED YEARS, 1949-66

(Thousands of dollars)

	Budgeted R&D	Departmental R&D	Total R&D
1949-50	3.2	16.3	19.5
1954-55	8.5	42.0	50.5
1959-60	16.8	67.0	83.8
1960-61	14.2	71.1	85.3
1961-62	19.4	82.4	101.8
1962-63	9.7	91.6	101.3
1963-64	15.8	111.3	127.1
1964-65	11.5	116.7	128.2
1965-66	95.6	129.2	224.8

Source: Data provided to the Commission by eight universities and colleges.

The Commission's survey also indicated that research in the agricultural engineering departments of Canadian universities is severely limited by the heavy teaching loads that exist in almost all universities. Teaching loads involving 14 to 16 classroom hours per week are still common, compared with six to nine hours in many other university departments. Only one university, Saskatchewan, reported that it had a policy of reducing teaching loads to support larger research commitments. The department at the University of Saskatchewan also reported the most extensive list of research projects among Canadian universities.

In its submission to the Commission, the National Committee on Agricultural Engineering expressed the view that: "The professional manpower devoted to research and development of agricultural engineering in Canada is wholly inadequate to serve the needs of the agricultural industry. Aside from the University of Guelph which has 22 engineers in a growing School of Agricultural

Engineering and the University of Saskatchewan with 18, it is doubtful whether any other organization has a sufficient number of engineers to constitute a 'reactive mass'." Only three Canadian universities offer a Ph.D. in agricultural engineering, and these programs were established only very recently. The National Committee also reported that there were currently in Canada about 50 students graduating in agricultural engineering and about 30 studying for advanced degrees.

Not only is the current research effort of Canadian universities in the farm machinery field small in comparison with private industry, it is also small compared with the research effort in American universities or in comparable institutions–for example, in West Germany. In 1966, research on farm machinery conducted in the State Agricultural Experiment stations attached to land-grant colleges and state universities in the United States amounted to $3,388 million. The comparable figure for Canadian universities is $95,600, about 2.8 per cent of the American total. Indeed, the total U.S. research expenditure on machinery related to peanuts was larger than the entire Canadian university effort. The U.S. program related to farm mechanization is discussed further in the next section.

While no complete data are available on the research programs of universities in West Germany, the Commissioner visited the agricultural engineering departments in two universities and in both cases found large well-equipped laboratory facilities and substantial research budgets. The Department of Agricultural Engineering at the University of Bonn reported a research budget of $37,500 and was currently engaged in research on sugar-beet planting, thinning, and harvesting equipment. Similarly, the Institut für Landmaschinen der Technischen Hochschule at Braunschweig reported a budget of $62,500. Basic research projects under way in this department included hay wafering, analysis of the stresses within a hay-baler, and hydrostatic transmissions. In West Germany as a whole there are four engineering-type schools with departments of agricultural engineering comparable to the one visited at Braunschweig, and seven departments associated with agricultural colleges, similar to the one visited at Bonn.

Research and Development: The Government Sector

Until very recently, support for research and development in farm machinery by Canadian governments has been almost non-existent. The Canada Department of Agriculture has for years had a small farm machinery unit, but the Department's annual reports suggest that its purpose was envisaged more as one of building research equipment for scientists in other areas than of carrying out research aimed at the development of new types of farm machinery. A survey completed in 1966 showed that, measured by professional man-years, agricultural engineers accounted for only 1.3 per cent of the Department's research staff and many of these would be engaged in research connected with irrigation, drainage, farm structures, and crop storage rather than farm machinery proper. The situation in the provinces has been little better. Before an expanded program of agricultural engineering research

was begun in 1966, the total intramural research program on farm machinery amounted to about two professional man-years at the Canada Department of Agriculture and about one professional man-year in *all* provincial departments. Indeed, the various departments of agriculture have been much more active in non-farm machinery engineering projects than in farm machinery projects.

A Special Committee on Agricultural Engineering set up by the Canadian Agricultural Services Co-ordinating Committee to study the need for more research in agricultural engineering reported the need for an expanded effort in all areas of the field. With its effort in 1965, the Committee reported, Canada was not able to even keep up with the latest developments in the United States and other countries. They also emphasized the need for training more Canadians in the field at both the graduate and post-graduate level. The Committee recommended a program of research grants beginning at $50,000 in 1966-67 and increasing by $25,000 a year for the following four years. The grant program was to be co-ordinated by a national committee and was intended to promote research and development in agricultural engineering at universities across Canada, and at Canada Department of Agriculture research stations, experimental farms, and in other similar bodies.

Although the Committee did not favour a strong central research institution, it recommended that a Technical Information and Liaison Unit be developed in the Canada Department of Agriculture whose functions would be to "provide information on agricultural engineering developments in the United States, Europe and elsewhere to maintain a technical reference file; to aid in the study and evaluation of agricultural engineering problems in any province, and to share responsibility for recommending R&D projects to solve these problems; to aid in maintaining liaison among regional centres, and especially with the agricultural engineering industry; and to prepare reports, abstracts, articles, and other publications, serving the engineering needs of the agricultural industry". The proposal called for one engineer to head the unit, a staff of five engineers and other supporting personnel, and an annual budget of about $150,000. Thus the Committee's expanded program called for an annual expenditure of around $300,000 to cover both its proposed research-grant program and its liaison and information services unit.

Even in terms of the proposed expansion the total effort appears small. Consider, for example, the situation in Britain where the National Institute of Agricultural Engineering has an annual budget of about $2 million, of which roughly three-quarters is devoted to the support of research and one-fourth is spent on testing. Thus the Institute has available a research budget about five times the size of the increased expenditure level proposed for Canada. The Institute employs about 360 people at its central station at Silsoe and about 40 at its Scottish station. About one-third of its employees are at the scientific level. Of these, some 30 per cent are basic engineers, 20 per cent are agricultural engineers, 40 per cent are agriculturalists with an interest in farm mechanization, and 10 per cent from other scientific disciplines such-as physics, botany, and mathematics.

Similar farm machinery research institutes can be found in a number of countries in Western Europe. In The Netherlands, the Institute of Agricultural Engineering and Rationalization at Wageningen engages in extensive machinery research, has a research staff of about 150 professional people and an annual budget of around $700,000. In Prague the Commission saw a well-equipped research institute that employed about 350 people and was carrying out an active program of research on machinery related to Czech agriculture. In West Germany, the government has established a machine design and development institute at Braunschweig which is pursuing a research program designed to provide more basic knowledge of all problems connected with farm machinery. Farm machinery research institutes also exist in Denmark, Sweden, Finland, and the Soviet Union.

The United States Department of Agriculture (U.S.D.A.) maintains a number of research stations which have major programs related to farm machinery. In addition, the Federal Government is a major supporter of the research carried out by the State Agricultural Experiment stations. A summary of the research effort on farm machinery by these two groups is given in Table 17.4. As these data show, total expenditures in 1966 amounted to just under $6 million, with $3.4 million of this carried out at the State Experiment stations and $2.4 million within the U.S.D.A. This program involves an estimated 165 scientist man-years. Almost one-third of the total program involves research related to fruits and vegetables. While this research program is large in absolute size, and very much larger even on a relative basis than the equivalent Canadian university and government research program, it is still small compared with the total U.S. agricultural research effort. Thus, in terms of dollars of expenditure, it is estimated that research in relation to agricultural machinery amounts to only about 1.6 per cent of the total research carried on by the U.S.D.A. and the State Agricultural Experiment stations. Measured by the number of scientists involved, the share of research related to mechanization is slightly larger, about 2.8 per cent of the estimated 6,000 scientist man-years involved in the total agricultural program.

TABLE 17.4–RESEARCH AND DEVELOPMENT SUPPORT FOR FARM MECHANIZATION, U.S. GOVERNMENT AND LAND-GRANT COLLEGES, 1966

	U.S.D.A.		State Agricultural Experiment Stations		Total	
Crop	SMY[1]	Dollars ('000)	SMY	Dollars ('000)	SMY	Dollars ('000)
Fruits and vegetables	14.7	428.5	50.3	1,470.0	65.0	1,898.5
Field crops	40.2	2,010.9	60.6	1,918.2	100.8	3,929.1
Total	54.9	2,439.4	110.9	3,388.2	165.8	5,827.6

[1] Scientist man-years.

Source: Data supplied by U.S. Department of Agriculture.

Having surveyed the present state of farm machinery research and development in Canada and compared it with the situation existing in the United States and a number of European countries, let us now consider the two basic questions raised at the start of this chapter. What contribution can research and development make to the viability and growth of the Canadian farm machinery manufacturing industry? What effect can it be expected to have on the competitive position of Canadian agriculture?

Research and Development and the Growth of Canadian Manufacturing

In recent years a number of economists have argued that a country's comparative advantage in international trade in particular products is often closely related to the level of its research effort in these products. This is particularly likely to be true for recently developed products, or products whose technology is changing rapidly. Thus the fact that the United States leads the world in the export of computers and jet aircraft undoubtedly reflects the large amount of government-supported research in a variety of related fields. If the product is still changing rapidly, the manufacturer will want to establish his production facilities close to his research and development facilities so that consultation on production problems, or problems that develop when the product is in use, can be more easily carried out. Even within a country there is some evidence that a strong R&D effort will encourage the growth of science-oriented industries near research centres. The growth of many science-oriented firms in the region surrounding Boston undoubtedly owes much to the strong R&D effort that is maintained by universities in this region. Not only are the individuals involved in these research programs available to advise firms producing science-oriented products, but many firms may be started by individuals who gained their initial knowledge working on research programs.

What application does this have to the farm machinery industry in Canada? Would an increased R&D effort on farm machinery encourage the growth of more manufacturing in Canada? There are strong reasons for believing it would. Although one executive in a medium-sized company argued before the Commission that there was no necessary relation between the location of research program and where the products developed by that program were subsequently manufactured, the whole pattern of the industry's growth in North America contradicts this assertion. Most of the research and development programs in the industry are attached to the plants manufacturing the products under investigation. Massey-Ferguson's concentration of a disproportionate amount of its North American research effort near Detroit may appear to be an exception to this pattern. But this location, too, is partially explained by factors closely related to research. It was explained to the Commission that Detroit has been a more favourable research environment for farm machinery than Brantford and Toronto because there are a number of major universities nearby (University of Michigan, Michigan State University, Ohio State University) that have large graduate programs and university

faculty engaged in research in agricultural engineering and a variety of related fields. In contrast, it is only very recently that the University of Guelph began to offer a doctor's degree in agricultural engineering. It is worth noting too, that White Motor's acquisition of the Cockshutt firm and its subsequent specialization in the production of combines was least partially explained by the fact that White needed an improved combine for its Oliver and Minneapolis-Moline product lines, and Cockshutt had a combine with a good reputation. Further, Cockshutt had just completed a major new product-development program on their combine.

The failure of any of the major firms to establish a manufacturing facility in Western Canada, despite the fact that two-thirds of the Canadian market is located in that region and the fact that production costs in the area are favourable, is another piece of evidence that points in the same direction. One of the region's handicaps has been its distance from any significant research and development effort.

This Commission was asked to recommend measures that would improve the competitive position of the Canadian manufacturing industry. It seems clear that one of the most significant steps the government could take to achieve this end would be to greatly strengthen the research and development effort on farm machinery in Canada. As will be pointed out below, there is strong reason to believe that the benefits obtained from improvements in farm machinery in the past have been very large. This suggests that future benefits could still be very substantial and would fully justify the cost of an expanded research effort.

An expansion in research effort is required at all three levels of industry, government and university. Attempts to encourage an increase in the research effort of industry alone is unlikely to be fully effective, for industrial research is likely to flourish best in the atmosphere created by an active university research effort, especially if the latter is supported by a good graduate-student program. It is in this area that Canada has fallen down most seriously in the past and it is in this area that it is still seriously deficient. Moreover, the very fact that the major portion of research and development on farm machinery has been concentrated in the industrial sector in the past has also meant that the interdisciplinary side of the program has failed to receive sufficient emphasis. Of all institutions, the university is the one that is in the best position to achieve the interrelation of different fields–of soil mechanics, plant growth, mechanical engineering, agricultural economics, and so on–that a good farm machinery research program requires. An expanded R&D effort in Canadian universities and an increased emphasis on graduate-student training would also greatly increase the supply of people with engineering and other knowledge related to farm machinery. One of the most significant features of the current Canadian picture in this field is the very limited number of people outside the industry with training and experience in farm machinery engineering. As a result, the small company or the individual farmer-inventor has no easy access to technical knowledge in the field. This cannot but handicap the growth of the small independent farm machinery manufacturer.

Universities would be expected to concentrate their research and development on the expansion of basic knowledge with respect to the behaviour and characteristics of different farm machines and their components. Particular attention should be paid to Canadian climatic and soil conditions and the machines suited to the crops grown in Canada. Private firms cannot be expected to spend an adequate amount on basic research. Their research programs are affected by the consideration that they must be able to anticipate the recovery of the cost of their research through the sale of improved farm machines to the farmer. Yet much of the benefit of their research may be shared by other firms or may be passed on to the farmer or to society in general in the form of lower farm production costs. Hence the need for public support of basic research in this area. There is also a special need for public support of research on specialty crops and products. For in these areas the market for any new improved machine is typically so small that the industry cannot afford to devote a significant amount of research funds to its development. Yet the potential benefit to society in the form of reduced production costs may often be substantial.

With an expanded research and graduate-student program at Canadian universities, what role should be envisaged for farm machinery research at the government level? The Information unit recently established in the Canada Department of Agriculture, designed to provide up-to-date information on developments in farm machinery in other countries, is a sound development.

The research and new product development programs currently taking place in industry, in government establishments, and in universities throughout the world, but especially in the United States and in Western Europe, are, in absolute size, very large. A very considerable effort is required just to keep informed on new developments and to evaluate machines and machine practices for their applicability to Canadian agriculture. However, this task can be most effectively performed if there is at least a moderate-sized research program carried out in association with it. An active involvement in research is also needed if the Agricultural Engineering Research unit which will be proposed later in this Report is to be able to effectively co-ordinate the research programs carried on in Canadian universities.

There is also need to encourage an expanded research and development program on the part of the farm machinery industry in Canada. Currently, with one exception, R&D expenditures in Canada by all the major firms are much smaller in relation to sales or manufacturing than is true for the United States. Unless there is an expansion of such activity in this country, Canada is unlikely to receive the share of North American manufacturing that her locational and competitive advantages justify. The Government of Canada has introduced over the past few years a number of programs designed to increase the research and development expenditures of Canadian industry. At the time of the Commission's hearings in late 1967 and early 1968, no farm machinery manufacturer had been able or willing to take advantage of any of these programs. In part, this reflects a weakness in the programs' conception. Discussion with farm machinery executives suggests that the

definition of "scientific research" which must be met to qualify for support under the tax- or grant-based general incentive programs is such that most of the R&D expenditures normally carried on by the farm machinery industry are excluded. Consideration will need to be given to making the definition less restrictive. In respect to the Program for the Advancement of Industrial Technology, it is less clear why the industry has not taken any advantage of it. The program is newer and it may be that firms have not yet had time to develop worthwhile proposals. But its relative failure in the farm machinery industry to date suggests that still further or different incentives will be required if a significant expansion of the industry's Canadian research effort is to take place.

Accordingly, it is recommended that the government review its requirements for research support under its general incentive programs to see whether these requirements cannot be better adapted to the kinds of research normally carried on in the farm machinery industry. It is also recommended that the Department of Industry, Trade and Commerce explore at some length with the various firms in the industry the potential application of the Program for the Advancement of Industrial Technology. However, the most important step that can be taken to increase the R&D efforts of the Canadian industry is to create a research environment in Canada that will encourage the major firms in the industry to expand their own programs. Specific recommendations to this end will be made in the next section of this chapter.

An expansion in R&D expenditures on farm machinery should do much to encourage the growth of the Canadian farm machinery manufacturing industry. However, there are other areas where the knowledge and skills needed to support the growth of Canadian manufacturing are deficient, and the Commission's attention was forcibly drawn to one of these. As part of its research program, the Commission initiated a study of farm tractor manufacturing costs.[3] To find a firm of consultants capable of carrying out a study of this kind it was necessary to go to United Sates.[4] A consulting firm with the kind of knowledge and information required to conduct such a study was simply not available in Canada. It is recommended that the Department of Industry, Trade and Commerce explore thoroughly the kinds of management consulting and advisory services available to Canadian industry, and take any steps deemed advisable to improve the range and depth of these services.

Research and Technology and the Competitive Position of Canadian Agriculture

Farm machinery is a major part of the capital used by Canadian agriculture, and the improvements in this machinery resulting from the inventions of individuals or the research and development carried on by industry, universities, and

[3]N. B. MacDonald, W. F. Barnicke, F. W. Judge, and K. E. Hansen, *Farm Tractor Production Costs: A Study in Economies of Scale*, Royal Commission on Farm Machinery, Study No. 2 (Ottawa: Queen's Printer, 1969).

[4]The firm in question has since established a Canadian office.

government, can significantly reduce the cost of agricultural production. Where improvements are widely adopted, much of the benefit from these improvements may be passed on to the consumer in the form of lower prices for food or fibre. However, to the degree that improvements are particularly suited to Canadian agriculture, a significant share of these benefits can be expected to accrue to the Canadian farmer. Thus, while the flow of new technology coming from other countries may often be adopted by Canadian farmers, these same farmers rather than Canadian consumers may be the group that has suffered most from the lack of a larger indigenous R&D effort.

TABLE 17.5–AN ESTIMATE OF THE BENEFITS OF IMPROVED FARM MACHINE TECHNOLOGY, CANADA, 1926 AND 1966

	1926	1926 adj.	1966
Improved acreage ('000)	75,175	108,154	108,154
Machinery repairs and depreciation ($'000)	72,525	104,300	550,167
Other machinery expenses ($'000)	53,370	76,800	339,074
Total machinery expenses	125,895	181,100	889,241
Total at 1961 prices ($'000)		369,000	855,000
Labour employed ('000)	1,251	1,802	544
Machinery employed–net at 1961 prices ($million)	1,068	1,540	3,011
Horses ('000)	3,361	4,850	386
Cost of maintenance of horses ($'000)		276,000	22,000
Total operation and depreciation at 1961 prices ($'000)		645,000	877,000
Return on capital invested in horses and machinery at 10 per cent ($'000)		219,000	306,000
Total operation, depreciation and capital return ($'000)		864,000	1,183,000
Estimated value of labour saved:			
at farm wages 840,000 at $2,800 = $2,352 million			
at non-farm wages 840,000 at $4,000 = $3,360 million			
Estimated net benefit annually from farm machinery technology:			
valued at farm wages $2,352 – $320[1] = $2,032 million			
valued at non-farm wages $3,360 – $320[1] = $3,040 million			

Note: "1926 adj." gives 1926 data adjusted for the increase in improved acreage from 1926 to 1966. Data on machinery depreciation and operating expenses are as given in Dominion Bureau of Statistics reports on Net Farm Income and were deflated by the price index for farm machinery and the price index of petroleum products. The cost of maintenance of horses was estimated at 3.8 acres per horse, valued at $15 per acre. Horses were valued at 1961 prices of $133 per horse. It was assumed that 418,000 of the 1,258,000 reduction in farm labour requirements was unpaid family labour.

[1] The $320 million represents the difference in total operating, depreciation and capital-return costs shown in columns 2 and 3.

Source: Commission estimates.

While no precise measurement can be made of the benefits that have resulted from improvements made to farm machinery in the past, a rough estimate of their magnitude is presented in Table 17.5. This estimate compares the position of

Canadian agriculture for the years 1926 and 1966. The estimate is based on the assumption that the reduction in labour requirements in Canadian agriculture over this period is almost entirely a result of improvements in farm machinery technology, where this technology is broadly interpreted to include improvements in materials-handling and building design for livestock, poultry, and milk production as well as field machinery. In some measure this may be an underestimate of total benefits, since the improved equipment now available has undoubtedly also been reflected in higher yields and in improved quality. For example, the farmer's ability to seed, cultivate, and harvest his crop more rapidly with the large-scale power equipment now available has allowed him to time his operations so as to obtain higher yields and avoid the deterioration in quality that often occurred with earlier methods.

Since the acreage under cultivation was much smaller in 1926, the magnitudes for labour and capital in 1926 were increased in proportion to the increase in total acreage of improved land over the 40-year period. Thus, taking the 1966 acreage of improved land as a base, a comparison is made between the 1926 levels of labour, capital, and technology and those in existence in 1966. There have, of course, been many other changes in agricultural technology over this period. These include the use of improved varieties of grains and livestock, increased inputs of fertilizer, herbicides and insecticides, and so on. Invariably these changes have been reflected in increased yields rather than reduced labour requirements. In fact, the higher yields taken by themselves would involve increased labour requirements. This, again, is a reason for supposing that the estimate in Table 17.5 underestimates the benefits of improved technology.

Using this approach, it is estimated that total labour requirements over the period declined by 1,258,000. Recent experience suggests that about one-third of this decline represents unpaid family labour. Omitting this entirely, we are still left with a decline in farm labour requirements of 840,000 between 1926 and 1966. If this labour is valued at the wages of farm labour in 1967 of $2,800 a year, it gives a gross annual benefit of $2,352 million. To arrive at an estimate of net benefits, a deduction was made for the increased operating, maintenance, and depreciation costs of the farm capital and horses in use in 1966, compared with the amount that would have been required to operate the 1966 acreage on the 1926 basis of farming. A similar deduction was made for the increased cost of providing an estimated 10 per cent return on the capital equipment and horses in use in 1966. On this basis of estimation the annual net benefit from the improvements that have occurred in farm machinery technology over the period amount to over $2 billion. If the labour saved is valued at non-farm rather than farm wages, say at $4,000 per annum, this net benefit is increased to around $3 billion. Thus it can be concluded that inprovements in farm machinery technology over this period provide a net benefit to the Canadian economy of the order of $2 to $3 billion annually.

Clearly, the benefits from past improvements in farm machinery in use in Canada have been extremely large. The improvements were derived from many

different sources. Some, such as the swather and disker, were originated by individual farmers. Others, such as the Ferguson system, were the product of brilliant inventors. Still others, such as the self-propelled combines, were produced by the research teams of the farm machinery manufacturers. Research in the automobile and other related industries has also made a contribution.

Given the large size of past benefits it seems reasonable to expect that there are still substantial benefits to be derived from further research. And given the relative neglect of farm machinery research in Canada in the past, particularly by governments and universities, one must suppose that many peculiarly Canadian problems have received little attention. But how does one decide what is a reasonable research effort?

The total research expenditure of the Canada Department of Agriculture for 1969-70 is budgeted for $41 million. Out of this total only about $425,000 is planned for expenditure on farm machinery. Yet for Canada, over the period 1926 to 1966, the benefits from improved farm machinery probably exceed the benefits from all other agricultural improvements. The size of these benefits, at $2 to $3 billion, is larger than the annual net income produced by Canadian agriculture. And the benefits from other agricultural improvements must somehow be reflected within net farm income. On this basis one might argue that half of Canada's total agricultural research effort should go towards the improvement of machinery and equipment. However, it would not be possible to reorient the total research effort to this extent except over an extended period of years. Nevertheless, it is clear that a very major reorientation is called for.

It is recommended that the Canada Department of Agriculture set as an immediate goal the allocation of 10 per cent of its research budget to supporting improvements in farm machinery, with this goal to be reached by 1980. By 1985 the allocation should be raised to 15 per cent.

Whether this goal can best be reached by simply expanding the total amount of support for research or by cutting back some existing research programs will be for the government to decide. However, the lack of rationale in some aspects of Canada's present agricultural research suggests that a major reassessment should be made of the whole program with a much more conscious attempt to relate costs to potential benefits.

In expanding its research program the Department of Agriculture will need to give careful consideration on how best to obtain a broad, long-range, balanced development of research on farm machinery. In the early years of the program, particular attention will need to be given to encouraging an expansion in the supply of graduate students by offering adequate scholarships or research assistantships. Special emphasis should be placed on an expansion of basic knowledge about farm machines, and specific provision should be made for research involving a number of different disciplines. In the immediate future, too, there may be a particular need for providing capital funds so that the universities involved can build and equip

adequate research laboratories. The Department of Agriculture should expand its own program of research on farm machinery very substantially as well. Rather than attempt to outline a detailed program of action, it is recommended that the Department set up an advisory committee with personnel drawn from the government, universities, and industry, and representing a number of different disciplines, to help it plan its expansion program. Implementation of the program recommended here could easily make Canada one of the leading countries in the world for the development of new farm machinery technology.

Chapter 18

MANAGEMENT IN THE FARM MACHINERY INDUSTRY

If generalizations are dangerous, they are doubly so in relation to management in the farm machinery industry. The wide divergence between companies–in size, number of products, and distribution methods–clearly makes an analysis of the management function in different companies a description of widely differing operations. The management operations of the giants of the industry (Massey-Ferguson, Deere, International Harvester, and Ford) are characterized by central control, with delegation of responsibility and the necessary authority to discharge it. Smaller companies are often run by one or two men who can be in the office, on the shop floor, or visiting dealers personally. The dichotomy between the different sizes of companies is striking. The large companies–including Case, the White Motor group, and Allis-Chalmers–contrast strongly in management roles and performance with the smaller firms such as Versatile Manufacturing Co., Killbery Industries Ltd., Dion Frères Inc., and McCoy-Renn Manufacturing. Each size level seems to carry a certain management type, suited to its needs.

Management performance in the Canadian farm machinery industry is important, both to the farmer and the country. The ability of any industry to compete–to develop new products that offer significant improvements over competition (whether foreign or domestic), to provide employment, and develop the profits necessary for continuing corporate existence–depends, in large measure, on the quality and effectiveness of its management. Management approaches used in this industry in Canada are substantially dependent upon the market and economic environment in which the industry operates, and on the fact that North America is regarded, by all large companies at least, as a single market. Canada, accessible on a free-trade basis to all North American farm machinery manufacturers, is looked on and managed as part of the continental market by top management. As such, the management of the Canadian subsidiary may not be required, or have the opportunity, to perform all the functions assigned to management. In the case of those companies not manufacturing in Canada, the only activities performed by Canadian management are distribution and sales; in the case of those making machines in Canada, more of the total concept of management in a manufacturing-marketing organization is evident.

For all companies manufacturing and selling farm machines, six problem areas exist. They impose strains on management skills, place a distorted emphasis on certain aspects of management at the expense of others, influence the priorities to which management resources are allocated, affect industry cost structures, and must inevitably have some bearing on the recruiting, training, and promotion of management. These problem areas are:

(1) Product Mix—The tremendous diversity of products produced and sold in the industry is a major factor affecting its management. The Commission has estimated that it can identify no less than 100 different basic machines sold by the major full-line company. Many of these are produced in a large number of models which are basically different, in that one size with its component parts cannot be substituted for another. Nearly all have many options that can be added to make the end-products diverge further. The only common denominator for all the machines sold by the farm machinery company is that they are used by the farmer. This is increasingly a customizing industry, where the individual purchase can be tailored to the individual user's requirements.

The problem diminishes in complexity as the size of the company decreases, of course. It is mainly a problem of the large company; and the larger the company, the greater the problem appears to be.

Two results of the very large product-mix are production control problems, including higher inventories, and quality control problems.

The then President of C.C.I.L., Mr. John B. Brown, when he appeared before the Commission,[1] explained the problem of predicting needed production volumes far in advance of time of sale. Both for finished machines ordered from European suppliers and for products manufactured in their own Winnipeg plant, they were locked into a schedule for the subsequent calendar year in March of the preceding year, i.e. in March 1969, they had to predict what they would sell between April and November of 1970—14 to 21 months later. While minor modifications were possible, particularly for the whole machines imported from Europe (because their requirements were such a small proportion of the total production of Deutz or Claas), their own factory in Winnipeg was largely programmed some 15 to 18 months in advance of the point of sale. In no case was the period less than 12 months. Other companies, such as Cockshutt, have confirmed the same rigid prediction of sales volumes for production scheduling far in advance of time of sale.

(2) Unpredictability of Demand—Farm machinery is characterized by very great fluctuations in year-to-year demand for the same product. While all industries face this sort of problem, the farm machinery industry suffers from both unpredictability and seasonality to an extreme degree. The farmer generally has a good deal of discretion regarding the timing of a major machinery purchase. He is,

[1] Royal Commission on Farm Machinery, Transcript of Evidence, *Hearings*, Vol. No. 34, December 13, 1967, p. 3760.

therefore, strongly influenced by his own cash and anticipated income position. As noted elsewhere in this Report, he tends to purchase a new tractor, on the basis of need, in the spring to put his crop in the ground. He delays his purchase of harvesting equipment until just before the crop is ready for harvest. If the crop is heavy, and the crop marketing prospects are good, he will buy the combine; if either or both are poor, he will make do until the following year.

A senior representative of Massey-Ferguson, Mr. J. Staiger, President of Massey-Ferguson Inc., emphasized the problem facing the industry at the public hearings, "A drought in western Canada shuts off farm machinery 'bang' like that, and you may end up with all next year's supply of certain kinds of equipment sitting there waiting for the farmer who won't buy it. This is what we mean when we say that we have to make long term commitments but our customers just don't have to."[2]

(3) Seasonality of Demand–For most farm machines, the demand is highly seasonal. As noted above, part of this is related to the demand unpredictability, but much relates to the fact that farming is a seasonal industry.

(4) Service and Repair Facilities–The timing of farming operations is often very critical, and a farmer whose equipment breaks down during a busy season may incur a serious loss of income if it cannot be repaired quickly. For this reason the farm machinery companies have had to organize facilities for supplying repair parts quickly in time of emergency, and for providing service outlets where the machinery can be repaired. As machines have become more complex and sophisticated, the problem of providing adequate service and repair parts has become more difficult, as described elsewhere in this Report. It is the critical importance of this question that helps explain the industry's shift to the franchised-dealer type of organization at the end of the Second World War, and the continuing changes that have been occurring in the number and size of dealers and in the companies' branch-house organization. The provision of a warranty on major machines, and the problems of effectively supervising it, have added to management problems. Indeed, the entire dealer organization received a great deal of supervision, with regular calls from blockmen or district managers to record inventory, assist with sales, and adjust warranty problems.

(5) Technological Obsolescence–New developments in agriculture are making accepted ways of accomplishing tasks obsolete and the pace of technical change may well be accelerating. The disker made the plow almost obsolete in the Prairies, and with remarkable rapidity. Large tractors displaced smaller machines, and the first company to offer a significantly larger tractor found a real marketing advantage, for a season or two at least, in Western Canada and the United States. Corn heads on combines have at least partially displaced corn harvesters.

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[2] *Ibid.*, Vol. No 37, January 9, 1968, pp. 4099-4100.

(6) Conservatism of the Farmer—The farmer accepts change slowly and somewhat reluctantly. While he does not refuse to adopt innovations, he will accept modest departures from his present system more readily than radical changes.

The farmer also prefers step-by-step change, simply because of the cost of capital which he would have to write off for a major replacement of all his machinery. Then, the farmer who has accepted radical innovations has sometimes been hurt by equipment that was not fully functional.

To an important degree, these various factors interact and further aggravate the management problem. New machines introduced as a result of research and development have changed the optimum size of farms, and over time have produced a strong trend towards fewer and larger farms. This not only reduces the volume available to the industry, in terms of the number of machines of any one type that can be sold, but it also may produce changes in the size and structure of the dealership system needed to service the changing farm market.

How do these factors affect management in the farm machinery industry? It can be shown that each should place a certain pressure or constraint on management, which probably encourages the recruiting of managers with certain types of personality, training, and experience. It will also reward the display of certain attributes associated with the industry.

The complexity of the product mix of the major companies is primarily the result of the diverse requirements of different types of farming in different geographical areas, and of the conventional wisdom of the industry that the heavy cost of the distribution system must be spread across as wide a product base as possible. The ideal farm, as far as the industry is concerned, is one where all machinery shows the same colour scheme—Deere's green (carried over to the green blood of its executives!), Massey-Ferguson's red and grey, International Harvester's red and white, and Cockshutt's red and cream. They must be able to provide all the farmer's needs, no matter the size or crop type. The growing number of models and different sizes may also reflect the industry's preference for non-price, as compared to price, competition.

The result has been a proliferation of models, accompanied by design and manufacturing problems created by low-volume production of designs, many of which are only slightly different from others in the same company, and which must sometimes be rushed into production to plug a marketing hole in the company's product line-up created by a rival entry. It shortens production runs to the point that one company in the United States, reporting privately to the Commission, produced 816 tractors in January 1968, 815 of which differed in specifications!

In this context, management would be selected and rewarded for its ability to develop a new product, to respond quickly to a competitor's challenge in new products, or to improvise and make do with inadequate production facilities.

If demand in any year is as unpredictable as described to the Commission, it would be hard for top management or shareholders to find fault with a market planner who did not anticipate it correctly. Since it would at times be natural to expect to have to carry over large stocks of machines from one year to the next, it would not be considered necessary, or even possible, to develop tight inventory controls. The cost of a "stock-out" in terms of a lost sale, and the loss of a future contact with a farmer who has bought a rival machine, would indicate that a high inventory was justified.

Then, too, the distribution budget of a company is developed, not on the basis of its real sales but of its anticipated sales. Branch offices, blockmen, and advertising are all planned as tools to achieve a certain sales volume. If demand falls short of prediction, the room for manoeuvre to reduce expenses is small. The closing of branch offices would exacerbate the situation; if good branch personnel were laid off, they would not be available when business eventually picked up again.

The unpredictability of demand, then, works against quick response by a company to a market decline. The company's distribution costs go on, and its products are already manufactured. Its reaction is likely to be to spend more to promote the highest level of sales possible under poorer market circumstances. This is "mini-max" strategy: if profits cannot be maximized, losses must be minimized.

The highly seasonal nature of demand reinforces its unpredictability. In Canada, 85 per cent of combines are sold in August, September, and October; 61 per cent of tractors are sold in the spring (April to June) and in October (see Table 6.1).

As a result, what the demand is going to be in any season is not known until the short selling season is over. One can compare sales of tractors in April, for example, with those of the previous year. By the time the data are available in May, however, the tractor plant in North America has been locked into a production schedule which is fixed, or largely so, at existing volumes until December. Commitments will have been made to suppliers for raw materials and parts to the extent that it will be necessary to "build out" the relatively rigid production schedule. The schedule may be stretched out over a longer period and options changed, at increased costs, but it will be difficult to change the total volume of production planned without incurring heavy obsolescence charges, in-house and at suppliers.

In May, too, the problem exists as to how to read the April sales. Was it the late spring that caused the decline; will June sales recover? Was it a regional slump only, affecting certain models in the schedule, or does the slump represent or predict an across-the-board lowering of demand? Can additional marketing action be taken to counter the effect of the slump? Can incentive programs or additional advertising make the effect less on the company than on its rivals, increasing its penetration as a percentage of the whole market?

The fifth factor affecting management is the imminent threat of technological obsolescence. For example, is the hay-baler to become obsolete with the hay-cuber or the hay-waferer? If so, how much additional development money should be spent on the hay-baler? Can much higher performance be secured from it? Or will an extensive redesign of the appearance of the machine–a "facelift"–be enough to increase sales? These are the sorts of questions which the farm machinery executive must constantly consider. Where should the always limited development resources of men and money be allocated? Where will the next breakthrough come?

The conservatism of the farmer with relation to radical new ideas will join with the existing manufacturing technology and investment to limit major new innovations. In the case of the hay-waferer, or a similar machine, it is likely that it will not be copied by a rival until it is a proven technological and market success. The risks are too great.

Emphasis in new product design will be placed on the feed-back of information from the farmer and the farm community. The disker originated on the Prairies, not from a company's development program, but from farmers' ideas developed into machines by local blacksmith shops. It was first marketed commercially not by a major machinery company, but by the newly established C.C.I.L. The Commission was told that Massey-Ferguson's pressure control was developed in the late sixties from a dormant idea which had first been used by the old Ferguson company in adapting their light tractors to move heavy aircraft engines around factories in Britain during the Second World War.

Although patent suits were prominent in the industry's early history, the industry now readily licenses its patents to its competitors, often with only a one-year lag. Undoubtedly this practice reflects one method of reducing uncertainty in an industry which faces uncertainty from a number of sources.

The management profile which emerges from this recital of the problems to be solved, and opportunities to be exploited, in the farm machinery industry emphasizes the sales executive. The availability of men who know how to reach the farmer, who have a sixth sense of what is going to happen, may well mean the difference between the success and failure of an organization.

The industry is dominated by the problems of market unpredictability and seasonality, while burdened with a production system which has to turn out products on a regular basis. The sales manager who is able to flog the merchandise may represent the difference between his company's losing its market position and beating out another rival company lacking the same sales resources.

Where will such an executive come from? It would appear that many of the senior executives in the farm machinery industry have come up through the selling side of their companies. Particularly in Canada, the production- or finance-oriented top executive is rare.

One way in which market unpredictability and seasonality may be countered is to consider a market larger than North America. Thus the Big Three of the industry produce and sell throughout the world. All wheat lands do not suffer from drought simultaneously; markets for all kinds of farm produce do not decline together; the dead winter-sales period of the northern hemisphere is offset by the concurrent summer in the southern hemisphere. Thus tractor manufacturers, manufacturing for a world market, have significant advantages over those who are limited to the North American market. Senior management in the industry tends therefore to be very mobile, both physically and in its thinking. There is always some area about which to be optimistic.

The uncertainty and fluctuation in the industry and the slow long-term growth of demand make it difficult to justify the use of new production facilities. New facilities are generally much more productive than those they replace, but how is the new production to be sold? Is there certainty that it can be sold? Given that the market for farm machinery is small and highly diversified, there may appear to be less justification for the automated technologies of modern metal-working than in other industries.

Fundamentally, much farm machinery is produced on a job-shop basis. Many factories batch their production operations to achieve lowest costs. The lowest-unit-cost machine is produced first and the highest-cost last, in order to reduce the inventory-holding costs of finished goods. If the year's supply of manure spreaders is produced, however, in November and December of the previous year, the company is "locked in" to a volume which must be sold to avoid accepting an unbudgeted loss. In the same way, it cannot sell more of a product than has been made, no matter how much greater the demand.

Another method used by the farm machinery companies to reduce their risk has been the development of interest-free floor-planning in the hands of the dealer. The dealer is encouraged in this way to buy, and stock on his premises, finished farm machines. Although he owns them and is obliged eventually to pay for them if they are not sold, his first payment may not be due for from 12 to 23 months. And where adverse circumstances cause sales to fall sharply, the company may make special arrangements to extend further credit, so the dealer's inventory can be carried for a further period. To some degree, however, the risk attached to holding large inventories has been passed on to the dealer.

As was shown elsewhere in the Report, major companies are reluctant to make price cuts, because they can rarely expect the increase in sales volume necessary to make such a price cut profitable. At times, an alternative to price cuts may be increased expenditure on promotional devices. Since this does not permanently depress price levels, it is more acceptable to the companies, and may result in less loss of profits in a difficult period than either the maintenance of higher prices or outright price reductions.

The farm machinery industry will, therefore, tend to attract managers oriented towards sales activities. Its production operations must be organized so that they are as flexible as possible. Production costs will be less critical than production flexibility. Designs will be often secured from outside sources rather than from within the company (although this is changing for some of the larger companies), and copying competitors' designs appears to be the recognized way of expending product lines to meet new developments.[3] Efforts spent on selling machines already produced will be more profitable than the almost impossible task of trying to match production to a largely unpredictable market.

Farm machinery industry managers will, therefore, tend to be conservative, cautious in their forecasts, and careful in their investments. The high average age of machine tools in the industry[4] indicates the reluctance of managers to invest in high-risk situations. While all metal-working industries reported only 23 per cent of their machine tools to be older than 20 years, the farm machinery industry reported 41 per cent of its equipment in this category. As well, it may indicate the fact that machine tools have become capable of producing higher volumes than the farm machinery industry can absorb.

Within the general pattern of management, variety does exist. There are very large companies like Deere & Company and Massey-Ferguson Limited, along with relatively small specialty producers–ranging, in Canada, from Golden Arrow Manufacturing Limited of Calgary, Alberta (largely producing sprayers) to the new Thomas Equipment Ltd. of Centreville, New Brunswick, concentrating on potato-harvesting equipment capable of discriminating between potatoes and stones.

Massey-Ferguson's management problems over the years have been recorded by Neufeld in *A Global Corporation.*[5] While the extensive difficulties encountered in its growth to a world corporation do not need to be repeated here, its management difficulties, dead ends, and triumphs make fascinating reading. It is hard not to conclude that part of its problems after the Second World War stemmed from its being a farm machinery company. Its growth to world stature and solid viability required extensive management inputs from outside the farm machinery industry. It is at least possible that it would not be in its present strong position if it had not, more or less accidentally, expanded into overseas markets under the pressure of tariffs relating to foreign markets into which it had penetrated. One senses that a number of key decisions were made–the merger with Ferguson, and the acquisition of Perkins' engine and Standard Motors' tractor facilities–without a clear appreciation at the time of how important they were to be in the longer-run growth of the company.

These large companies vary in management resources and sophistication from one to another, and within their own organizations. Deere & Company has

[3]White Motor's and Deere's four-wheel-drive tractors with centre-articulated steering appear to be functionally identical to the Versatile concept.

[4]D. Schwartzman, *Oligopoly in the Farm Machinery Industry,* Royal Commission on Farm Machinery, Study No. 12 (Ottawa: Information Canada, 1970), Table 7.8.

[5]E. P. Neufeld, *A Global Corporation,* University of Toronto Press, 1969.

consistently had a high earnings record for the industry. As shown elsewhere, it appears to be the price leader and to be able to price somewhat above the levels of its rivals for comparable models. Its consistent ability to market its products at higher prices indicates a management which has been successful in meeting the problems of the industry. Its continued record of highest pre-tax earnings among the major farm machinery companies also emphasizes this fact.

Although smaller in size, J. I. Case has been able to adjust successfully to the changes in the industry. After nearly going under in the early sixties, new management proceeded to pull it out of its difficulties, concentrating on product improvement and dealer development.

The most spectacular growth of all companies in the farm machinery industry in North America has probably been that of Versatile Manufacturing Ltd. This company was started as a two-man organization, concentrating on low overheads and low distribution costs, specializing in a narrow range of machines with a limited series of options. Its growth to a significant factor in the industry—to the point that it became the leading producer of swathers—indicates that the industry as a whole is still responsive to new approaches.

The many smaller companies represent, in many cases, one- or two-man shops. The farmer-blacksmith-inventor designs a better machine, peculiarly adapted to a certain situation. An example of invention to meet a local requirement is the Morris rod weeder. Machines are built and sold; modifications to designs are made; but most of the management decisions are informally made by a single man only. As long as specialty machines are built, for particular crops or local conditions, the small companies will flourish, because they have flexibility and low overheads which are not available to the giants of the industry.

The way in which the farm machinery industry is managed is of interest to the farmer. At the one end of the size spectrum, he sees a small group of industrial giants; at the other, local organizations making special-purpose equipment. To the extent that large firms concentrate their management talents on selling, deeming it relatively more important than production and cost control, the farmer may have to pay relatively more for his farm machine, or receive poorer service, than he would in the case of another industry that was able to balance its efforts.

At times in the past, the farm machinery industry has marketed machines that were not fully tested for the situations in which they were used; its quality control functions have proved in certain cases to be less than adequate. Some of its production centres are obsolete, too small, or both; and its production control system is still unable to cope with the fluctuations of a volatile and uncertain market. Having to concentrate much of its managerial resources on selling may prevent it from improving in these other areas. The heavy emphasis on selling diverts management resources from other areas where, from the viewpoint of the farmer, they might be better employed in improving the design and quality of the machine, and in reducing its cost of manufacture.

Chapter 19

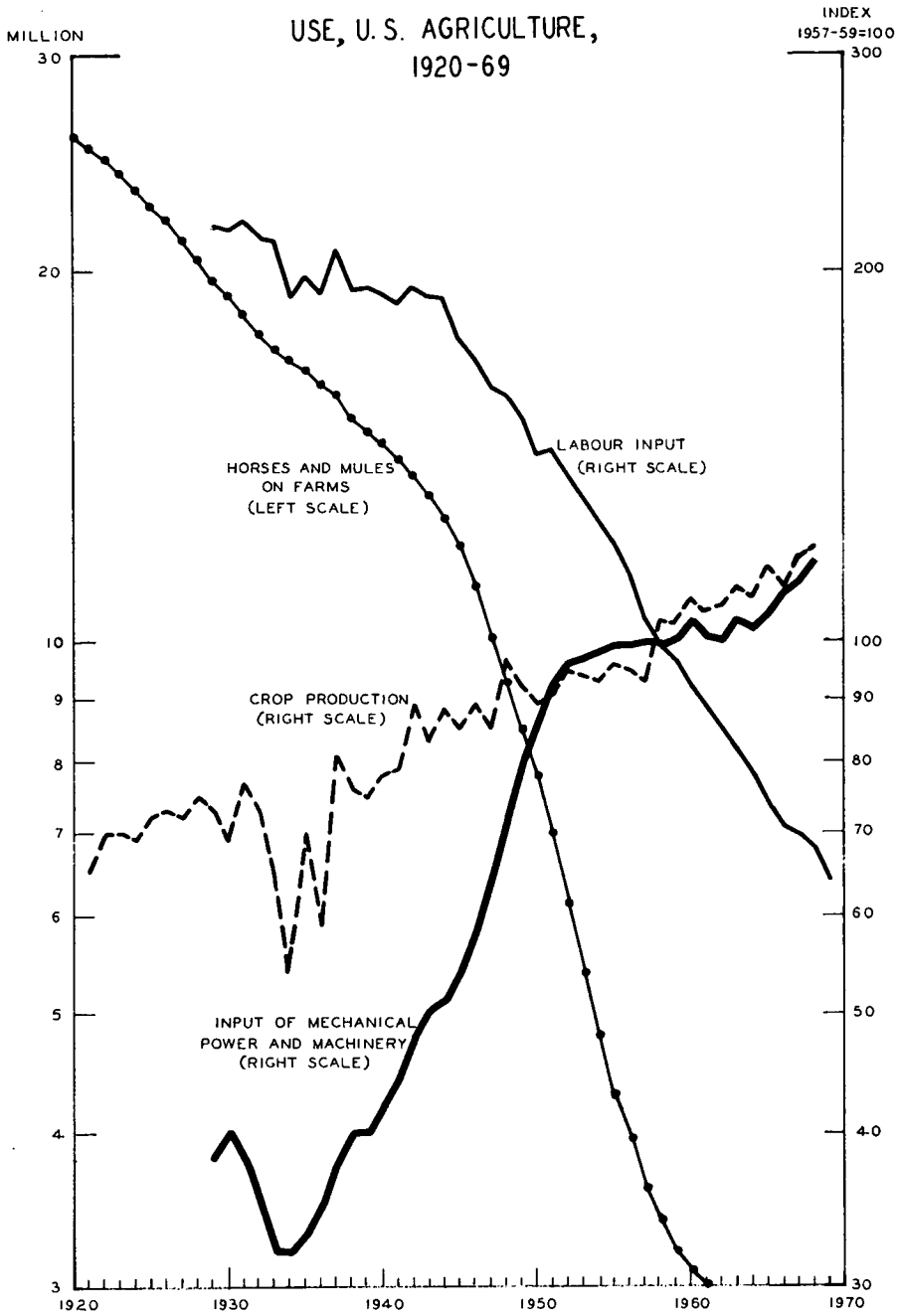
THE FUTURE MARKETS FOR FARM MACHINERY

This chapter examines the market demand for farm machinery. In analyzing this market it is useful to divide the world into three major areas–Western Europe, North America, and the rest of the world. The latter area can, in turn, be divided into the Communist-bloc countries, the developing countries, and a few other advanced countries such as Australia, New Zealand, and South Africa. Because these latter markets are relatively small and very distant from Canada they have been neglected here. The market for farm machinery in the Communist-bloc countries, especially Russia and Eastern Europe, is important, and these countries are also potential suppliers of farm machinery to the West. Up to the present, however, there has been relatively little trade in farm machinery between these countries and the western world. Since there is no accurate way to assess the future potential of this trade, these have been neglected in this chapter also. Accordingly, the topic will be treated under three major headings–Western Europe, North America, and the Developing Countries.

Before proceeding to an analysis of each of these markets it will be useful to consider briefly some of the characteristics of the demand for farm machinery and the changes that have occurred in this demand over the past few decades. When the principal tools used by a farmer were a hoe, spade, sickle, and flail, his requirements for farm machinery were comparatively simple. However, with the introduction of domesticated animals (the horse, the mule, and the ox), more sophisticated implements began to appear–first the plow and reaper, and later the binder, the thresher and a range of seeding, cultivating and harvesting equipment. With the development of the tractor, animal power gradually disappeared, and with a continued flow of new inventions, farming became more and more fully mechanized.

In North America the tractor first came into extensive use in the twenties and thirties, but it was not until the war and early postwar years that farming became almost completely a tractor operation. The result of this shift from animal power to machine power has been a significant increase in the total farm demand for machinery. This structural change is evident in Figure 19.1 where a strong upward

FIGURE 19.1-FACTORS AFFECTING MACHINERY USE, U. S. AGRICULTURE, 1920-69



trend in the input of mechanical power and machinery can be seen between 1929 and 1952, a period that pretty well coincides with the demise of the horse and mule as a feature of American agriculture. Since 1952, the input of mechanical power and machinery has paralleled fairly closely an index of crop production. This reflects the fact that farm machinery is still predominantly oriented to use in the production of field crops rather than livestock or livestock products.

The upward trend in the use of machinery also has its counterpart in the decline in the use of farm labour. In the United States this decline has taken place at a rapid and remarkably steady rate throughout the period since 1944. By 1969 the labour input into U.S. agriculture was only about one-third of its amount in 1944. This reflects both a decline in the farm labour force and reduction in hours worked per week. As is described elsewhere in this Report (see Chapter 23), labour has been both pulled and pushed off the farm. It has been pulled off by the attractions of wages and employment opportunities in non-farm activities; it has been pushed off by the continuous flow of technological change in farm machinery which has steadily reduced labour requirements in agriculture despite continued growth in farm output.

Developments in Canadian agriculture over the past few decades have been broadly similar to those in the United States. Thus, as is evident from Figure 19.2, the same upward shift in the use of farm machinery relative to the volume of field crop production has occurred in the postwar period. This corresponds pretty well to the "tractorization" of Canadian farms. Its counterpart was the precipitous decline in the number of horses on farms from about 1943 onwards. Also evident is the rapid decline in the farm labour force.

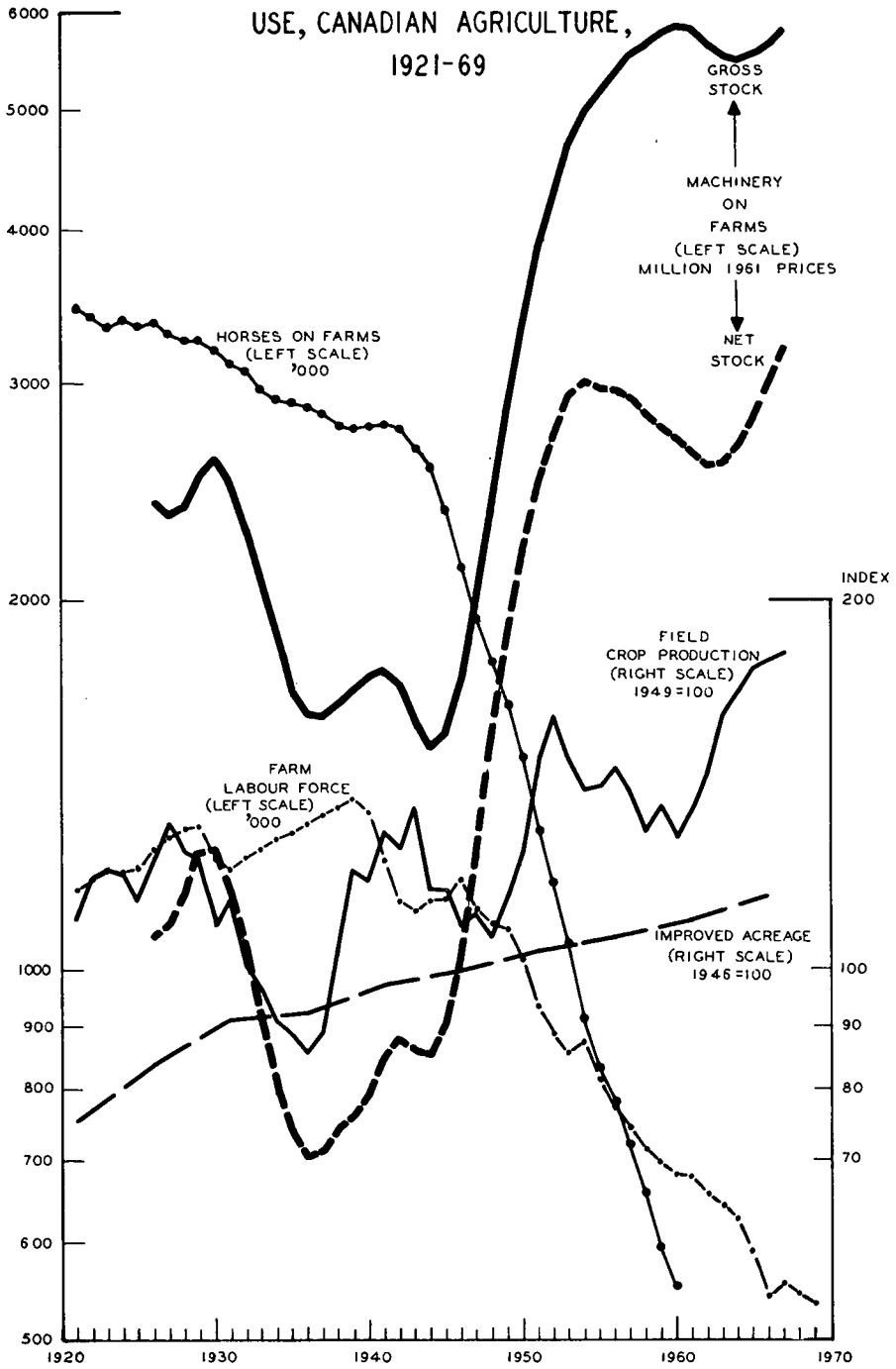
A significant part of the increase in the stock of machinery and equipment on farms, shown in Figure 19.2, represents trucks and a share of passenger cars considered to be used for farm purposes, rather than farm machinery in the conventional sense. Thus, as the data in Table 19.1 show, by 1966 about $11.60 of

TABLE 19.1–GROSS STOCK OF MACHINERY AND EQUIPMENT ON CANADIAN FARMS, PER FARM AND PER IMPROVED ACRE, SELECTED YEARS, 1926-66 (1961 PRICES)

	Including Trucks and Share of Passenger Cars		Excluding Trucks and Passenger Cars
	Per Farm	Per Improved Acre	Per Improved Acre
1926		$30.60	$27.70
1931	$ 3,440	29.20	24.10
1941	2,410	19.20	15.30
1951	6,130	39.50	32.30
1956	9,350	53.50	41.30
1961	12,100	56.30	44.80
1966	13,150	52.40	40.80

Source: Commission estimates.

FIGURE 19.2-FACTORS AFFECTING MACHINERY USE, CANADIAN AGRICULTURE, 1921-69



the total investment per improved acre on Canadian farms consisted of farm trucks and the farm-purpose share of passenger cars. However, when cars and trucks are excluded, there is still a significant upward shift in investment in machinery and equipment per improved acre. The gross stock in use on this basis increased from $27.70 per acre in 1926 to $44.80 in 1961 and $40.80 in 1966.

Undoubtedly, part of this increased stock of machinery and equipment in use on Canadian farms simply represents the effects of the replacement of the horse by the tractor. Another factor has been the mechanization of an increased range of farming activities; haying, for example, is now almost completely mechanized. This mechanization has been induced by the scarcity and increasing cost of farm labour. It has also resulted from the effects of technological progress in farm machinery, which has had a strong labour-saving effect. An additional source of this increased demand for, and use of, farm machinery has been the desire on the part of the farmer to eliminate much of the back-breaking labour formerly associated with farm activities and the related demand for increased comfort. Hence the demand for grain augers to move grain, front-end loaders for lifting and loading, and tractor cabs and improved seats for greater comfort.

Any explanation of the increased demand for farm machinery that has occurred in various countries must take some account of all these considerations. The emphasis above has been on changes in the stock of machinery in use on farms. Annual purchases of machinery produce the net and gross changes in this stock. Because machinery is durable and older machinery can often be used for several more years, annual expenditures on machinery may fluctuate markedly from year to year, depending on the farmer's net income position, his income prospects in future years, the availability of credit and the price of machinery. The effects of all these factors will be evident in the discussion of the three major areas which follows.

The Market for Farm Machinery in Western Europe

At the end of the Second World War farm mechanization in Western Europe was less advanced than in North America, but since that time it has advanced rapidly.[1] This can be seen from the data in Table 19.2 which show the worldwide distribution of farm tractors for a period of several years after the war and in 1966. Thus by 1966 the number of tractors in use in Western Europe had increased almost threefold over the level of 1952-56, and was beginning to approach the number on North American farms. In this same period the number on American farms increased by only 13 per cent. Large percentage increases were also shown during this period in Asia, Latin America, and in Eastern Europe and the U.S.S.R.

Because of its intensive agriculture, Western Europe has now achieved a high level of tractor use per unit of land. However, relative to the farm labour force, the

[1] For a full discussion of this market for farm machinery, see H. G. Scott and D. J. Smyth, *Demand for Farm Machinery—Western Europe*, Royal Commission on Farm Machinery, Study No. 9 (Ottawa: Queen's Printer, 1970).

use of tractors is still far below the level prevailing in North America and in Australia and New Zealand (see Table 19.3). In Eastern Europe and the U.S.S.R. the use of tractors in relation to both land and labour is well below levels prevailing in either Western Europe or North America.

TABLE 19.2–TRACTORS ON FARMS, BY MAJOR AREAS OF THE WORLD, 1952-56 AND 1966

	Average 1952-56	1966	Increase 1952-56 to 1966
	(Thousands)		(Per cent)
Western Europe	1,580	4,536	187
Eastern Europe and U.S.S.R.	957	2,368	147
North America	4,793	5,425	13
Latin America	199	512	157
Asia	85	251	195
Africa	58	103	77
Oceania	249	406	63
World Total	8,006	13,812	73

Note: Data for Asia exclude China and Israel. Data for Africa exclude South Africa. The world total includes Israel and South Africa, but excludes China.
Source: H. G. Scott and D. J. Smyth, *Demand for Farm Machinery–Western Europe*, Royal Commission on Farm Machinery, Study No. 9 (Ottawa: Queen's Printer, 1970), Table 2.1.

TABLE 19.3–TRACTOR USE PER UNIT OF LAND (1954 AND 1966) AND LABOUR (1954 AND 1964), BY REGION

	Tractors per 1,000 Hectares of Arable Land		Tractors per 100 Farm Workers	
	1954	1966	1954	1964
Western Europe	16	44	5	17
Eastern Europe and U.S.S.R.	3	8	2	7
North America	21	24	67	90
Latin America	2	5	n.a.	n.a.
Australia and New Zealand	7	10	41	66

Source: H. G. Scott and D. J. Smyth, *Demand for Farm Machinery–Western Europe*, Royal Commission on Farm Machinery, Study No. 9 (Ottawa: Queen's Printer, 1970), Tables 2.2 and 2.3.

Data on the world use of combine harvesters is less complete than for tractors, but the data available indicate that Western Europe has a smaller share of the world total of combines than of tractors, and has less in absolute numbers than North America or Eastern Europe and the U.S.S.R. However, measured in terms of cereal production and the amount of land devoted to cereals, the use of combines in Western Europe is only moderately lower than in North America and is much higher than in the U.S.S.R. This is evident from the data given in Table 19.4. The

lesser use of combines in Western Europe may reflect in part the smaller farms which are less suited to the use of combine harvesters. The increased use of combines over the postwar period in Western Europe has been particularly strong, thus making the region an important source of demand for this machine. By 1954, North America had more or less reached a replacement level for this machine although an upgrading in the size and quality of combines in use has been occurring there since that date.

TABLE 19.4–TOTAL COMBINE HARVESTERS IN USE, BY REGION, RELATIVE TO CEREAL CULTIVATION AND PRODUCTION, 1954 AND 1964

	Combines in Use		Combines in Use in 1964	
	1954	1964	Per 1,000 Hectares of Cereal Acreage	Per 1,000 Tons of Output
	(Thousands)			
Western Europe	90	420	11	4.5
Eastern Europe and U.S.S.R.	350	600	4[1]	3[1]
North America	1,100	1,160	14.5	5.5
Oceania		70	8	6

[1]Data are for U.S.S.R. only.

Source: H. G. Scott and D. J. Smyth, *Demand for Farm Machinery–Western Europe*, Royal Commission on Farm Machinery, Study No. 9 (Ottawa: Queen's Printer, 1970), Tables 2.4 and 2.6.

Absorption is defined as the value of production, plus imports and less exports. On this basis, the absorption of agricultural machinery in Western Europe had reached about 2.6 billion U.S. dollars by 1965, about $1 billion less than its level in North America. In relation to agricultural employment, absorption in Western Europe is still very much lower than it is in North America. This is evident from the following data:

Absorption of Agricultural Machinery per Farm Worker, 1964-65

(U.S. dollars)

	Tractors	Other Machinery	Total
Western Europe	49	66	115
North America	270	380	650

Thus in 1964-65 the annual purchase of farm machinery in Western Europe amounted to only about $115 per farm worker compared with $650 in North America. Data are at factory prices. On the other hand, in relation to total arable land, annual absorption of farm machinery is higher in Western Europe, amounting in 1964-65 to about $27 per hectare compared with just $16 per hectare in North America.

Within Western Europe, there is a decided contrast in respect to the extent of farm mechanization between the industrialized countries of Northwestern Europe, with their comparatively high per capita incomes, and the poorer and less industrialized countries of Southwestern Europe. Southwestern Europe is taken here as Greece, Italy, Portugal, and Spain, although Italy has some of the characteristics of both regions. Northwestern Europe has little more than half the total arable land and little less than half the agricultural labour force of the two areas; yet it dominates the use of, and demand for, farm machinery. This is clearly evident from the data in Table 19.5.

TABLE 19.5–FARM MACHINERY USED (1966) AND ABSORBED (1965), WESTERN EUROPE, BY REGION AND MAJOR COUNTRY

	Used (1966)		Absorbed (1965)	
	Tractors	Combines	Tractors	Other Machinery
	(Thousands)		(Millions of U.S. dollars)	
Western Europe	4,453	498	1,100	1,500
Northwestern Europe	3,760	460	900	1,300
Southwestern Europe	693	38	200	200
France	1,051	109	250	313
West Germany	1,215	142	344	492
Britain	455	65	134	139
Italy	461	14	126	147

Source: From H. G. Scott and D. J. Smyth, *Demand for Farm Machinery–Western Europe*, Royal Commission on Farm Machinery, Study No. 9 (Ottawa: Queen's Printer, 1970), Table 2.9.

Other measures as well indicate the much more advanced state of mechanization in Northwestern Europe. Thus the tractor horsepower in use per person employed (1966) at 10.6 is almost five times as high as the level of 2.2 for Southwestern Europe. Again tractor horsepower per 100 hectares of arable land at 226 in Northwestern Europe is about four times as high as the 57 HP for Southwestern Europe. Similarly, Northwestern Europe has 19 combines per 1,000 hectares of cereal acreage compared with just 2 in Southwestern Europe.

There are also significant variations in the extent to which tractors and combines are used among the major countries. Thus, as the following data show, Britain uses more tractor horsepower per employee than either West Germany or France; yet West Germany uses more tractor horsepower and more combines in relation to her land area.[2]

[2] *Ibid.*, Tables 2.10 and A.9.

	Tractor Horsepower		
	Per Farm Worker	Per 100 Hectares of Arable Land	Combines in Use per 1,000 Hectares Of Cereal Acreage
Northwestern Europe	10.6	226	18.5
Southwestern Europe	2.2	57	2.3
France	9.5	161	12.0
Germany, Federal Republic	9.7	340	29.0
Britain	21.2	250	17.0
Italy	3.6	110	2.5

Since 1950 Western Europe has undergone rapid mechanization. However, the rate of growth in machine utilization has varied widely among different countries. In Britain and Sweden, mechanization was already well advanced by 1950, and subsequent progress as a consequence has been slow. Some countries like West Germany, Belgium and Denmark underwent rapid mechanization in the early 1950s and slowed down later. Others like Spain started with very little machinery but in the past few years have experienced rapid growth.

At the beginning of the period, Southwestern Europe was virtually unmechanized. By 1966 it had attained the level of Northwestern Europe in the early 1950s. However, over the period, most of the growth in both tractors and combines has been in Northwestern Europe. Because it started from such a low use level, even rapid growth in Southwestern Europe did not bulk large in absolute terms. This is evident from the data in Table 19.6.

TABLE 19.6–MECHANIZATION OF AGRICULTURE IN EUROPE, 1950-66

	1950	1956	1960	1966
	(Millions of horsepower)			
Tractor Horsepower in Use				
Western Europe	22.1	52.5	75.8	139.5
Northwestern Europe	19.8	46.0	66.0	114.3
Southwestern Europe	2.3	6.5	9.3	25.1
	(Thousands)			
Combine Harvesters in Use				
Western Europe	29	110	239	498
Northwestern Europe	28	107	228	460
Southwestern Europe	1	4	11	38

Source: H. G. Scott and D.J. Smyth, *Demand for Farm Machinery–Western Europe,* Royal Commission on Farm Machinery, Study No. 9 (Ottawa: Queen's Printer, 1970), Tables 2.11 and 2.12.

Related to the demand for farm machinery in Western Europe have been the changes in the pattern of use of other resources–in particular, land, fertilizer, labour, and animal power. Consider each of these in turn. Over the period examined there has been very little change in the total stock of arable land and in the amount

used for cereal cultivation. The same is true for both major areas in respect to arable land. Land under cereal cultivation declined by about two million hectares in southern countries and increased by about the same amount in the Northwest. However, there was a major increase in the use of fertilizer over this period—from six million tons in 1954-55 to 13 million tons in 1964-65—mainly in the Northwest. It consumed 83 per cent of the total in the latter year.

Employment in agriculture has declined rapidly in both areas—more rapidly between 1950 and 1960 in the Northwest, but swifter in the South since 1960. Over the period, the decline in both areas has been almost the same. Six countries account for 80 per cent of Western Europe's agricultural labour force. There are also large farm labour groups in Yugoslavia and Turkey. Among these the level of tractorization varies widely. Thus the number of tractors per 100 farm workers varied as follows in 1966: France 31.0, West Germany 42.0, Greece 2.5, Italy 9.9, Portugal 1.8, Spain 4.2, Turkey 0.5, and Yugoslavia 1.0.

The replacement of animal power was evidently an important source of demand for tractor power during the fifties. If one horse is taken as the equivalent of seven horsepower, the comparison provided in Table 19.7 can be made. The data given there indicate that the replacement of animal horsepower has accounted for more than half of the increased use of tractors in Western Europe. For Southern Europe the proportion has been even higher. Animal power replacement has been particularly important in France, West Germany, and Spain. As of 1960 there was still the equivalent of 65 million horsepower of animal power in use in agriculture in Western Europe, about 30 million in the Northwest, and 35 million in the South. However, a substantial part of this may well have been replaced during the past decade.

TABLE 19.7—NET CHANGE IN TRACTOR AND ANIMAL HORSEPOWER ON FARMS, EUROPE, SELECTED YEARS, 1950-65

(Millions of horsepower)

Net Change 1950 to 1960	Tractor	Animal	Total
Western Europe	53.7	−27.4	26.3
Northwestern Europe	46.2	−22.1	24.1
Southwestern Europe	7.5	− 5.3	2.2
Net Change 1960 to 1965			
France	11.8	− 4.8	7.0
West Germany	10.7	− 3.9	6.8
Italy	7.5	− 1.7	5.8
Spain	4.0	− 3.4	n.a.[1]

[1] Since the Spanish animals include some for non-agricultural uses, totals are not given.

Source: H. G. Scott and D. J. Smyth, *Demand for Farm Machinery—Western Europe*, Royal Commission on Farm Machinery, Study No. 9 (Ottawa: Queen's Printer, 1970), Tables 2.18 and 2.19.

The continued use of animal power and the comparatively low rate of tractorization per unit of labour in a number of European countries suggests that there is still a large potential market for farm machinery in this region.

The econometric analysis of the demand for tractors in Western Europe, carried out for the Commission, indicated that for 15 different countries there was a significant relation between the amount of tractor horsepower used per farm worker and the ratio of farm wage rates to farm tractor prices. Thus, as farm wage rates in a country increase in relation to tractor prices, there is an incentive to substitute tractor power for labour. This same analysis showed that the proportion of all farms over 10 hectares and 20 hectares in size also had a significant effect on the amount of tractor horsepower in use.[3] Many of the farms in Western Europe are so small and fragmented as to make the use of tractors difficult. Thus, if the provisions in the *Mansholt Plan,* calling for incentives for the amalgamation of many of these very small units, are carried out, it should have some further favourable effects on the demand for farm machinery. The relationship between the use of tractor horsepower per farm worker and the relative prices of tractors and labour was confirmed by a study of the growth of the use of tractors in Britain over the period from 1948-65.[4] Taken together, the two studies suggest an elasticity of substitution of about 1.5. In other words a 1 per cent increase in the tractor/labour-price ratio will lead to a 1.5 per cent increase in the amount of tractor horsepower used per worker. Thus the steady rise in non-farm incomes, which in turn helps pull up farm labour rates, provides a substantial incentive to substitute machinery for labour on European farms.

Some attempt was also made to assess the effects of changes in the type of farming on the amount of machinery used in relation to labour. Shifts from the production of crops to livestock products is associated with a decrease in the use of machinery relative to labour. On the other hand, a shift in production from traditional, extensive livestock production to factory-type methods, as are already used for broilers, involves an increase in the relative use of machinery. Since both of these shifts seem to be occurring, they will partially offset each other.

In sum, the rapid mechanization in Northern Europe which followed after the war and which has now shifted to Southern Europe can be expected to continue for some time to come, especially in countries such as Italy, Spain, and Greece, where the amount invested in tractors and other farm machinery per farm worker is still comparatively low, and where the replacement of animal power by tractor power is still not complete. Further progress in the amalgamation of farm units will also stimulate machinery demand. However, machinery use in Britain and some of the other more advanced countries of Northwestern Europe has now reached a high level and is becoming more a replacement than a growth market.

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[3] *Ibid.*

[4] A.J. Rayner and K. Cowling, "Demand for a Durable Input: An Analysis of the United Kingdom Market for Farm Tractors", *Review of Economics and Statistics,* 49:590-598, November 1967.

The Market for Farm Machinery in North America

The United States – The market for farm machinery in the United States is a rich and varied one. For 1967, total sales of farm machinery and parts at wholesale prices to dealers amounted to about $3,067 million. Some indication of the importance of different commodity groups for both the United States and Canada is given by the data in Table 19.8. In this table, imports into the United States are not broken down by commodity group. However, it is known that a significant part of these consisted of combines.

TABLE 19.8–TOTAL SALES OF FARM MACHINERY IN NORTH AMERICA, 1967

(Values given in thousands of U.S. dollars[1] at wholesale value or price to dealers)

Machine Title[2]	Canada	United States
Planting, seeding, fertilizing equipment	21,836	183,312
Harrows, rollers, pulverizers	[3]	196,196
Plows and listers	19,299	117,386
Harvesting machinery	99,172	624,187
Haying machinery	26,802	158,684
Sprayers and dusters	3,716	61,266
Cultivators, weeders	31,231	102,387
Farm wagons and other transportation equipment	5,339	77,623
Tractors (excluding garden)	136,541	895,459
Farm elevators and blowers	[4]	44,592
Machines for preparing crops for market or for use	13,783	102,578
Silo unloaders	1,758	22,983
Parts[5]	57,349	172,938
Imports[6]	–	307,270
Total	416,826	3,066,861
Total–North America	3,483,687	

[1] Canadian dollars converted to U.S. dollars at rate of 92.5.

[2] Based on classifications from U.S. Current Industrial Reports (S.I.C. classification).

[3] Included with "cultivators and weeders".

[4] Farm elevators included with "machines for preparing crops for market or for use". Blowers included with harvesting machinery.

[5] U.S. figures include value of parts for all machines except tractors. Figure of $172,938 is for tractor parts. Canadian parts figure is for all machines, including tractors. Because some machine categories are not included in this table, e.g. farm dairy machinery and equipment, the figure for parts may be slightly overstated.

[6] Canadian imports included in Dominion Bureau of Statistics, *Farm Implement and Equipment Sales,* Cat. No. 63-203. U.S. imports taken from U.S. Bureau of the Census, *U.S. Imports–General and Consumption,* Washington, 1968, U.S. imports exclude "farm wagons and other transportation equipment" but include mowers. U.S. imports of parts exclude parts for tractors and include parts for plows and listers, cultivators and weeders, and harvesting machinery only.

Source: D. Schwartzman, *Oligopoly in the Farm Machinery Industry,* Royal Commission on Farm Machinery, Study No. 12 (Ottawa: Information Canada, 1970), Table E.1.

Measured in 1958 dollars the gross stock of farm machinery on farms in the United States amounted to $24.7 billion in 1965, more than three times the level of the late twenties. The growth in this stock by five-year intervals has been as follows (in billions of 1958 dollars):

1925	7.3	1950	16.8
1930	9.3	1955	22.7
1935	8.1	1960	24.7
1940	8.8	1965	24.7
1945	10.5		

Growth was rapid during the first decade after the war, but since then, has been much slower; between 1960 and 1965 the total stock remained stationary.

While the over-all demand for machinery by the American agricultural industry appears to be approaching a replacement level, at the individual farm level investment is still increasing. This reflects the fact that recent developments in technology—in particular, the larger-horsepower tractor—have favoured the growth of larger farming units. However, the adjustment to a larger farm size takes place slowly, since many existing farm operators are not willing to leave the industry. Thus the availability of additional land is a constraint on changes in the size structure of farms.

Other major variables affecting the demand for farm machinery are the relative prices of labour and machinery, farm-input prices relative to farm-product prices (a measure of the profitability of farming), and the capital or equity situation in the industry. Over the postwar period, except for an initial postwar price readjustment, farm labour prices have risen significantly more than farm machinery prices. Thus, between 1950 and 1960, farm wages increased by 49 per cent compared with 37 per cent for farm machinery, and between 1960 and 1968, wages rose 52 per cent compared with 29 per cent for farm machinery. Moreover, to some degree, the farm machinery price index overstates the relative price of machinery, since the index takes no account of the degree to which new machines provide cost-saving replacements for obsolete machines, and it fails to record many minor improvements. Further, the relevant comparison is between the operating costs of farm machinery and labour rates. Since the price of diesel fuel and lubricating oil has risen very much less than machinery, the use of the machinery price index overstates the true cost comparison to the farmer. Over the longer period since 1929, farm wage rates have risen just over five times, compared with the slightly more than threefold increase recorded by farm machinery prices. Thus the more rapid increase in wage rates over this period must have provided a substantial incentive to substitute capital for labour.

In a major study published in 1963, Heady and Tweeten estimated that "the elasticity of annual investment with respect to prices of machines or prices received approximately is unitary in the short run".[5] In other words, they estimated that a

[5] E. O. Heady and L. G. Tweeten, *Resource Demand and Structure of the Agricultural Industry* (Ames: Iowa State University Press, 1963).

1 per cent increase in farm machinery prices or a 1 per cent fall in prices received by farmers would cause a decline in demand for farm machinery by 1 per cent. They also estimated that the elasticity of demand for farm machinery with respect to the farm equity ratio was –.41. In effect, a 1 per cent increase in the farm-equity/farm-liabilities ratio would increase demand for farm machinery by .41 per cent, and a 1 per cent decrease in the ratio would cause a corresponding decline in demand for machinery. The study also indicated that over time improved technology had been an important source of increased demand for farm machinery.

Heady and Mayer[6] also estimated the effects of changes in farm cash receipts on the demand for farm machinery and on some individual types of farm machines. Some of these results are shown in Table 19.9. For the shorter period they suggest a very high responsiveness of farm machinery demand to farmers' cash receipts. Thus the data indicate that a 1 per cent increase in cash receipts would lead to a 3.7 per cent increase in the demand for all farm machinery and a 9 per cent increase in the demand for tractors. However, over the longer period since 1911 the estimated elasticities are much lower.

TABLE 19.9–ELASTICITIES OF DEMAND FOR DIFFERENT TYPE OF FARM MACHINES WITH RESPECT TO CHANGES IN CASH RECEIPTS RECEIVED BY FARMERS

	Derived Elasticity over Period 1911-62	Derived Elasticity over Period 1946-62
All farm machinery	0.34	3.70
Farm tractors	0.84	9.00
Farm trucks	0.50	(1)
Other farm machinery	1.21	(1)

(1) Estimates for farm trucks and other farm machinery for the shorter period, 1946-62, were inconclusive.

Source: E. O. Heady and L. V. Mayer, "Aggregate Demand for Farm Machinery", *Computers and Farm Machinery Management*, Conference Proceedings, December 1968, American Society of Agricultural Engineers, St. Joseph, Michigan, Table 3.

The paper by Heady and Mayer also made some estimates of the stock and annual demand for farm machinery for the year 1980. Thus, depending on what assumption is made about export programs and farm policies in effect at that date, a total stock of machinery, at 1965 prices, of from $38 to $48 billion was projected. The higher estimate assumes that U.S. agriculture is able to produce at full capacity with the 1965 cropland base. The lower estimate assumes a free market and U.S. agricultural exports at their 1965 level. With the present type of grain and cotton programs in effect, and with exports increasing in line with past trends, they estimate a total machinery stock of about $43 billion. Their estimates of the annual expenditures on farm machinery for 1980 were in the range of $5.3 to $5.7 billion.

[6] E. O. Heady and L. V. Mayers, "Food Needs and U.S. Agriculture in 1980", National Advisory Committee on Food and Fibre Tech. papers, Vol. 1, Washington, D.C., 1967.

In sum, there is evidence to suggest a further significant growth in the demand for farm machinery in the United States. In the future, demand for farm machinery may be expected to have two major components. A major part will reflect demand for the work capacity embodied in this machinery–work capacity needed to handle the growing volume of agricultural output. In addition, there will be demand for a higher level of comfort and services to be embodied in machinery–services to reduce the farm workers' effort and fatigue and increase his personal comfort.

Canada – Because some two-thirds of all sales of farm machinery in Canada are concentrated in the Prairies–an area that is heavily dependent on a single crop, wheat–the Canadian market for machinery is unusually vulnerable to fluctuations in demand. Both the weather and market prices strongly affect the annual value of the wheat and other grains grown on the Prairies. Even apart from this consideration, the demand for machinery is difficult to anticipate and predict. Annual sales of farm machinery are affected by many different considerations. Consider, for example, what has happened to the total stock of machinery in use over the past 50 years. In the twenties, although tractors were coming into use, horses were still the primary power source in Canadian agriculture. The machinery in use was designed for use with horses, and for smaller farms which were best suited to this type of power. During the thirties improvements in the tractor and the development of the combine foretold the end of the horse-operated-machinery era, but the low level of farm income and farm prices prevented any substantial change at the time. The shift to the tractor-combine era was further delayed during the Second World War by the limited availability of machinery. As a result, the early postwar years witnessed a period of buoyant farm machinery sales. Two things were happening. A long period of deferred replacement was being made good. At the same time, farmers were replacing horses with tractors and were buying machinery suited to a tractor-farming operation. Binders and threshers were replaced by combines. By about 1953, the extraordinary demand created by these two influences was pretty well satisfied, and sales slumped sharply. Because the stock of machinery on farms was now relatively new, replacement demand was comparatively low.

During the post-1945 period other forces were affecting the demand for machinery as well. As labour was attracted off the farm by job opportunities in urban areas, farmers were induced to mechanize because of the scarcity of labour. The increase in farm wage rates provided an economic incentive in the same direction. In some measure, both these factors–the movement off farms and the rise in farm wage rates–vary directly with the buoyancy of employment opportunities in urban areas. Further, rising farm incomes (in terms of real income per farm operator) create a demand for machinery which reflects a direct income effect. Machinery is desired to eliminate some of the heavy labour associated with farming, to increase the amount of leisure available, and to allow the farmer to work in greater comfort.

Technological change also exerts an effect on the demand for machinery. For example, the rapid increase in the size of the farm tractor, and the shift from gasoline to the more expensive diesel engines to provide the extra power, has exerted far-reaching influences on farm machinery demand. This change made larger farms more economical and at the same time created a demand for the larger equipment needed to complement the larger tractors. While this gave an immediate stimulus to the demand for machinery, the longer-run effects on the demand for machinery may be adverse, for there is evidence that investment in machinery per acre declines as farm size increases. Moreover, the adjustment to technological change takes place slowly, since farms can be enlarged in size only as additional pieces of land become available. All of these forces interact, with varying strengths in different periods.

Thus to explain past variations in farm machinery sales and to offer any hope of forecasting future variations in demand is not an easy task. Nevertheless, the Commission sponsored some econometric analyses of farm machinery demand in Canada, and the results of these studies are described below.[7] However, before proceeding to these results it will be useful to provide some quantitative assessment of the current stock of machinery on farms, some information on the current level of sales, and some data on changes that have occurred in machinery operating and depreciation expenses over the past four decades.

Estimates derived from census data place the depreciated value of machinery and equipment on Canadian farms in 1967 at just over $3.7 billion. This estimate includes the value of farm trucks and the farm share of passenger automobiles. Another estimate, using a different source,[8] puts the value of machinery and equipment in use on Canadian farms at $5.5 billion. This estimate is for the 1966 stock valued at 1969 prices and is for the gross stock before depreciation. The corresponding net stock is estimated at $2.9 billion. It excludes farm trucks and passenger cars. Corresponding to this gross stock, farmers are estimated to have charged depreciation against machinery in use (excluding cars and trucks) in the amount of $360 million in 1968. This is about 6.5 per cent of the gross stock and 12.4 per cent of the net stock cited above. Annual expenditures by Canadian agriculture on new machinery reached a peak of about $472 million in 1967 and have since declined moderately. Sales in 1969, about $370 million at the farm price level, were only slightly below the total amount of depreciation on existing stocks (excluding cars and trucks), estimated at about $400 million.

An examination of machinery operating and depreciation expenses for Canadian agriculture over the past four decades shows a significant increase in the importance of these expenses, measured either in relation to gross farm income or total farm operating and depreciation expenses. The relevant data are given in Table

[7] The results reported here were obtained by Dr. P. S. Dhruvarajan, Department of Economics, University of Manitoba.

[8] Based on unpublished capital stock estimates prepared by Dominion Bureau of Statistics.

19.10. Thus, as these data show, machinery operating expenses increased from 7.1 per cent of gross farm income in 1927-29 to 10.6 per cent in 1967-68. As a percentage of total operating and depreciation expenses, the increase over this period was from 13.3 to 16.1 per cent. Both measures show a decline from a still higher level reached in the 1957-59 period. Similarly, estimated annual machinery depreciation charges have increased from 5.7 per cent of gross farm income in 1927-29 to 8.9 per cent in 1967-68. Measured relative to total operating and depreciation expenses, the increase was from 10.4 per cent in 1927-29 to 13.4 per cent in 1967-68.

TABLE 19.10–MACHINERY OPERATING AND DEPRECIATION EXPENSES AS A PERCENTAGE OF GROSS FARM INCOME AND TOTAL FARM EXPENSES, CANADA, SELECTED YEARS, 1927-68

	Machinery Operating Expenses as Percentage of		Machinery Depreciation Expenses as Percentage of	
	Gross Farm Income	Total Farm Expense	Gross Farm Income	Total Farm Expense
1927-29	7.1	13.3	5.7	10.4
1937-39	9.7	16.8	5.6	9.7
1947-49	8.7	18.6	4.5	9.6
1957-59	12.6	20.3	8.4	13.4
1967-68	10.6	16.1	8.9	13.4

Source: Dominion Bureau of Statistics, *Handbook of Agricultural Statistics*, Part II, Farm Income, 1926-65, Cat. No. 21-511, June 1967. DBS, *Farm Net Income*, 1969, Cat. No. 21-202, June 1970.

Econometric analyses of the demand for farm machinery attempt to identify factors which are important in influencing farmers' decisions to purchase new machinery and try to quantify their importance as a basis for forecasting future levels of demand. Demand can refer to either the stock of machinery on farms or new purchases of machinery. The stock of machinery is demanded for the annual flow of services it provides, whereas new purchases can be for replacement of existing machines or for adding to the stock of machinery in use. Economic theory argues that at any time, given the prices of machinery, the prices of other agricultural inputs such as labour and fertilizers, the prices of farm products and the cost of borrowed funds, and given the present level of farm machinery technology, there will be some stock of machinery that farmers would consider an optimum. If any of the variables listed above change, the optimum will also change and farmers will attempt to adjust their machinery stock to this new optimum for any particular farm. Their annual purchases of machinery will reflect the speed with which they attempt to reach this new optimum.

The analyses undertaken for the Commission examined changes in the stock of machinery in use on Canadian farms and annual expenditures on machinery over three separate sets of time periods–1926-67; 1926-41 and 1947-67; and 1926-41 and 1952-67. For the second and third sets of time periods, the war years were

omitted because only a very limited supply of machinery was available for purchase in that period. The third set of time periods also omitted the early postwar years from 1948-51; these were years when machinery purchases were heavily influenced by the need to make good a long period of below-normal purchases caused by the lack of purchasing power during the thirties and the lack of available supplies during the war and early postwar years. In general, the third set of time periods gave the most satisfactory results, and the results presented here are limited to these periods. The study also examined the variations in demand for different provinces or regions of Canada as well as for Canada as a whole.

One of the limitations on the farmer's ability to adjust his stock of machinery to what he considers an optimum level is the availability of capital funds to finance his machinery purchases. The study discussed here used lagged income as a rough measure of the availability of capital funds. Three different income variables were tried in the analysis: (1) total farm cash receipts, Y^c; (2) adjusted cash income, Y^a, defined as income from crops plus 60 per cent of the income from livestock and livestock products; and (3) land values, V. All were measured at constant prices. The second income variable places primary emphasis on income from field crops, on the grounds that farm machinery is still most heavily used in relation to field crops. Both lagged income and land values also reflect to some degree the farmer's expectations about future income.

Apart from these income measures, the principal variables used were the following: P_M/P_L, a ratio between the price of machinery and the price of labour; P_M/P_R, a ratio between the price of machinery and the prices received for farm products; i, total farm interest payments at constant prices; F, a measure of the average farm size; S_{t-1}, the stock of machinery on farms in a preceding period; and T, a measure of technical progress represented by time. For the first of these variables, a negative relationship is expected, since an increase in the price of farm machinery relative to the price of farm labour would discourage the substitution of capital for labour and reduce machinery purchases. For similar reasons, the second relation should also give a negative sign. The third variable, i, is intended to measure the cost of investment; as the total interest payments increases, investment would be discouraged. An increase in average farm size should lead to a more efficient use of machinery, so again a negative sign is anticipated. Finally, lagged stock has two effects: a higher stock leads to a higher replacement expenditure and thus encourages investment; on the other hand, a higher existing stock relative to other variables may lead a farmer to postpone purchases longer. The former effect should be larger and the net effect positive.

In the statistical analysis, each of the regressions was calculated three times, each time with one of the income variables Y^c, Y^a and V. It was found that in almost every case, the regression that included Y^c did better than the ones with Y^a or V. In view of this, only those regressions that included Y^c were used for further analysis, except in certain cases where, for various reasons, computer output for

regressions with Y^c was not available. In the latter case, regressions with Y^a as the income variable were used.

Using least-squares regression methods, four types of models were examined. These were as follows:

a) stock-demand equations based on stock-adjustment models,
b) investment-demand equations based on investment-adjustment models,
c) investment-demand equations based on stock-adjustment models,
d) demand equations with adjustment assumed complete within a year.

In general, the results of this analysis indicated that the most important variables in explaining changes in farm machinery sales and the stock of machinery in use on farms were lagged cash receipts of farmers, the ratio of farm machinery prices to the prices received by farmers, and the ratio of machinery prices to farm wage rates. In some results, the stock of machinery in the preceding year and time taken as a measure of technical progress also entered as important explanatory variables. Of these variables, some measure of gross farm income was much the most important. This is evident from the data presented in Figure 19.3. Fluctuations in farm machinery sales, measured in constant dollars, parallel in a general way the realized gross farm income deflated by the farm machinery price index.

The most satisfactory results in terms of the proportion of the variation in gross investment explained by the model, the level of significance, and the absence of auto correlation, were provided by the investment-demand/stock-adjustment model. The best equations obtained with this model are given in Table 19.11. Elasticities calculated from this model indicated that a 10 per cent increase in real gross cash receipts (all other things held fixed) would lead to a 19.3 per cent increase in real farm machinery purchases; a 10 per cent rise in the real price of machinery would lead to a 1.5 per cent fall in machinery purchases; and a 10 per cent rise in the price of machinery relative to labour would lead to a 2.2 per cent fall in machinery purchases. The two latter elasticities are both low compared with results cited earlier for the United States.

The Demand for Farm Machinery in Developing Countries

This section examines the prospective demand for farm machinery in the developing countries of the world. It first considers some reasons why increasing mechanization in these countries can be anticipated. It then surveys different methods that can be used to predict the future demand for farm machinery in these countries. On this basis some quantitative assessment is made of this demand.

As a group, the developing countries are characterized by low per capita incomes and recurrent or continuous shortages of food. Moreover, with their high rates of population growth and with some continued growth in per capita incomes, at least part of which will be spent on food, a substantial growth in the demand for

FIGURE 19.3 - FACTORS AFFECTING DEMAND FOR FARM MACHINERY, CANADA, 1920-69

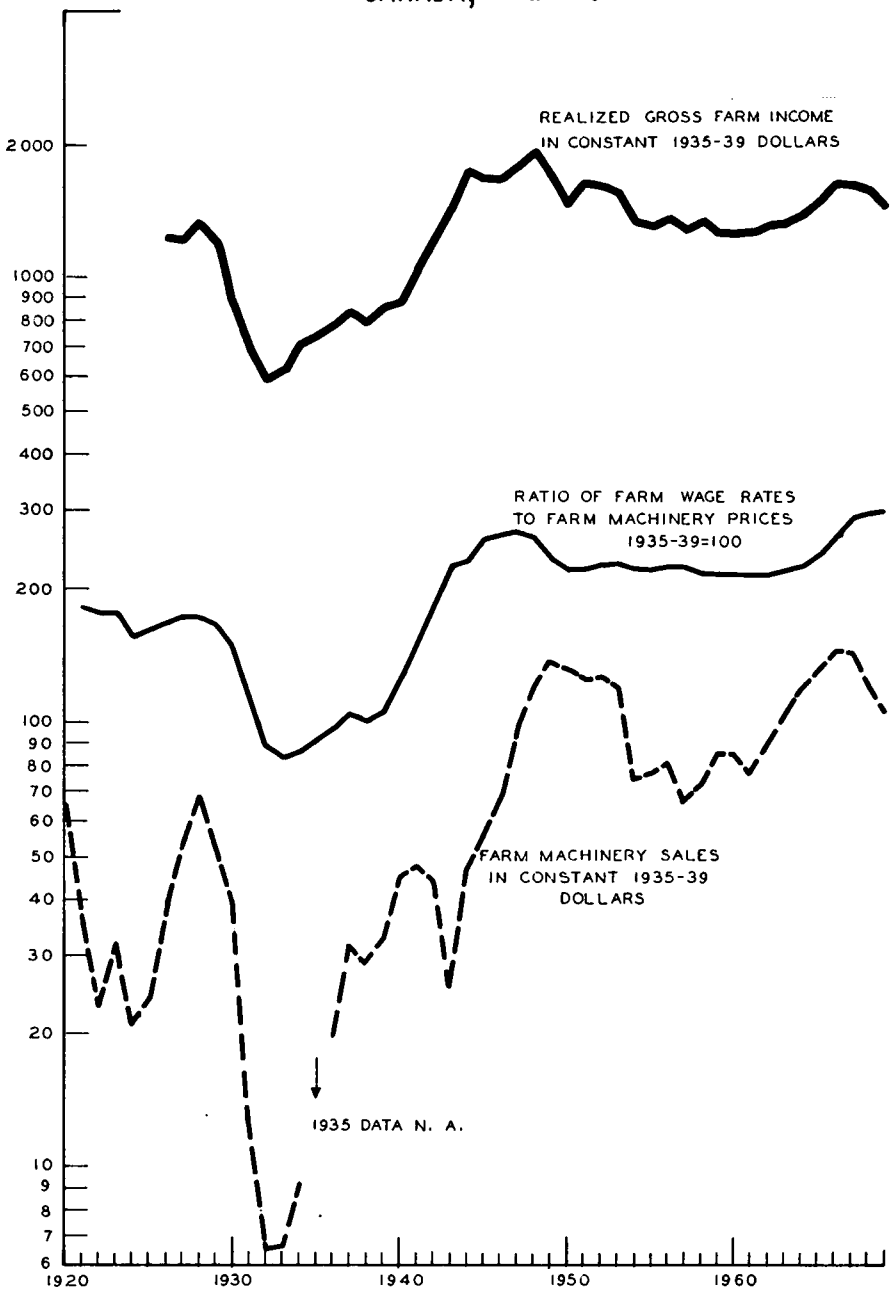

TABLE 19.11—BEST EQUATIONS: INVESTMENT-DEMAND/STOCK-ADJUSTMENT MODEL, DEPENDENT VARIABLE, I_t (GROSS INVESTMENT)

	Period	Constant Term	P_M/P_L	P_M/P_R	Y^a_{t-1}	Y^c_{t-1}	T	F	S_{t-1}	R_2	$D.W.$
Canada	1931-41,	8.92	−20.98	−52.07	45.58		1.94	−252.99	−.014	.959	2.14
	1952-61	(40.56)	(117.95)	(95.76)	(15.92) **		(6.97)	(1,217.58)	(.034)		
Quebec	1938-41,	−.96	−3.20	−1.57		8.05			.011	.987	1.80
	1952-60	(.88)	(4.61)	(3.72)		(3.74) *			(.011)		
Ontario	1938-41,	21.28	−9.43	−18.93		8.01			−.006	.992	2.61
	1952-60	(1.06) **	(4.70)	(4.21) **		(1.64)			(.005)		
Prairies	1938-41,	102.84	−40.56	−62.07		11.14			−.021	.893	2.23
	1952-60	(12.60) **	(54.20)	(38.99)		(6.43)			(.025)		

Note: One asterisk indicates that the coefficient is significant at the 5 per cent level. Two asterisks indicate significance at the 1 per cent level. If no asterisk appears, the coefficient is not significantly different from zero.

R_2 is the coefficient of determination and *D. W.* is the Durbin-Watson statistic. Standard errors appear in parentheses.

foodstuffs can be expected in these countries for some years to come. This suggests that the prospective demand for farm machinery in developing countries may be very large. For there is increasing evidence that mechanization affords one of the most effective ways of increasing food supplies.

The contribution that mechanization can make to increased food supplies takes three forms. First, many of these countries still use draught animals as their main source of power. A replacement of these animals by tractor or stationary engine power will release for human food many acres that are now devoted to supporting draught animals. It has been estimated that 30 per cent of the increased food supply in the United States between 1920 and 1942 came from acres formerly used to feed horses and mules. Second, modern power equipment permits greater timeliness in seeding and harvesting operations. One Indian agronomist has estimated that crop yields fall about 1 per cent per day when seeding is delayed beyond the optimum 10- to 15-day period. Finally, the increased speed of operations, made possible by tractor power, enables double or triple cropping where only one crop is possible in a draught animal economy. Each of these points will now be examined in more detail.

In the earliest stages of man's agricultural development, human energy provided his principal source of power. Human energy is extremely adaptable and versatile, but its power output is low. During continuous work one man can produce a work output of only about .1 HP.[9] Because the work output of one person was so small, agriculture based on human energy had to be divided into very small units and processes. For this reason, many years ago man began to use draught animals such as horses, mules, oxen, cattle, and donkeys to supplement human energy. This greatly increased the power available to him. One horse

TABLE 19.12–NORMAL DRAUGHT POWER OF VARIOUS ANIMALS

Animal	Average Weight (kilograms)	Approximate Draught	Average Speed of Work (m./sec.)	Power Developed (kg./sec.)	Horse-power
Horse (light)	400-700	60-80	1.0	75	1.00
Bullock	500-900	60-80	0.6 to 0.85	56	0.75
Cow	400-600	50-60	0.7	35	0.45
Mule	350-500	50-60	0.9 to 1.0	52	0.70
Donkey	200-300	30-40	0.7	25	0.35

Source: H. J. Hopfen, *Farm Implements for Arid and Tropical Regions,* FAO, Rome, 1960, p.9.

produces ten times the work output of one man and an ox seven or eight times as much (see Table 19.12). Animal power was best suited to straight pulling, as when hitched to a plow, harrow, or wagon. It could also be adapted by means of gears and wheels to various other jobs such as pumping, threshing, and crushing

[9] H.J. Hopfen, *Farm Implements for Arid and Tropical Regions,* FAO, Rome, 1960, p. 4.

sugar cane. At this stage agriculture not only provided its own source of power, it also grew the feedstuffs needed to support the draught animals used in industry and for other urban purposes. In effect, agriculture was a net exporter of power.

However, compared with the power available from a tractor, or even electric motors and stationary engines, the power provided by draught animals was still rather limited. Farmers began to use steam tractors and stationary steam engines in the nineteenth century. The tractor came into widespread use during the 1920s and 1930s. It has been greatly improved in recent decades. Equipped with rubber tires, a power take-off, a three-point hitch and hydraulics, it can be used for a wide variety of farm jobs. It is particularly suited to farms of 10 hectares (25 acres) or over in size. For still smaller farms, the power tiller is becoming an increasingly important source of power.

In agriculture, mechanization has typically been applied first in the farm yard where the controlled environment is well adapted to the use of mechanical power. Mechanization in the field and for farm transportation was more difficult because of the wide variety of environmental conditions under which the farm machine has to operate. It was only after a great many improvements had occurred in the design of tractors, combines, and other implements that it became possible to mechanize agricultural field work in a wide variety of circumstances. Even today, modern farm machinery is more adapted to the type of agriculture that prevails in North America and Western Europe than to that of the tropical and semi-tropical developing countries. And while the tractor is being increasingly used as a source of power in these countries, draught animals are still the predominant power source. This is evident from the data given in Table 19.13.

TABLE 19.13–SELECTED AGRICULTURAL STATISTICS, DEVELOPING COUNTRIES, 1966

	Africa	Asia	Latin America	Developing World
Arable land and land under permanent crops (million hectares)	216.9	328.1	109.0	654.0
Land in cereals (million hectares)	54.7	179.3	43.3	277.3
Cereal output (millions of metric tons)	45.1	200.8	55.6	301.5
Agricultural population (millions)	225.2	684.1	140.2	1,049.3
Livestock total (millions)	125.2	287.2	267.2	679.5
Cattle	119.9	280.4	234.6	634.9
Horses and mules	5.3	6.9	32.6	44.7
Tractors (thousands)	127.7	236.5	512.1	876.3

Source: FAO, *Production Yearbook, 1967*, Rome, Italy.

A study of tractor mechanization in Northwestern India shows that the annual use of 8.8 tractor hours per acre reduces the use of animal power by about

46 animal hours per acre per year.[10] Hours of human labour were reduced by almost an equal amount–namely, 48 hours per acre per year. The data from this study are given in Table 19.14. In relative terms, the impact of the tractor is much greater on the use of animal labour than on human labour. In this instance, the number of bullock hours per acre declined 75 per cent, whereas human hours fell by only 27 per cent. The impact of the tractor in replacing animal power was much greater in land preparation and in harvesting than in any other phase of the farm operation.

TABLE 19.14–EFFECT OF TRACTOR POWER ON ANIMAL POWER, AND HUMAN LABOUR UTILIZATION PER ACRE, PUNJAB, INDIA

(Hours per acre)

	Time Spent for Different Activities on:				
	Farms Using Animal Power		Farms Predominantly Using Tractor Power		
	Human Labour	Bullock	Tractor	Human Labour	Bullock
Pre-sowing	34.8	34.1	5.4	9.5	3.8
Sowing	9.2	8.1	0.1	8.0	6.7
Post-sowing	22.7	–	–	12.2	–
Irrigation	12.7	3.9	–	14.6	4.3
Manuring	2.0	0.7	0.3	3.6	–
Harvesting	81.4	12.7	2.8	69.8	0.2
Miscellaneous	11.8	2.2	0.2	9.4	0.6
Total	174.6	61.7	8.8	126.9	15.6

Source: Adapted from Bhagat Singh, "Economics of Tractor Cultivation – A Case Study", *Indian Journal of Agricultural Economics,* Vol. XXIII, No. 1, January-March 1968, p. 85.

As these data show, in Asia, Africa, and Latin America there are one billion people–roughly one-third of the world's population–dependent on agriculture. These people own and employ 680 million animals, of which 635 million are cattle and 45 million are horses and mules. As of 1966 they owned about 877,000 tractors or about one for every 800 head of livestock. While not all these animals are used for draught purposes, a great many are. In Asia and Africa the ratio of livestock to tractors is more than 1,200 to 1. There is clearly a very large potential for the replacement of animal power with tractor power. These countries currently have about 1.3 tractors per 1,000 hectares of arable land. This contrasts with 44 in Western Europe and 24 in North America.

The value of the tractor as a substitute for animal power is enhanced by the extremely seasonal character of most farming operations. During the tillage, planting, and harvesting seasons–often only a few months of the year–animal power tends to be used to the limits of its capacity. During much of the year, animals are idle or used only occasionally. They must still be fed and looked after.

[10] Bhagat Singh, "Economics of Tractor Cultivation – A Case Study", *Indian Journal of Agricultural Economics,* Vol. XXIII, No. 1, January-March 1968, p. 85.

With the increasing use of electric motors and diesel engines for stationary work in developing countries, the period when animal power is idle is tending to lengthen. This increases the relative cost of animal power.

In addition, the adoption of new high-yielding grain varieties, the use of more fertilizer, and the practice of multiple cropping is intensifying the demand for power during the critical tillage, planting, and harvesting periods. As a result, the limited supply of animal power available during such periods becomes a bottleneck, limiting the scope of the farming operation. Farmers are shifting to tractors as a method of removing this bottleneck. Moreover, there is some evidence that net income per acre is higher on tractor-using farms than on farms that rely on animal power. This confirms the view that the tractor is becoming an economic substitute for draught animals as a power source in these countries.[11]

Unlike the traditional varieties, the new higher-yielding varieties of grain developed in Mexico, the Philippines, and elsewhere are highly responsive to fertilizer, water, improved tillage, and better cultural practices. Their success will require changes in nearly all the components of farm production technology in these countries. This will include the increased use of power and implements.

The increased yields that arise with better timing and precision in farm operations result from a number of sources. Reference was made earlier to the loss in yield through delay in seeding. The slowness with which human or animal power performs farming operations can result in other losses as well. One man working one hectare of land by hand will require from 20 to 30 days' hard labour for a single spading. In the meantime weeds will be growing back, and productive time will have been lost. With animal power the same land may be cultivated in from four to seven days, and the loss will be smaller. With tractor power, time lost is reduced to a minimum. As one author observes, "moreover, when the rainy season is short, rapid land preparation ensures good weed control and the best use of the rainy season. Following the harvest of the rice crop, rapid land preparation and reseeding also make use of the residual soil moisture to grow a crop of wheat, grain sorghum or pulses."[12] The same author cites a number of experiments where better seeding equipment and more precise placement of fertilizer resulted in substantial increases in yields. He also cites evidence that improved timing in harvesting and threshing helps save a larger proportion of the crop, and results in an improved quality product. In areas where moisture is assured or irrigation water is available, the shift towards multiple cropping is facilitated by the use of the tractor. It greatly reduces the time required to prepare the land, seed, and harvest successive crops.

Before turning to a more detailed examination of the different sources of demand for farm machinery in developing countries, it will be useful to examine

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[11] *Ibid.*, p. 83.

[12] L. Johnson, cited in G.W. Giles, *World Food Problems: Basic Needs*, a paper presented at the Annual Meeting of the American Society of Agricultural Engineers held jointly with the Canadian Society of Agricultural Engineering, June 1967.

the relation that exists between the value of agricultural machinery and draught animals in use, and the value of agricultural output. A recent analysis of the ratio between these two totals by Colin Clark has shown that this ratio has varied over a comparatively narrow range, both over time in individual countries and between different countries at the same date in time.[13] Thus, for India in 1961, this capital output ratio was .58, that is, the value of draught animals and implements was equal to about 58 per cent of the annual value of agricultural output, net of the input of seed and feed. In Lower Saxony, West Germany, for 1956, the study showed a ratio of .34 for small farms and .27 for larger farms. In the United States in 1949-51 the ratio was .47, only slightly different from the ratio of .52 in 1870 and .48 for 1880. Only in *hand-hoe agriculture* is the ratio substantially lower than this. In this latter case, it is usually between .1 and .2. Some of these data are summarized in Table 19.15.

TABLE 19.15–CAPITAL-OUTPUT RATIOS IN AGRICULTURE, INDIA, WEST GERMANY, AND THE UNITED STATES, SELECTED YEARS

		Ratio of Value of Draught Animals and Implements to the Annual Value of Agricultural Output
India	1961	.58
West Germany	1956	.30
United States	1870	.52
	1880	.48
	1890	.55
	1900	.53
	1910	.62
	1919-21	.70
	1924-26	.58
	1929-31	.55
	1939-41	.40
	1949-51	.47

Source: From C. Clark, "Capital Requirements in Agriculture: An International Comparison", *The Review of Income and Wealth*, No. 3, September 1967, Tables 2, 5, and 11.

This comparatively stable relationship suggests that further increases in agricultural output in developing countries will be accompanied by a corresponding growth in the use of machinery. Thus the primary source of demand for machinery in these areas will be to replace draught animals and to provide for an increased supply of power and other equipment as total agricultural output increases. In addition, existing stocks of equipment must be replaced as they wear out.

Several approaches can be taken towards estimating the potential demand for tractors and other farm machinery in developing countries. One approach is to consider the amount of equipment that would be required to raise the power

[13] C. Clark, "Capital Requirements in Agriculture: An International Comparison", *The Review of Income and Wealth*, No. 3, September 1967, p. 205.

available in developing agriculture to certain minimum levels. Another approach is to project recent trends in the growth of tractor use in developing countries. Still another approach is to estimate the amount of tractor power that would be needed to replace animal power in agriculture. Let us consider each of these approaches in turn.

The first approach was used in some estimates of future tractor and other farm machinery requirements prepared for a publication entitled *The World Food Problem.*[14] This study first examined the relation that exists in different countries between the yield of various crops and power used per acre (see Figure 19.4). As the data in this chart show, the more advanced agricultural countries, which produce outputs of 2,000 kilograms or more per hectare, make use of from 1.0 to 2.5 HP per hectare of land. In contrast, as shown on Table 19.16, at the present time, available horsepower per hectare of arable land and land under permanent crops is only .19 in Asia, .05 in Africa, and .27 in Latin America. After examining past trends this Report concludes that it is reasonable to assume that Latin America could achieve a power use of .5 HP per hectare by 1986, Asia a level of .33 HP per hectare by 1998 and Africa .20 HP per hectare by 1998. The estimates make no allowance for the replacement of animal power by tractor power but simply assume an increase in power available, all to be supplied by tractors.

On this basis these experts concluded that annual expenditure for tractors would more than double before 1986 (see Table 19.17). However, estimated expenditures for all other equipment including animal-drawn machinery would change relatively little over the period. No reasons are given for the comparatively constant level of the non-tractor components of machinery expenditures.

TABLE 19.16–AVAILABLE HORSEPOWER PER HECTARE OF ARABLE LAND AND LAND UNDER PERMANENT CROPS, BY REGION

	Asia[1]	Africa	Latin America	United States	Europe
Tractor (riding)	.02	.03	.18	1.00	.78
Garden tractor	.03	.00	.00	.014	.02
Animal	.09	.01	.05	.00	.08
Human	.05	.01	.04	.003	.05
Total	.19	.05	.27	1.02	.93

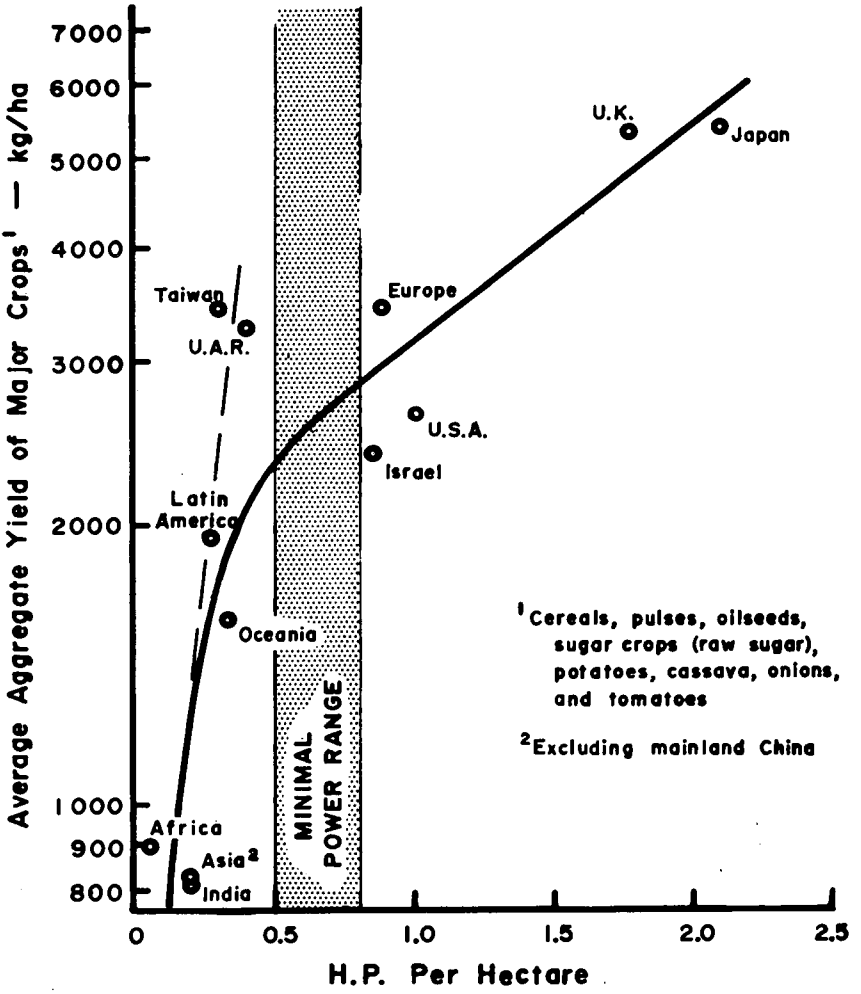
[1]Excluding mainland China and Japan.

Source: *The World Food Problem,* A Report of the President's Science Advisory Committee, Vol. II, The White House (Washington: U.S. Government Printing Office, May 1967), p. 397.

[14]A report of the President's Science Advisory Committee, Vol. II, The White House (Washington: U.S. Government Printing Office, May 1967).

FIGURE 19.4 - RELATIONSHIP BETWEEN YIELDS IN KG/HECTARE AND POWER IN HORSEPOWER PER HECTARE

MAJOR FOOD CROPS



SOURCE: PRESIDENT'S SCIENCE ADVISORY COMMITTEE, THE WORLD FOOD PROBLEM, VOL. II (WASHINGTON: U. S. GOVERNMENT PRINTING OFFICE, MAY 1967).

TABLE 19.17–ESTIMATED ANNUAL COST TO FARMER, TRACTORS AND OTHER FARM MACHINERY, DEVELOPING COUNTRIES, ASIA, AFRICA AND LATIN AMERICA, 1966-86[1]
(Millions of U.S. dollars)

	1966-70	1970-76	1976-86
Tractors	368	494	786
Other machinery	1,022	1,018	1,021
Total	1,390	1,512	1,807

[1]Excluding mainland China and Japan.

Source: *The World Food Problem*, A Report of the President's Science Advisory Committee, Vol. II, The White House (Washington: U.S. Government Printing Office, May 1967), p. 401.

A second approach to estimating demand for farm machinery in the developing areas is to project the growth in demand experienced over the past decade or more. Data for this purpose are available for tractors only. Table 19.18 shows the number of tractors on farms, in the world as a whole and in developing countries, over the period 1954-66, together with the growth rate over this period. Tractors in use in developing countries have been increasing more rapidly than in the world as a whole. As a result the developing countries' share of the world total has increased from 4.6 per cent in 1954 to 6.3 per cent in 1966. However, if allowance could be made for the horsepower size of tractors in use, it is doubtful

TABLE 19.18–TRACTORS ON FARMS, WORLD TOTAL, AND DEVELOPING COUNTRIES, 1954-66[1]

	World Total	Developing Countries	Developing Countries as a Percentage of Total World
	('000)	('000)	
1954	8,010	366	4.6
1955	8,643	411	4.8
1956	9,150	466	5.1
1957	9,639	525	5.5
1958	10,094	504	5.0
1959	10,488	552	5.3
1960	10,888	598	5.5
1961	11,325	635	5.6
1962	11,808	639	5.4
1963	12,411	699	5.6
1964	12,917	763	5.9
1965	13,362	809	6.1
1966	13,811	876	6.3
	Compound Growth Rate (Per cent)		
1954-66	4.6	7.5	

[1]Data exclude mainland China. As far as possible, data are for tractors used in agriculture. However, a few countries report total tractors in use, including garden tractors.

Source: FAO, *Production Yearbook*, 1956 through 1967 inclusive.

TABLE 19.19–PROJECTIONS OF TRACTORS IN USE IN DEVELOPING COUNTRIES, BY REGION, 1966-85

	Asia	Africa	Latin America	Total Developing Area
		(Thousands)		
1966	237	128	512	876
1970	378	157	681	1,216
1975	679	203	971	1,853
1980	1,220	263	1,386	2,869
1985	2,191	340	1,978	4,509
		Compound Growth Rate (Per cent)		
1966-85	12.4	5.3	7.4	9.0

Note: Totals may not add due to rounding.
Source: Commission estimates.

whether the developing countries have increased their share of the total horsepower in use on farms, for the shift to larger-horsepower tractors has been very pronounced in Canada, the United States, Australia, and several other countries.

A projection of tractor stocks in developing countries by major region, for the period 1966 to 1985, is given in Table 19.19. If the net increase in tractor stocks is converted to average annual totals and is then multiplied by $3,000 (representing the price of a small tractor), to convert them to a dollar total, the following estimates are obtained:

	Annual Expenditure for Tractors
	(Millions of dollars)
1966-70	255
1970-75	384
1975-80	609
1980-85	984

Although the data are not for precisely comparable time periods, the latter estimate does not differ very substantially from the one presented above in Table 19.17. Moreover, this latter estimate includes the growth in stocks only and thus makes no allowance for replacement demand. However, it may imply some replacement of animal power by tractor power.

Still another approach to assessing the demand for farm tractors is to consider tractor power as a potential replacement for animal power. Assuming some continued growth in the stock of animal units (horses, cattle, caribou, and mules) on farms in developing areas, it is reasonable to assume that the total number in 1970 was about 750 million. No precise basis exists for estimating how many

of these were being kept for milk or raised for beef rather than used for draught purposes, but 150 million appears to be a reasonable estimate. On this basis the current stock of draught animals amounts to 600 million. Suppose half of these were replaced by tractor power over the next 30 years. This would require the replacement on the average of 10 million animal units per year. What would be the tractor equivalent of this?

Earlier in this section it was noted that in India 8.8 tractor hours had replaced about 46 animal hours. This is a ratio of 5 to 1. In Canada between 1941 and 1956 the stock of horses on Canadian farms declined by just over two million while the stock of tractors increased by 340,000. This suggests that one tractor replaced about six horses. If the 5-to-1 ratio is used, it would require two million tractors to replace 10 million animal units. This would mean an annual demand for tractors, presumably of the smaller 30-to-35 HP variety, of two million per year for the next 30 years. When this is compared with the present stock of tractors on farms throughout the world—14 million in 1966 and perhaps 15 million today—or with the current world tractor output of about 700,000, it is evident that the potential requirement for tractors in developing countries is enormous. Requirements are not, of course, effective demand. Nevertheless, the tractorization of farming in developing countries may be one of the most effective ways of solving the world's food problem. For that reason, as the world's population continues to increase, more and more pressure may develop to help realize this potential tractor requirement.

A comparison with the two other estimates of this potential demand for tractors as animal replacement makes it clear that the last estimate implies a very much larger expenditure. Two million tractors implies an expenditure in the order of $6 billion annually. Thus it is clear that the earlier estimates imply only very limited animal-power replacement.

A more sophisticated approach to estimating the demand for tractors would distinguish between tractors and two-wheel power tillers. The latter have begun to receive extensive use in countries where small farms predominate, such as Japan. This is evident from the data in Table 19.20 on the extent of farm mechanization in different countries. The experience of advanced countries is that when the tractor is first adopted, it is used mainly on larger farms. However, as mechanization proceeds, the availability of the tractor begins to influence the size of farms, and farms become progressively larger.

The modern farm tractor would appear useful on farms of 10 hectares or more. For farms of less than 10 hectares, the power tiller is likely to be more suitable. Thus data on the number of farms in different developing countries which are above or below 10 hectares in size may provide some indication of the potential demand for tractors and power tillers. In time, of course, as mechanization proceeds, the availability of tractors may lead to a consolidation of many of the farms that are now below 10 hectares in size. Table 19.21 provides some data on

TABLE 19.20–FARM MECHANIZATION IN SELECTED DEVELOPED COUNTRIES

	Average Arable Land Holding	Four-wheel Farm Tractor[1]	Two-wheel Power Tiller	Tractor Horsepower per Hectare of Arable Land
	(Hectares)	(Thousands)		
United States	38.7	4,625	525	1.51
Britain	13.8	389	48	1.51
France	9.4	1,060	380	1.29
West Germany	5.5	1,107	100	2.43
Italy	3.6	377	75	0.76
Japan	1.1	28	2,490	2.20

[1] All 1964, except Britain (1963) and Japan (1966).

Source: I. Hayashi and S. Miyoshi, *Features of Japanese Rice Farm Machinery*, Society of Automotive Engineers, West Coast Meeting, San Francisco, Calif., August 12-15, 1968.

TABLE 19.21–NUMBER OF FARMS AND PROPORTION OF ACREAGE IN DIFFERENT SIZE GROUPS, DEVELOPING COUNTRIES, 1960

	Number of Farms		Percentage of Acreage in Farms	
	Under 10 Hectares	10 Hectares and Over	Under 10 Hectares	10 Hectares and Over
	(Thousands)			
Colombia	926	284	8.8	91.2
Brazil	1,499	1,839	2.5	97.5
Peru	803	67	8.5	91.5
Venezuela	218	102	2.9	97.1
Paraguay	104	46	2.3	97.7
Uruguay	26	61	0.7	99.3
Ceylon	1,156	14	61.4	38.6
Lebanon	122	5	60.2	39.8
Philippines	2,045	121	66.7	33.3
West Pakistan	5,303	387	57.3	42.7
East Pakistan	6,438	26	95.2	4.8
Iraq	175	78	5.0	95.0
Iran	1,563	314	40.0	60.0
India	31,748	2,606	63.4	36.6
Turkey	2,122	406	39.3	60.7
Libya	71	75	5.9	94.1
Senegal	277	18	73.9	26.1
Total	54,594	6,448		

Source: Based on data compiled from FAO, *1960 World Census of Agriculture*, other unpublished data provided by FAO, and agricultural or land-holding censuses of individual countries.

the number of farms in these two size groups for a number of developing countries. For the 16 countries for which data are available, there were, in 1960, 54.6 million farms of less than 10 hectares and 6.4 million farms of 10 hectares or over. Some of the farms in the former group, of course, might be so small that they would not justify even a power tiller.

Demand for other machinery is very difficult to estimate because data on the amount of this machinery in use are very limited. Data presented earlier suggest that annual expenditures on all farm machinery, excluding tractors, in both North America and Western Europe amount to about 120 per cent of annual expenditures on tractors. On this basis, if it is assumed that total expenditures on machinery, excluding tractors, are roughly equal to expenditures on tractors, an expenditure of $6 billion annually is implied in this area as well. For the developing region this implies an annual expenditure of about $18 per hectare of arable land, including land under permanent crops. This compares with an expenditure by Canadian farmers in 1967 of about $11 per acre, equivalent to about $27 per hectare, of improved land. For the most part, the developing areas engage in a much more intensive type of agriculture so that higher expenditure levels for a fully mechanized agriculture may be justified. However, the very size of the expenditure levels implied suggests the magnitude of the problem that will be involved in mechanizing agriculture in the developing countries.

In concluding this discussion, it may be desirable to consider briefly the amount of research expenditure that is currently devoted to developing improved machinery for use in the agriculture of developing countries. As was noted earlier, about one-third of the world's population is dependent on agriculture in developing countries. Yet the amount of research and development expenditures oriented to improving the machinery and equipment used by farm workers and farmers in these countries has been very limited. The National Institute of Agricultural Engineering in England had a small research program oriented to this task, but their total expenditure amounted to little more than a few hundred thousand dollars. Some of the major farm machinery companies may have made some expenditures oriented to agriculture in these countries; Ford recently announced a new tractor designed for use in developing areas. But the overwhelming proportion of the world's research expenditures on farm machinery is oriented to the agriculture of developed countries rather than developing countries. Although no totals are available here, it is clear that total annual expenditures on research and development in the former area is very large. Total research and development expenditures by the farm machinery industry in the United States in 1960 were reported as $75 million. Expenditures by two major companies, Deere and Massey-Ferguson, have doubled since that date. In addition, there are significant expenditures by industries in other countries, especially Western Europe, and by governments in both Europe and North America. Thus total world expenditures may well exceed $200 million annually. Compared with this, the amount spent for improving machinery suited to the agriculture of developing countries is very small indeed.

This suggests that there may well be very large returns from a research and development program designed to improve machinery for use in developing areas. One aspect of such a program, meriting particular attention, would be the development of improved machinery for use with the farm tractor in developing countries. Accordingly, the Commission recommends to the Canadian International Development Agency a careful study of the desirability of encouraging the establishment of several research institutes in different parts of the developing world, the task of which would be the development of improved machinery for use with tractors or power tillers in these countries.

Chapter 20

THE FUTURE OF THE CANADIAN INDUSTRY: AN EVALUATION

The Commission was asked to examine

> the present and prospective competitive position of the Canadian agricultural machinery industry in Canadian and in export markets as compared with agricultural machinery industries in other countries, including an examination of research and development activity and its relationship to the establishment of new facilities in Canada.

It was also asked to consider and report upon

> measures that would contribute to the expansion of efficient production of agricultural machinery, the attainment of technological advances, the improvement of distribution, financing and servicing facilities and the enhancement of the industry's competitive position so that Canadian farmers would be ensured most favourable prices for, and availability of, machinery and parts.

The present section of the Report has reviewed a number of considerations that have a direct bearing on the competitive position of Canadian manufacturing firms in both the Canadian and world market. This chapter will summarize some of these factors and outline some steps that could be taken to improve the industry's present competitive position.

In examining this question it is useful to distinguish between Canadian firms that are subsidiaries of major international enterprises and the smaller independent Canadian firms. The former group currently account for about 80 per cent of the value added by the industry in Canada and have long held a dominant position. There is also some reason to believe that the major international companies have been gaining an increasing share of the world trade in farm machinery. However, a number of the independent firms have enjoyed rapid growth in recent years, and although precise data are lacking, it seems likely that their share of Canadian output has been increasing. For the subsidiaries of major companies any decision to expand Canadian production will be made in the context of an assessment of the worldwide interests of the international company. In the short run this decision may be dominated by the availability of productive capacity in one country rather than another. In the longer run, these international enterprises will locate their

production in the lowest-cost country, taking full account of manufacturing costs, transport costs, tariffs and various production risks and including in this assessment prospective changes in these costs in the near-term future. For in a jet age these global corporations find it increasingly easy to use their management, marketing, and research skills to source machines and components from the lowest-cost location on a worldwide scale and to market their products on a broad international basis.

However, for newer products initial production will often be located close to the research and development unit where the product was designed and developed. New products often go through a period of progressive development in their early stages of use, and it is economical to keep the factory responsible for it close to the design engineers who originated the basic idea. Thus one way to influence the location of manufacturing is to influence the location of research and development units. Moreover, given the strong labour-saving emphasis that characterizes most new developments in farm machinery, these new products often find their earliest acceptance in high labour-cost areas. Thus for these companies the key to expansion in Canadian output lies in the encouragement of more research and development in Canada.

The independent Canadian firms view the production-location decision from a much narrower viewpoint. Until they reach a size where a subsidiary manufacturing plant in another country becomes feasible, they are likely simply to expand their original plant. Given the cost advantages of their location and the efficiency with which they manage their manufacturing operations, their success is likely to depend largely on their ability to identify markets which they are well equipped to enter. For example, two firms that have enjoyed substantial growth in recent years–Versatile and Thomas Equipment–have successfully identified markets which they were equipped to satisfy. For Versatile this success lay in the production of machines well suited to the Prairie grain-growing areas in Canada and the United States. For Thomas Equipment it was their successful innovation of potato-harvesting equipment, well suited to the stony soils of Maine and the Maritimes. However, in the longer run the smaller independent firms may be handicapped in competing with the international giants unless they receive some support on the research and development side from government or university research facilities.

As has been outlined in some detail in earlier chapters, the world market for farm machinery can be conveniently grouped into three major areas–North America (Canada and the United States), Western Europe, and the rest of the world. At the present time the first two areas are far the most important in absolute size, with markets in 1965 of around $3.6 billion and $2.6 billion, respectively. In the rest of the world, the developing areas are an important subgroup. Although their present market is fairly small in absolute size–these countries accounted for just 6 per cent of the farm tractors in use in 1966 (excluding mainland China)–it is likely to be a rapidly growing market in the future. Over the past two decades,

the market in Western Europe has grown much more rapidly than the North American market, and this pattern is likely to continue for some years to come.

Of these three markets, it is the North American market that is, by a wide margin, the most important to the Canadian producer and this is likely to continue to be true. Except for specialty products, the European market is likely to be difficult for the Canadian producer to penetrate. Not only are there tariff barriers to overcome, but, in addition, ocean transport costs for traffic moving from east to west are higher than in the reverse direction, and manufacturing costs are significantly lower in Western Europe than they are in North America.

On the other hand, although the North American market has a comparatively slow rate of growth in absolute size, it is a rich and diverse market and probably has a more rapid rate of new product development and acceptance than is true for any other market area.

Moreover, the location of the Canadian industry is still well suited to the manufacture of machinery for the North American market. The major disadvantage faced by manufacturing plants in Ontario is that of being somewhat away from the centre of the North American market. However, as was shown in Chapter 16, this disadvantage in terms of transport costs for the finished product is more than offset by lower manufacturing costs, although the recent appreciation of the Canadian dollar will have reduced this advantage. Manufacturing plants in Winnipeg enjoy much lower manufacturing costs than those in the United States, and while this advantage is partially offset by its distance from some of the major market areas, it is in a strong competitive position to cater to markets in the western part of the continent. Some of these same cost advantages may be present in other Prairie locations as well. At the present time Canadian manufacturing plants account for about 7 to 8 per cent of manufacturing shipments and value added by the industry in North America. At the same time, about 12 per cent of all farm machinery sales in the two countries takes place in Canada. Thus the Canadian manufacturers' share of the North American market is well below Canada's share of total sales. Even a modest increase in Canada's share of the market would mean a fairly major increase in total Canadian production. To raise it to 12 per cent would require more than a 50 per cent increase in total output.

If one considers the four leading manufacturers of farm machinery in Canada–Massey-Ferguson, International Harvester, Deere, and White Motor–it is clear that there are very wide variations in the share of their North American sales which they choose to source from plants in Canada. The reasons for this variation are far from clear, but they may well include both historical development and company philosophy. Of these four companies, Massey-Ferguson provides much the largest share of its sales on this continent out of Canadian plants. Because the total market grows slowly, once a complex of plants has been established, any change in location is likely to take place slowly. Massey's plants at one time catered to an important off-shore export market, and for this reason some of its production

facilities are well in excess of what is needed to satisfy the Canadian market alone. Massey's one major new plant in Canada–the combine plant at Brantford–was located there partly because of special tax incentives for locating in areas of above-average unemployment.

The second most important manufacturer of farm equipment in Canada –International Harvester–produces its machinery in a plant in Hamilton which was first established in 1908. However, its Canadian production, as a proportion of the parent company's total North American sales, is very much smaller than that of Massey-Ferguson. For Deere and White Motor, Canadian manufacturing output represents a still smaller share of the parent company's total sales on this continent. It is hard to explain on rational economic grounds why there should be such a wide variation in the share of total North American sales sourced from Canadian plants. However, it is probably not accidental that the firm with the largest share manufactured in Canada is owned and controlled in Canada. A number of other North American firms with substantial sales in Canada, such as Case, Allis-Chalmers, New Holland, and New Idea, do not manufacture any of their machinery in Canada, although Case has some machines produced on a contract basis by independent Canadian manufacturers.

Probably the most important single step that can be taken to induce these firms to increase their Canadian manufacturing production is to strengthen greatly the research and development base for this industry in Canada. A number of recommendations designed to achieve this goal are contained in Chapter 17. Over the longer run the implementation of these measures will do much to encourage an increased amount of farm machinery manufacture in Canada. Up until now research and development in agricultural machinery in Canada has been extremely weak. Very little research has taken place either in the federal and provincial governments or in Canadian universities. And many of the major firms that manufacture in Canada have done a disproportionate share of their research in the United States. With improved support for research and a strengthening of graduate programs in agricultural engineering in Canadian universities, and with a greatly expanded research program by the Federal Government, the whole atmosphere for research will be greatly improved. The industry should find this atmosphere conducive to an expansion of their own research program in Canada. And an expansion in their Canadian research facilities will lead in time to an increase in their manufacturing output in Canada.

The smaller independent Canadian firms should benefit from the expansion in Canadian research facilities as well. Not only will new developments in farm machinery be provided by this research, but the development of these facilities will provide a much larger number of personnel with expertise in agricultural engineering whose services can be drawn upon on a consulting basis, or who can be recruited to form part of the permanent staff of these firms.

The smaller Canadian companies should also benefit from a greater input of management know-how. Many of these firms are too small to afford the specialized management resources of large organizations. Their product designs, plant engineering, production control, quality control, and financial management would all benefit from higher quality inputs. Perhaps one of the best ways the government could aid such companies would be to underwrite the costs of management consultant studies, which could identify areas of potential improvement in their operations, and then provide financial support for a limited time to implement the changes recommended.

PART IV

THE MECHANIZATION OF AGRICULTURE

Chapter 21

THE DEVELOPMENT OF FARM MECHANIZATION

Canadian farming in the last quarter century has experienced a technological revolution. Its most visible form has been mechanization. Facilitated by many advances in non-machinery technology, mechanization has had far-reaching effects on farming structure, production techniques and management methods.

Economists often distinguish between two types of technological change. *Output increasing* innovations result in increased production from a given level (or cost) of inputs, and they include new crops or varieties and agricultural chemicals. *Cost reducing* technology enables a given level of output to be produced from a reduced level (or cost) of inputs. Such economies arise from the substitution of one type of input for another, such as machinery for labour. The distinction collapses, however, once it is seen that any particular technological innovation can be either output-increasing or cost-reducing or both, depending on how it is applied and what other adjustments in production are associated with its application.

No matter how it is labelled, technological advance can ultimately be viewed as the development of new or better inputs which may lead to a higher output, or substitute for more traditional inputs and enable cost reductions. Thus, in one sense all technological change can be viewed as a process of "factor substitution".

Agriculture reached its present level of mechanization through a prolonged evolutionary development. In its earliest stages the farmer made his own tools and equipment, first from wood and then from metal. In time, as the tools in use improved, specialized local tool makers appeared. This was the age of the blacksmith. Over the recent and much shorter period, the latter has been replaced by the manufacturer who builds and distributes his machines in large volume. The machines have become increasingly sophisticated and specialized.

Parallel to this evolution of farm machinery and its mode of manufacture have been changes in the use of power in farming. At first, man was the only source of power. Since one man can produce only about one-tenth of a horsepower, the tools that could be used and the farming operations that could be carried out were very limited. With the harnessing of domestic animals, mainly horses and oxen,

there was a great increase in the power man could apply and the amount of food that could be produced. Improved implements were devised to take advantage of this power.

Much more recently we have seen the application of mechanical power to farming, first with steam and then the internal combustion engine. Used initially as stationary engines, they were soon adapted to field operations in the form of the steam-powered and then the gasoline-powered tractor. The electric motor, the diesel engine, the rubber-tired and the caterpillar tractor were soon to follow. With the introduction of hydraulic transmission of power it became possible to use the same power unit for various lifting operations as well as for traction, and for operating other machines through the power take-off. As a result of these changes the power that can be applied and controlled by one man has steadily increased.

In this capsule history of agricultural development, certain landmarks stand out. The moldboard plow facilitated more effective tillage and initial weed control. Subsequently, the seed drill permitted more even seeding and by facilitating weed control in the growing crop, made possible the use of crop rotations. The use of draught animals for power had far-reaching effects on society as a whole for it allowed man to spend increasingly less time on food production, thus freeing labour for many non-farm activities. With the introduction and improvement in mechanical power sources this trend has steadily accelerated. Its effective limits have not yet been reached. Nevertheless, the massive and far-reaching changes of the last 50 years have caused greater adjustments in farming than in any previous period of ten times its length. For Canadian agriculture, a description of some of these recent changes is provided in the next chapter.

These changes in the farm equipment in use, the farmer's power sources and the way his machines are manufactured have produced and been accompanied by changes in the farmer's role in society. Initially, the farmer made his own tools and produced food largely for his own use. His position has gradually evolved into one where he markets most, if not all of his product, and buys a great range of machinery and other inputs from specialized suppliers.

In Canada, four overlapping phases can be distinguished in this agricultural development. First came the *ranging agriculture* of the native Indian tribes. Primitive in nature, making use of natural objects and artifacts, it was no match for the formal *land settlement* type of agriculture introduced by the Europeans. The eighteenth and nineteenth centuries witnessed the gradual spread of largely self-supporting often isolated, family farms. This type of farming spread through Upper and Lower Canada and the Maritimes and subsequently across the Prairies. Although these farmers often adopted indigenous crops such as corn to great advantage, many of their ideas and methods came from Europe.

With the coming of the steamship, the canal and the railway, Canadian farmers soon began exporting some of their surplus grain and other produce to Europe, importing breeding stock, farm equipment and other manufactured goods

in exchange. Faced with a perpetual labour shortage in relation to the land area available, there was a strong incentive for North American farmers to devise improved labour-saving machines. This in turn stimulated local manufacture of farm machines, a development that was so successful it soon led to a thriving export business in farm machinery. By the 1860s Canadian companies were making sizable exports of farm machines to the United States, Europe, and Australia.

From the beginning of this century until 1945 a third phase of Canadian agriculture characterized by *farm expansion* is discernible. As population grew, communications improved and trade developed, more land was cleared and brought under cultivation. There was a massive growth in the area of farmland and the number of farms, in agricultural output, in population on farms, and in the farm labour force. Situated on the edge of the Prairies, Winnipeg grew from a town of 2,000 in 1890 to a city with one-quarter of a million inhabitants by 1940.

The farms of the expansion era were characterized by larger acreages, by specialization in fewer enterprises and by extensive mechanization. The period saw the introduction and growing use of the tractor to replace horses and the early use of the combine harvester.

Subsequently, changing pressures have led to a period of *agricultural adjustment*. Many of the pressures were economic, arising from changing national and world circumstances. The result has been an increase in farm size, a major movement of people out of farming and the full development of agriculture as a specialist economic activity. At the farm level this has meant much larger and more sophisticated tractors and other farm machines, a much greater variety of equipment to choose from and an increasing reliance on machinery of all kinds. It has also meant more dependence on off-farm suppliers for production inputs and for expert services. As a result, the farm is taking on many of the characteristics of businesses in other sectors of the economy. It is with this transition and all the dynamic changes of this recent period that this section of the Report is concerned.

Chapter 22

THE CHANGING PATTERN OF CANADIAN AGRICULTURE

Canadian agriculture in the twentieth century has been moulded by the pressures of expansion and adjustment and a continuous process of technological change. Some of the effects of these interrelated changes are described and charted in the following pages.

Structural Changes in Farming

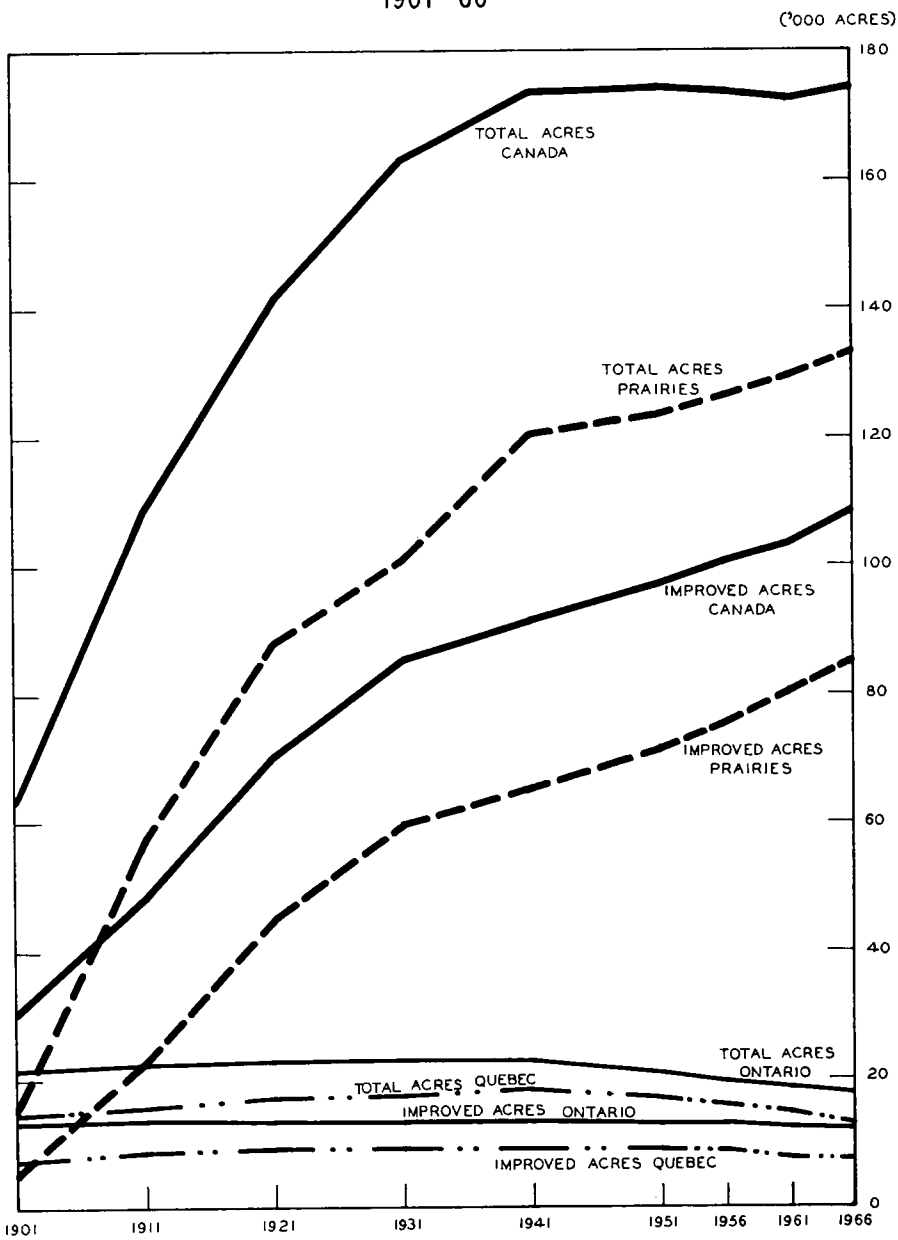
Agricultural Area – Virtually all the Canadian expansion of farmland between 1901-41 occurred in the Prairie Provinces, where the area in farms grew eightfold. Since 1945, the total area of farmland in Canada has remained almost constant and has actually declined in Ontario and Quebec with urban growth, reforestation and the abandonment of marginal farms.

In contrast, the area of improved land has grown consistently throughout this century. While it initially made up about half of the increasing total area of farmland, it has continued to expand since 1941 until now about 62 per cent of the total land in farms is classed as improved. The result has been an effective enlargement in farm size. The results of these changes are shown in Figure 22.1.

Farm Numbers – As the agricultural area grew so did the number of farms. New farms were established mainly on the Prairies. In Quebec there was little growth, while in Ontario, since 1921, the number of farms has fallen. From 1945 on, faced with the need for greater efficiency to survive, farm numbers began to decline in all regions of Canada. Much of the decline has been for farms of 200 acres or less. On the Prairies, even larger farms have been under pressure and only holdings of more than 640 acres have increased in number. While the pressures to form larger units are not as strong in Ontario and Quebec, where livestock and mixed farming are more prevalent, farms with less than 200 acres have been declining here as well as can be seen from Figure 22.2.

Farm Size Structure – The result of these changes has been an increase in average farm size. On the Prairies the average size of farm has doubled between 1921 and 1966, increasing to 685 acres. Larger farms have always been prevalent on

FIGURE 22.1 - AREA IN FARMS, CANADA BY MAJOR REGIONS, 1901 - 66



SOURCE: BASED ON DATA FROM CANADA DEPARTMENT OF AGRICULTURE, SELECTED STATISTICAL INFORMATION ON AGRICULTURE IN CANADA, OCTOBER 1969.

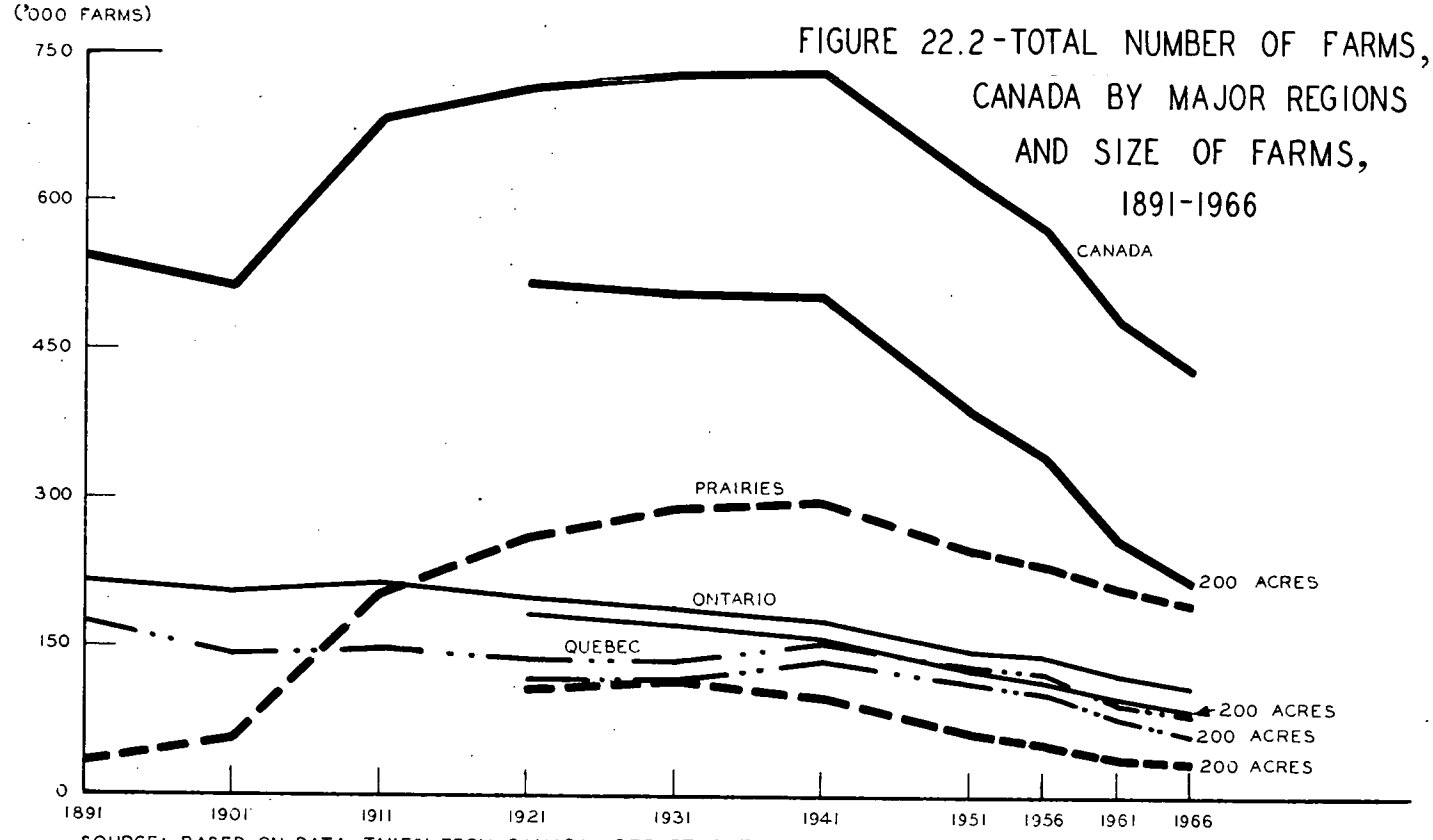


FIGURE 22.2 - TOTAL NUMBER OF FARMS, CANADA BY MAJOR REGIONS AND SIZE OF FARMS, 1891-1966

SOURCE: BASED ON DATA TAKEN FROM CANADA DEPARTMENT OF AGRICULTURE, SELECTED STATISTICAL INFORMATION ON AGRICULTURE, OCTOBER 1969.

the Prairies. Still, 41 per cent of all farms in this region were of less than 200 acres in 1921. This had fallen to 18 per cent by 1966. By contrast, in Ontario and Quebec the smaller farm has been dominant and even today three-quarters of these farms are of less than 200 acres. In these provinces the average size of farm has grown more slowly increasing over this period only from about 120 to 160 acres.

Farm Organization and Tenure – With the growth of corporate farms, co-operative farming ventures and part-time farms, the traditional family farm has lost some ground. Despite the fall in the total number of farms, holdings classified as "part-time" in the Census of Canada have doubled since 1951, numbering 130,000 in 1966. They now form the majority of so-called "non-commercial" farms, and constitute as much as 30 per cent of all farms, compared with 10 per cent in 1951.

Similarly, the pattern of land tenure has undergone a major transformation. In 1941, 12.9 per cent of Canadian farms (with 15.7 per cent of the total farm acreage) were operated by tenants. By 1966 this proportion had fallen to 4.6 per cent of the number of farms and about the same proportion of total farm acreage. Yet over the same period the percentage of fully-owned farms and farmland declined slightly. The greatest change was in farms that are part-owned and part-rented: this class doubled its share of the total farms over the 25-year period, and increased its proportion of the farmland area from 28 to 44 per cent. Most of these changes reflect the steps taken by successful owner-farmers to increase their farm size by renting additional land.

Similar adjustments are evident at the provincial level. In Quebec, some 90 per cent of farms are fully owned by their operators. Pure tenancy is almost non-existent. The period since 1941 has seen a small growth in the proportion of mixed-tenure farms. On the Prairies tenancy has been more widespread, perhaps because of the simplicity with which share-crop leases can be arranged. Even so, over the 25 years ending with 1966, the region has experienced a decline in the proportion of fully-rented farms from 21 per cent to less than 7 per cent. The proportion of owned farms has remained steady at 60 per cent while the proportion in the part-owned and part-rented category has increased. Farm enlargement has evidently been accompanied by a decline in full tenancy and a growth in combined ownership and rental. A similar pattern is evident in Ontario.

Labour Force – During the early part of the century the farm labour force expanded along with agriculture as a whole, reaching a peak about 1939. Since then there has been a large and steady decline (see Figure 22.3). The movement of labour away from the farm was stimulated by the attractions of non-farm employment. It has been made possible by the increased use of farm machinery as a substitute for labour.

More detailed examination of the data reveals that most of this labour loss has been in farm operators and family labour. In contrast, the decline in the hired

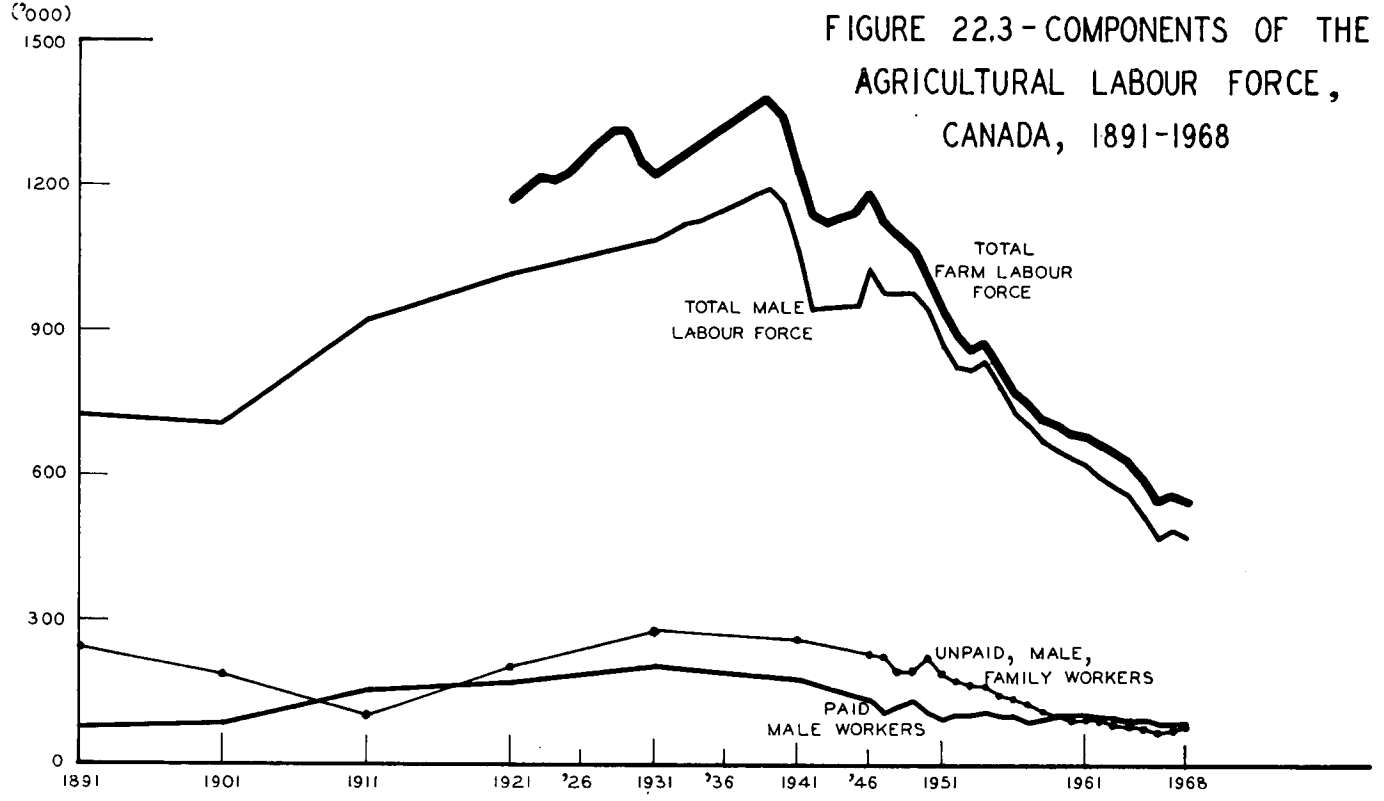


FIGURE 22.3 - COMPONENTS OF THE AGRICULTURAL LABOUR FORCE, CANADA, 1891-1968

SOURCE: BASED ON DATA FROM M. C. URQUHART AND K. A. H. BUCKLEY, EDS., HISTORICAL STATISTICS OF CANADA, TORONTO: THE MACMILLAN COMPANY OF CANADA LTD., 1965; DOMINION BUREAU OF STATISTICS, CANADIAN LABOUR FORCE ESTIMATES.

labour force has been very modest. Apparently, farm amalgamations have often caused whole families to leave the land.

In 1901 some 40 per cent of the Canadian labour force was employed in agriculture. By 1969 this proportion had fallen to less than 7 per cent. The national total masks strong regional variations, reflecting differences in the type of farming and the importance of agriculture in different regions. The Prairies show a relatively high proportion of the total labour force engaged in agriculture, but even there the figure has declined from 48 per cent in 1941 to 17.4 per cent in 1968. An even greater relative decline took place in the Central Provinces: in Quebec the decline was from 21.5 per cent in 1941 to 5.4 per cent in 1968, and in Ontario from 18.6 per cent to 4.9 per cent. The most dramatic decline was in the Atlantic Provinces, where by 1968 only 4 per cent of the labour force was engaged in agriculture, one-sixth of the proportion in 1941.

Because farm numbers were falling during this period also, there has been no parallel decline in the average labour force per farm. It fell only from 1.51 in 1951 to 1.26 in 1966. Accordingly, acreage worked per man almost tripled between 1941 and 1966, rising to 200 improved acres for Canada as a whole, and to 355 on the Prairies.

Agricultural Output – Despite this large decline in the farm labour force, agricultural output, aided by improved technology, has shown an upward trend (see Figure 22.4). All provinces have shared in this growth, the Prairies to the greatest extent: 53 per cent of Canadian agricultural output came from this region in 1966, compared with 43 per cent in 1941.

Still, in all regions the relative importance of agriculture has fallen sharply. Agricultural output amounted to 12.8 per cent of Gross Domestic Product in 1951. It accounted for only 4.6 per cent in 1967.

As the total area of farmland has not increased since 1941, the higher output levels imply an increased productivity from the available land. Some of this has been the result of land improvement. Increasing yields per acre have also contributed. Figure 22.5 shows the trend of yields for selected crops over the past 60 years. For some crops a rising trend is clearly evident. For others, such as wheat, yields are only marginally higher than they were early in this century. In part, this may reflect the emphasis that plant breeders have placed on disease resistance and milling quality rather than yield.

Machine Numbers and Types – That farms could lose so much labour and still increase their output is due in no small measure to the progress of agricultural technology, particularly to machine technology. Mechanization has thus played a double role, catering for both an increased output and a decline in the labour force. In addition, as will be seen later, by altering the whole nature of agriculture it has created its own set of pressures and problems.

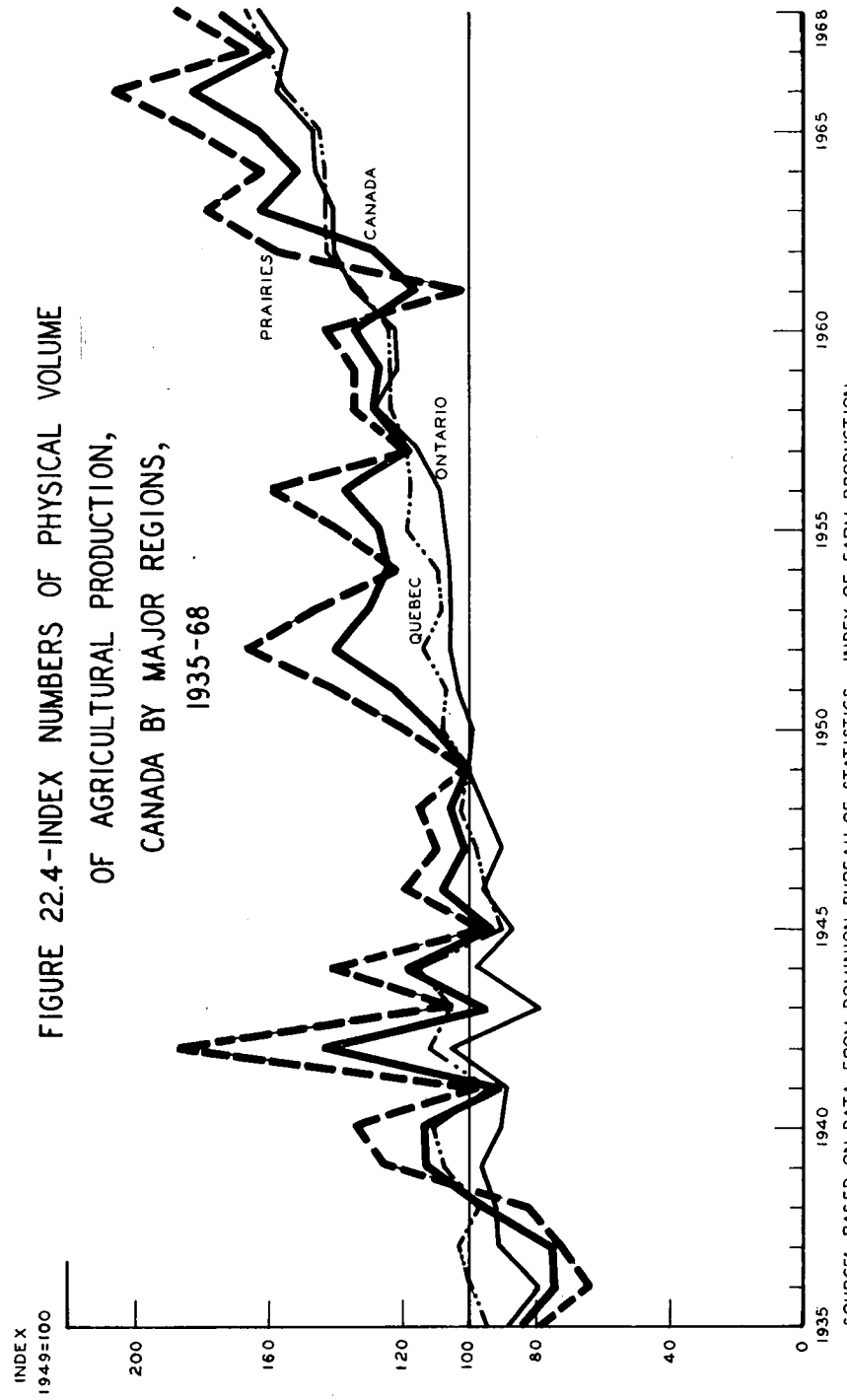


FIGURE 22.4-INDEX NUMBERS OF PHYSICAL VOLUME OF AGRICULTURAL PRODUCTION, CANADA BY MAJOR REGIONS, 1935-68

SOURCE: BASED ON DATA FROM DOMINION BUREAU OF STATISTICS, INDEX OF FARM PRODUCTION, 1968, CAT. NO. 21-203.

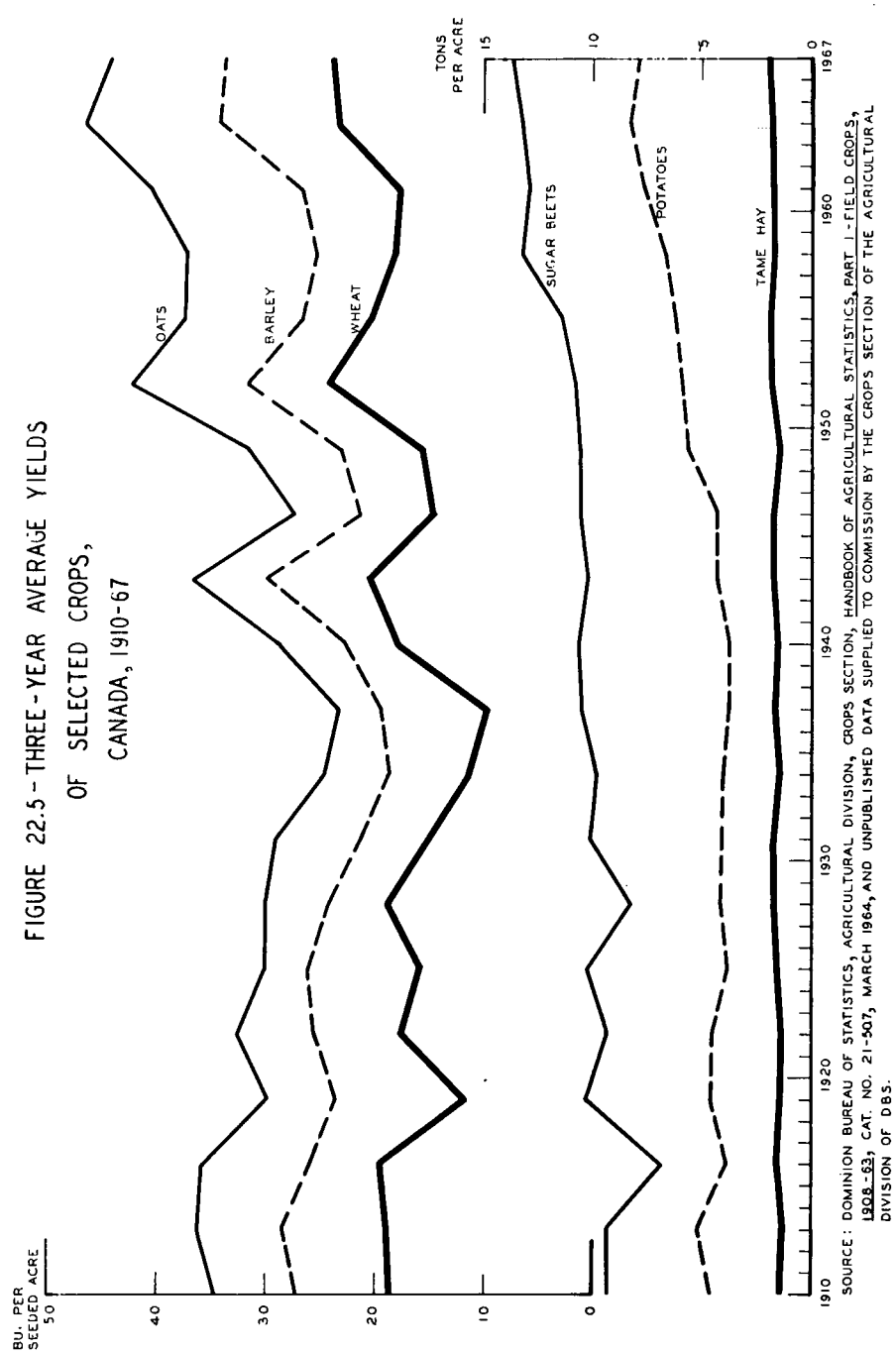


FIGURE 22.5 - THREE-YEAR AVERAGE YIELDS OF SELECTED CROPS, CANADA, 1910-67

SOURCE: DOMINION BUREAU OF STATISTICS, AGRICULTURAL DIVISION, CROPS SECTION, HANDBOOK OF AGRICULTURAL STATISTICS, PART I - FIELD CROPS, 1908-63, CAT. NO. 21-507, MARCH 1964, AND UNPUBLISHED DATA SUPPLIED TO COMMISSION BY THE CROPS SECTION OF THE AGRICULTURAL DIVISION OF DBS.

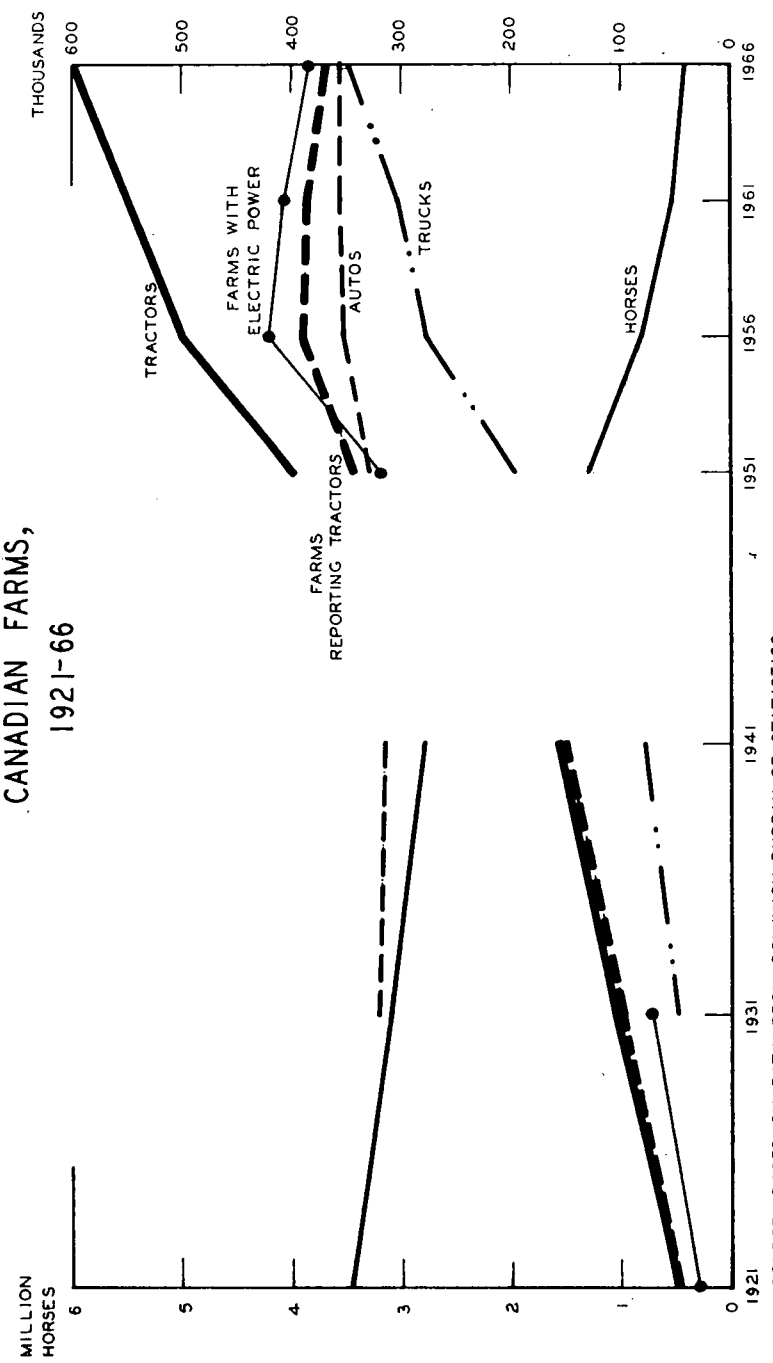
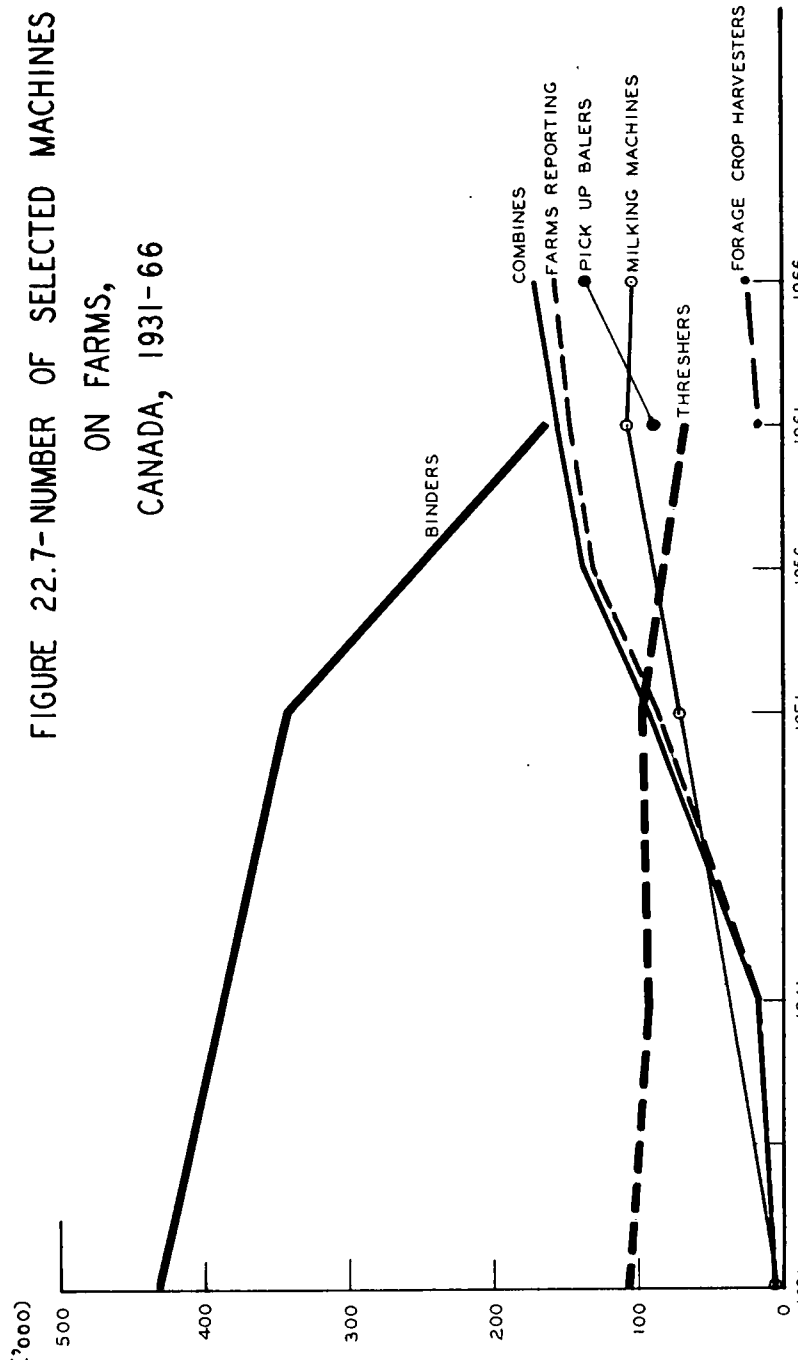


FIGURE 22.6 - SOURCES OF POWER, CANADIAN FARMS, 1921-66

SOURCE: BASED ON DATA FROM DOMINION BUREAU OF STATISTICS, CENSUS OF CANADA, 1966, TABLES 7 AND 8.

FIGURE 22.7-NUMBER OF SELECTED MACHINES ON FARMS, CANADA, 1931-66



SOURCE: BASED ON DATA FROM DOMINION BUREAU OF STATISTICS, CENSUS OF CANADA, 1966, TABLE 7, AND HISTORICAL STATISTICS OF CANADA, M. C. URQUHART AND K. A. H. BUCKLEY, EDS., TORONTO, MACMILLAN, 1965.

The use of machinery as a source of power and as a substitute for labour is shown in Figures 22.6 and 22.7. The growth in tractor numbers, mirrored by the decline in the horse population, proceeded at a steady rate until 1941, then accelerated. Between 1941 and 1951, the number of farms with tractors more than doubled. With the further growth in numbers since that time, there were, by 1966, about 1.4 tractors in use per occupied farm. A similar if less pronounced growth has occurred in the use of trucks and electric power.

The increase in the use of combines followed a similar pattern. Replaced by the combine, the number of binders and threshing machines with their high labour requirement has fallen sharply.

The postwar period has seen a change in the characteristics of farm machines, as well as in their number, and the engineering technology and work capacity of modern farm machinery has reached a high level. Tractors have increased greatly in power and sophistication. Before 1947, no tractors with a power rating above 30 HP were available. Even in 1960, two out of every three new tractors sold were in the under 35 HP category. This compares with 4 per cent today. By 1967, 30 per cent of all the farm tractors sold in Canada were in the 80 HP and over size class, a size sold by only one major company prior to 1959. The dominant fuel type in use has shifted strongly towards diesels, a move closely related to the trend to higher horsepower models. In 1953, only 13 per cent of the new tractors sold were powered by diesel engines. By 1967, some 78 per cent of the total and virtually all tractors over 80 HP were diesel-engined. As a result, sales of tractors in terms of horsepower have continued to rise steadily even though the number of new units sold has shown little change (see Figure 22.8).

The trend to larger tractors has been particularly strong on the Prairies. Over 50 per cent of the new units purchased by Prairie farmers in 1966 had in excess of 80 HP, with only 5 per cent of purchases being units with less than 40 HP. At the other extreme, virtually none of the very large units are sold in Quebec, where roughly 60 per cent of all sales are for tractors below 40 HP.

Regional differences in the rate of "tractorization" are shown in Figure 22.9. The Prairies and Ontario were the first to adopt the tractor in large numbers. But by the mid-1950s, it was a basic item of equipment on farms in all provinces.

Economic Patterns in Agriculture

Farm Revenues – During the early expansion phase of Canadian agriculture the value of farm products sold climbed steadily, then began to sag with the decline in prices in the late 1920s and slumped badly during the Great Depression. After 1933 prices gradually recovered and farm production began to expand again. Throughout the postwar adjustment phase, the combination of a rising volume of output and inflation in the prices received for farm products has provided farmers with a growing level of cash receipts. This rising trend has been further strengthened

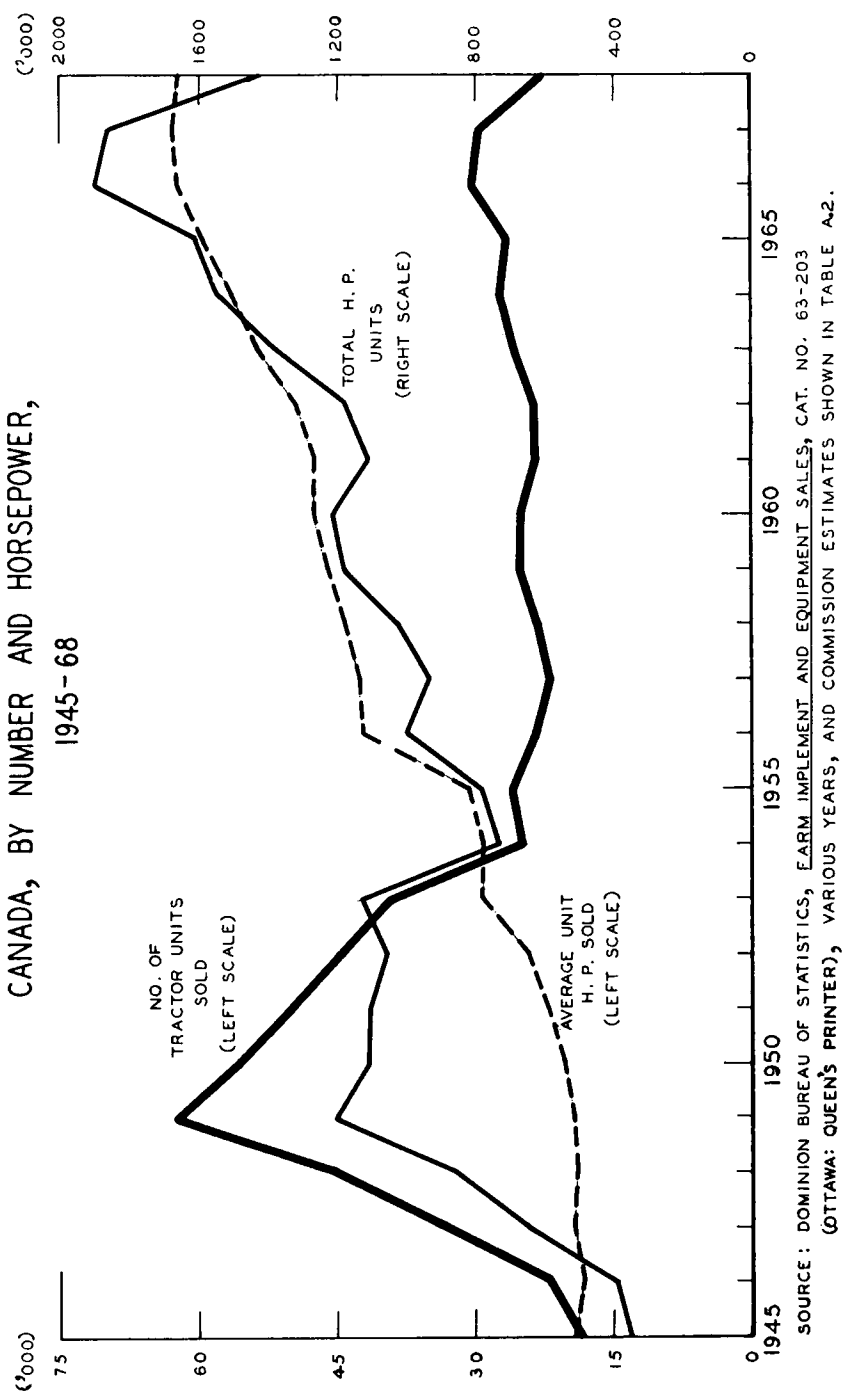


FIGURE 22.8 - TRACTOR SALES
CANADA, BY NUMBER AND HORSEPOWER,
1945-68

SOURCE: DOMINION BUREAU OF STATISTICS, FARM IMPLEMENT AND EQUIPMENT SALES, CAT. NO. 63-203 (OTTAWA: QUEEN'S PRINTER), VARIOUS YEARS, AND COMMISSION ESTIMATES SHOWN IN TABLE A-2.

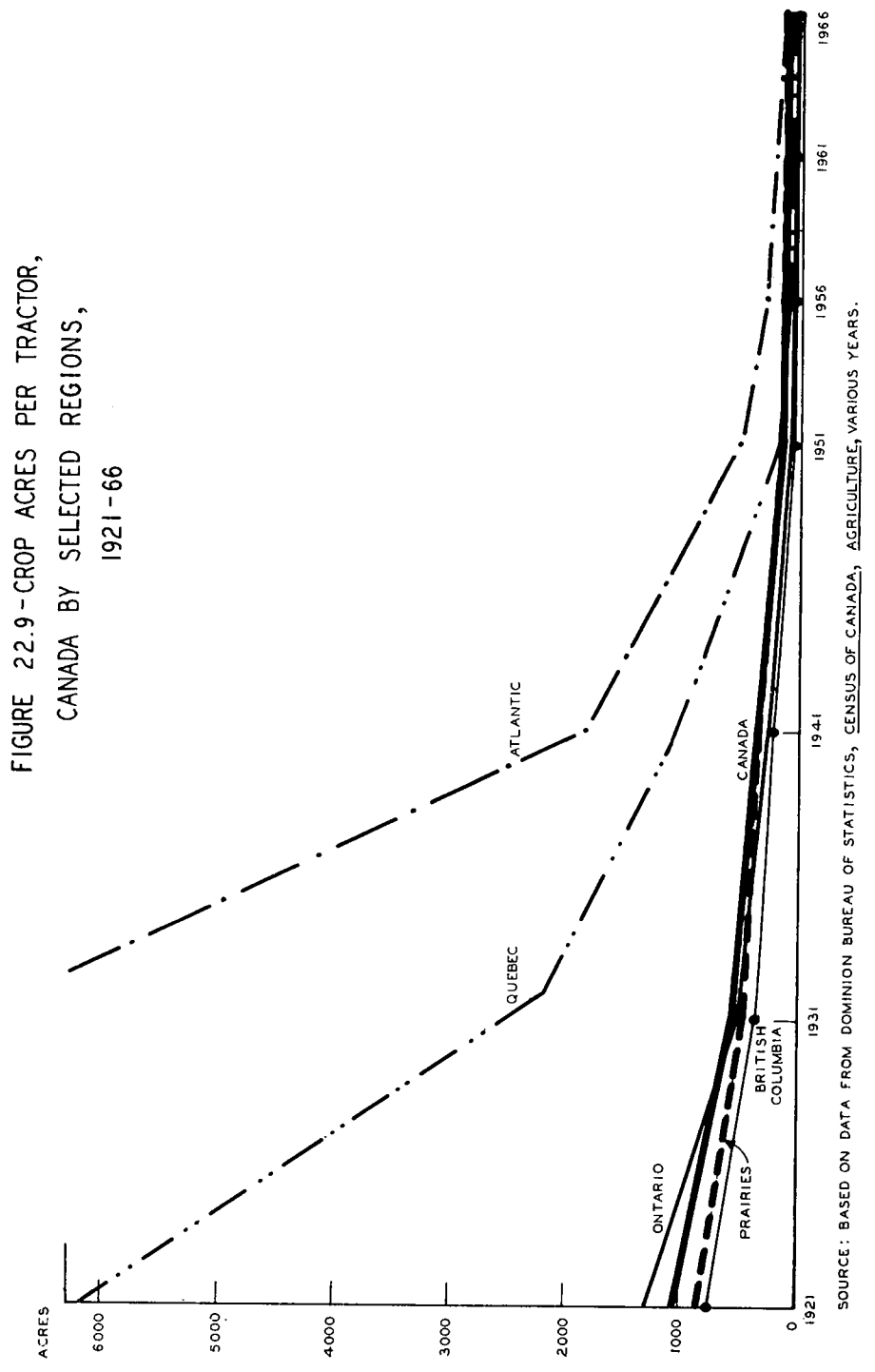


FIGURE 22.9 - CROP ACRES PER TRACTOR, CANADA BY SELECTED REGIONS, 1921-66

SOURCE: BASED ON DATA FROM DOMINION BUREAU OF STATISTICS, CENSUS OF CANADA, AGRICULTURE, VARIOUS YEARS.

by the growing commercial orientation of farming, whereby an increasing proportion of production is sold rather than consumed on the farm.

In general, the price indexes for livestock products have risen more than for crop products (see Figure 22.10). This reflects the shift in the pattern of food products consumed as incomes grow, coupled with a more rapid growth in productivity for field crops as compared with livestock products. In consequence, though the physical volume of output of both livestock and crop products have grown at much the same rate in Canada, total cash receipts from the former have increased faster than from the latter.

Farm Costs – The level of farm expenditures has shown a similar pattern of changes, declining as the general price level fell during the depression but rising continuously thereafter. Most of this increase, however, can be attributed to the rise in the index of prices paid for farm inputs. Thus, although the level of farm operating expenses (in current dollars) has increased by a factor of 5.5 since 1935, the real increase in constant (1935-39) dollars is a little over 1.5 times. There was a sharp rise in prices of all inputs during and after the Second World War and an especially large and sustained increase in wage rates. Farm machinery prices, too, have risen consistently since price controls were lifted in the late 1940s.

Farm Incomes – The path of farm incomes throughout this century is similar to the over-all pattern of farm costs and revenues. Certain differences arise, however, from two sources. Firstly, net incomes are determined by gross incomes, which include the value of produce utilized for farm consumption, inventory changes, and various subsidiary payments, as well as the cash receipts from sales of produce. Secondly, the paths of gross income and costs, although similar, have not experienced an identical growth throughout the period. Consequently, the difference between them, net income, reflects a particular pattern of its own.

Total net farm income suffered a severe decline during the early 1930s as the Canadian agricultural sector, in common with that of the United States, was hit hard by drought and depression (see Figure 22.11). Recovery was slow but steady until 1941. Thereafter farmers enjoyed a rapidly growing, if fluctuating, income. The peak was reached in 1951 when production and prices were at a high level, but for the subsequent three years product prices fell sharply while farm costs continued their rise. Total farm income dropped accordingly and did not show any significant rise until the 1960s.

To obtain a more realistic picture of farm incomes, several adjustments may be made. First, the effects of inflation can be removed to give the real purchasing power of income in constant dollars. Even so, the wide year-to-year fluctuations characteristic of agricultural production obscure the trends, which may be clarified by applying a moving average. Finally the net income per farm operator is perhaps the more meaningful measure of agriculture's prosperity.

Accordingly, Figure 22.12 shows the time path of real total net income (1949 dollars) and income per farm operator smoothed by a 4-year moving average. This

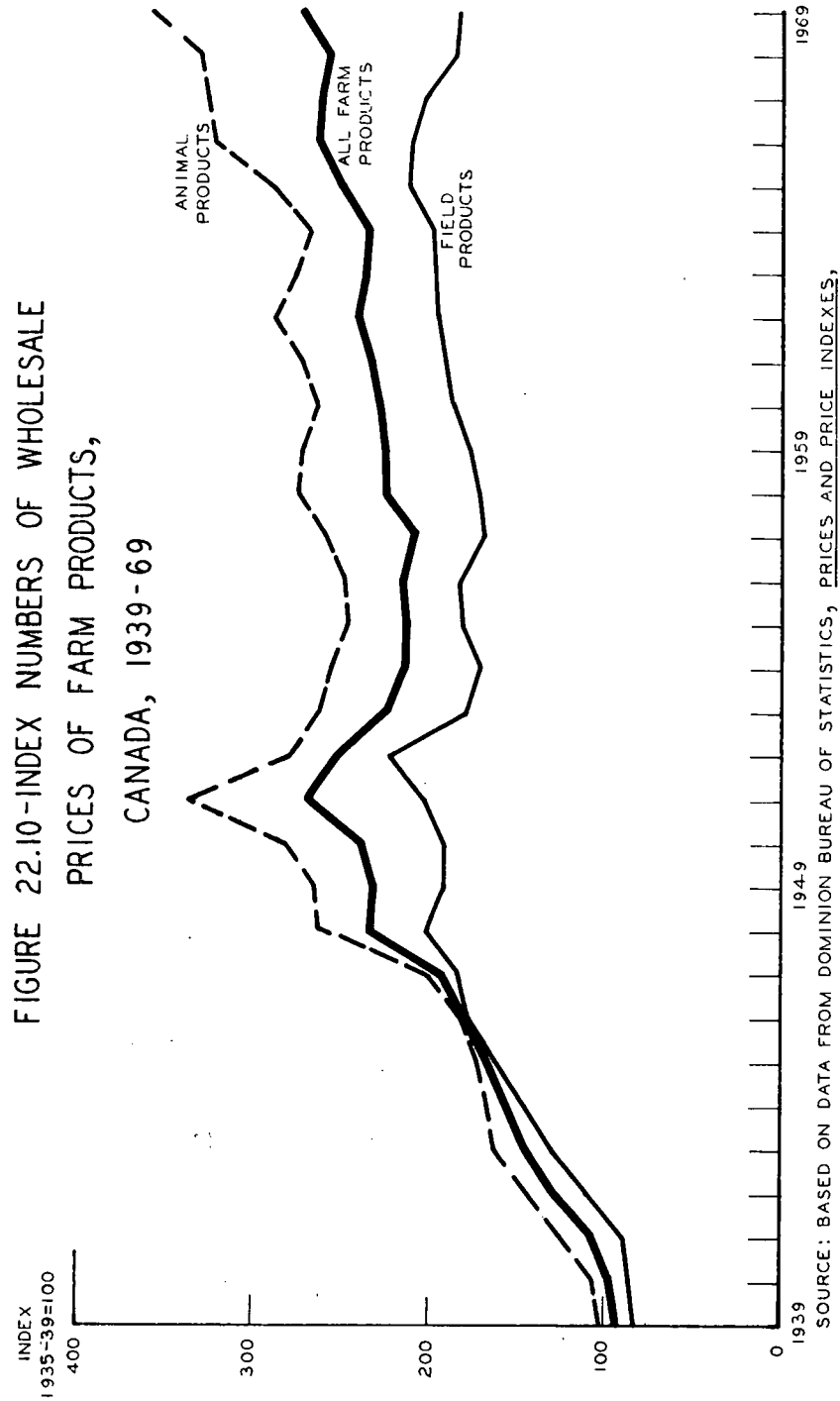
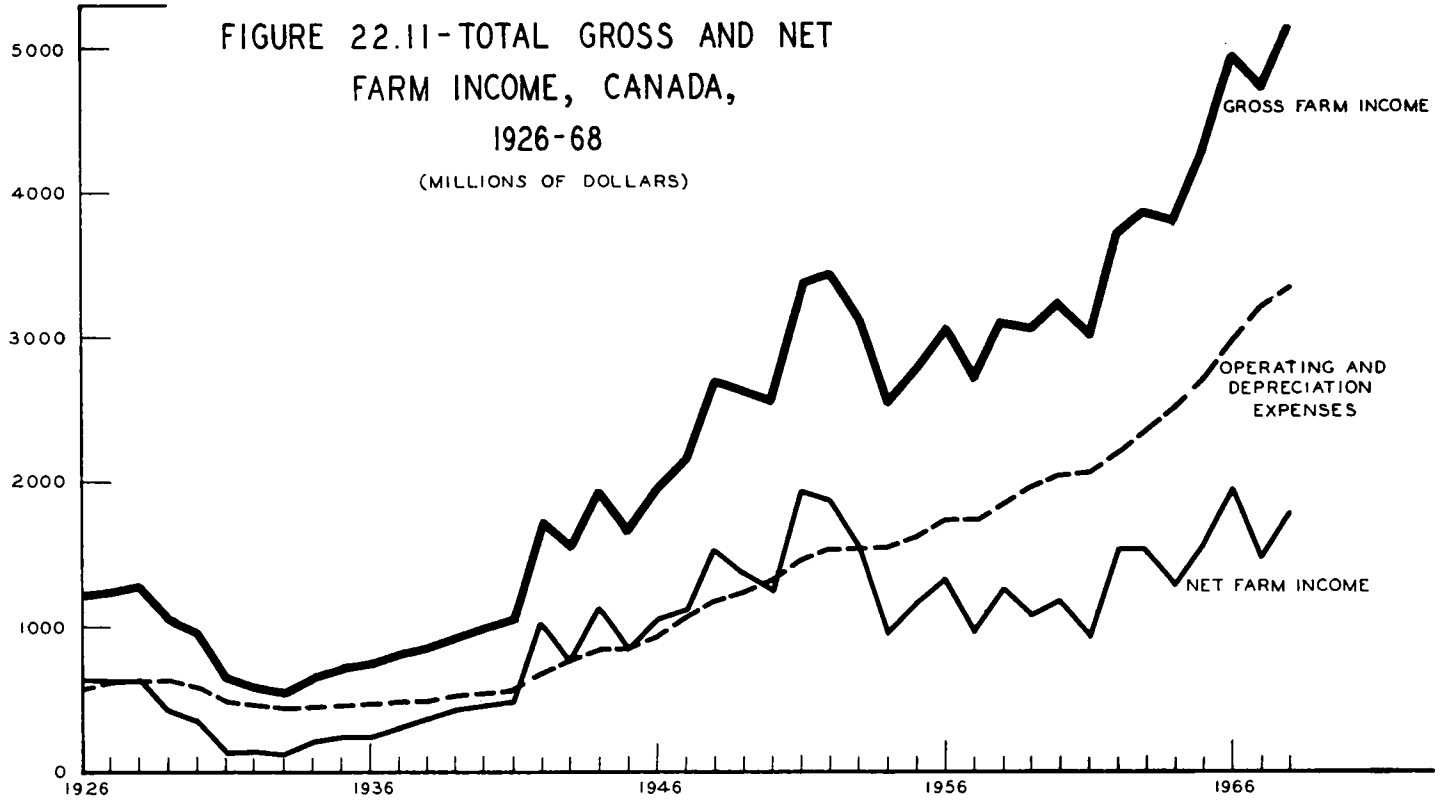


FIGURE 22.10-INDEX NUMBERS OF WHOLESALE PRICES OF FARM PRODUCTS, CANADA, 1939-69

SOURCE: BASED ON DATA FROM DOMINION BUREAU OF STATISTICS, PRICES AND PRICE INDEXES, CAT. NO. 62-202 AND CANADIAN STATISTICAL REVIEW, HISTORICAL SUMMARY, 1963 EDITION, CAT. NO. 11-502.



SOURCE: BASED ON DATA FROM DOMINION BUREAU OF STATISTICS SERIES PREPARED BY THE FARM INCOME SECTION OF THE AGRICULTURAL DIVISION, TAKING ACCOUNT OF ALL REVISIONS MADE TO SERIES UP TO AND INCLUDING THOSE RESULTING FROM THE 1961 AND 1966 CENSUS OF CANADA FOR AGRICULTURE; HANDBOOK OF AGRICULTURAL STATISTICS, PART II, FARM INCOME, CAT. NO. 21-511, AND FARM NET INCOME, 1968, CAT. NO. 21-202.

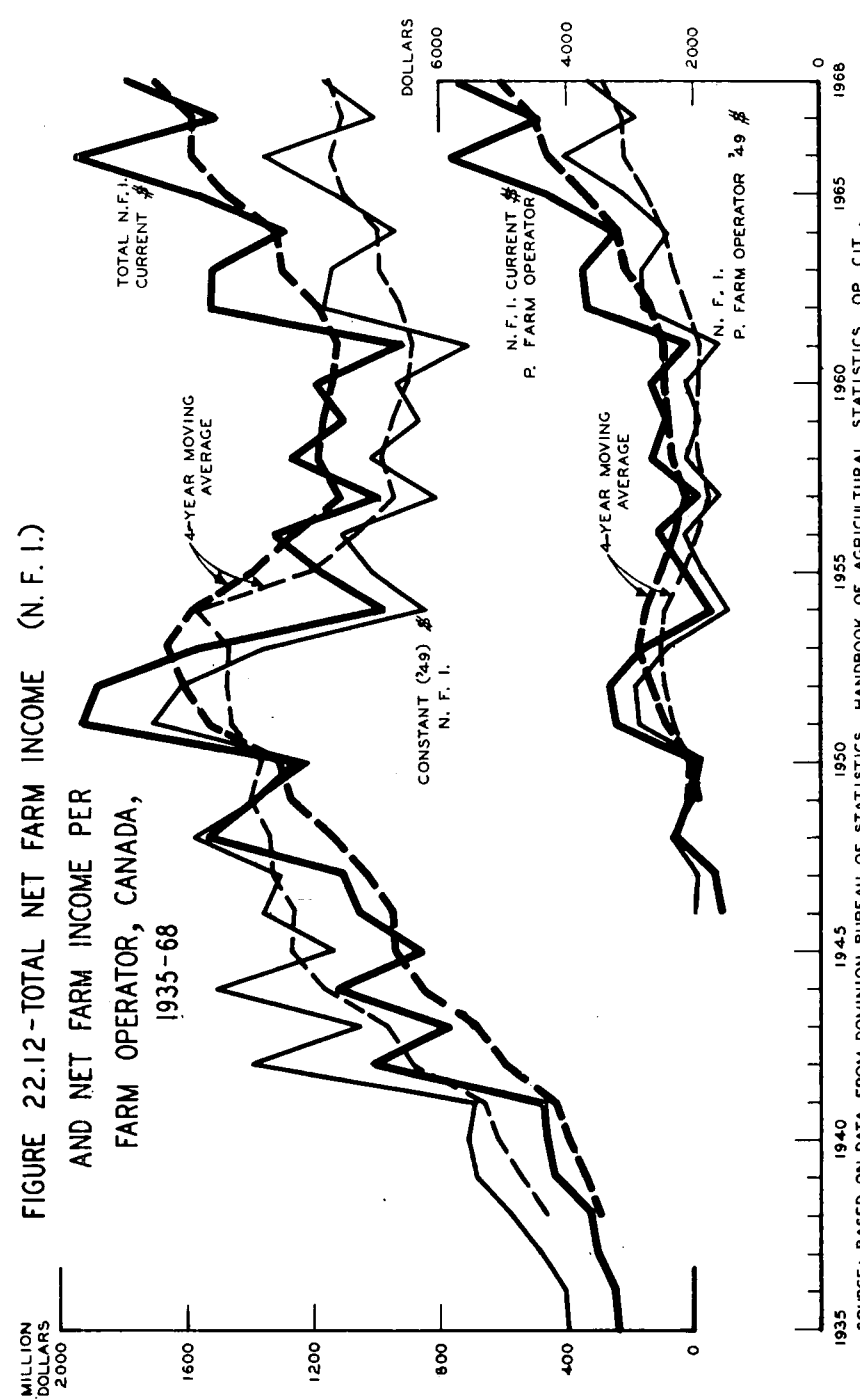


FIGURE 22.12-TOTAL NET FARM INCOME (N. F. I.) AND NET FARM INCOME PER FARM OPERATOR, CANADA, 1935-68

SOURCE: BASED ON DATA FROM DOMINION BUREAU OF STATISTICS, HANDBOOK OF AGRICULTURAL STATISTICS, OP. CIT., PRICES AND PRICE INDEXES, OP. CIT., CANADIAN STATISTICAL REVIEW, OP. CIT., AND DATA FROM SPECIAL SURVEYS DIVISION OF DBS.

reveals the general rise in real total farm income after the Second World War to a level in 1951 which has not been regained since. However, because the number of farm operators to "share the cake" has declined, real net income per farm has shown an appreciable growth since its doldrums of the 1950s—though this does, of course, have to service the correspondingly larger stock of resources under the farmer's control.

Capital Structure – The capitalization of Canadian agriculture has now reached a substantial level, with total farm assets valued at $21.2 billion in 1967 compared with $1.8 billion in 1901. This does not imply that the physical capital stock has risen more than tenfold, for much of the observed growth in value (especially in recent years) can be explained by the rise in real estate values rather than new capital formation in any real sense. Rising prices for livestock and machinery also have inflated farm capital values. Nonetheless, considerable growth in the real capital stock has taken place.

The remarkable rise in farm real estate values, shown in Figure 22.13, has occurred in all provinces, and is a phenomenon of some note. The major contributing factors have been the growth in output per acre coupled with a favourable market situation for agricultural products, the demand for land for farm enlargement (and urban growth in some areas), expanded credit availability, the possibility of (untaxable) capital gains, and the desire for an asset to hold as a hedge against inflation. Coupled to these are a variety of traditional and sociological aspects of landholding which influence the real estate market. The mixture of advantages and disadvantages to the farmer resulting from the rise in land values is examined later.

Machinery Investment – Investment in machinery has reflected, above all, the changing fortunes of farming, falling during the depression and rising sharply with the post-1945 prosperity. From 1941 to 1951, the capital value of machinery on farms more than tripled with the rise in the numbers of tractors and combines. Despite the inflation in land values, the relative importance of real estate in the asset structure fell to below 60 per cent, while machinery capital rose to over 20 per cent of the total.

All provinces have shown the same cyclical growth path in machinery investment, the intensity of mechanization reflecting differences in the type of farming practised. The Prairies, although characterized by highly mechanized crop production, have a lower machinery investment per improved acre (see Figure 22.14) than Ontario and Quebec. Having smaller farms and more mixed production patterns, these provinces appear to utilize a higher level of capital per acre. This is clear in the case of Ontario, the southern regions of which engage in highly capitalized, intensive crop production.

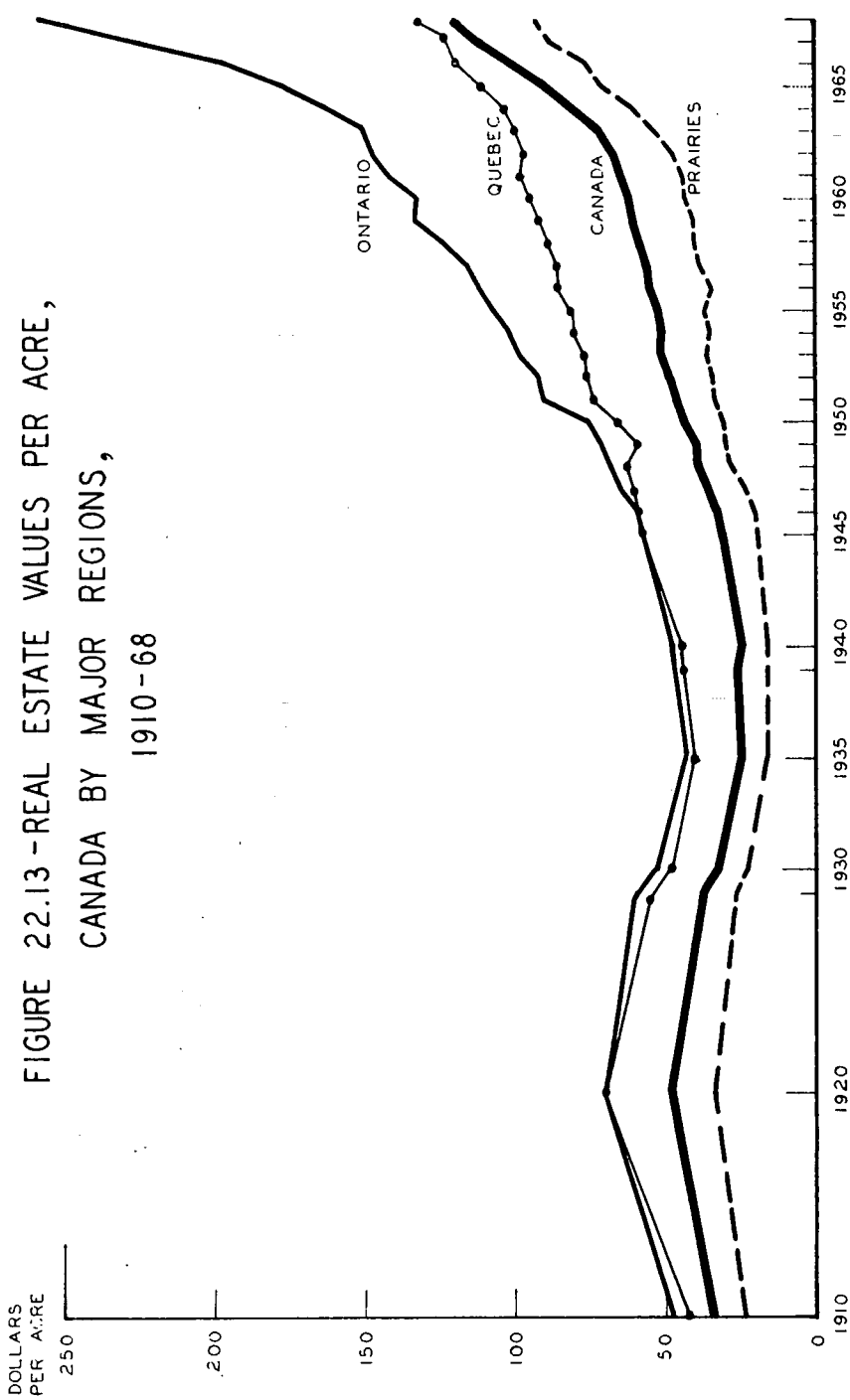


FIGURE 22.13 - REAL ESTATE VALUES PER ACRE, CANADA BY MAJOR REGIONS, 1910-68

SOURCE: BASED ON DATA FROM DOMINION BUREAU OF STATISTICS, AGRICULTURAL DIVISION.

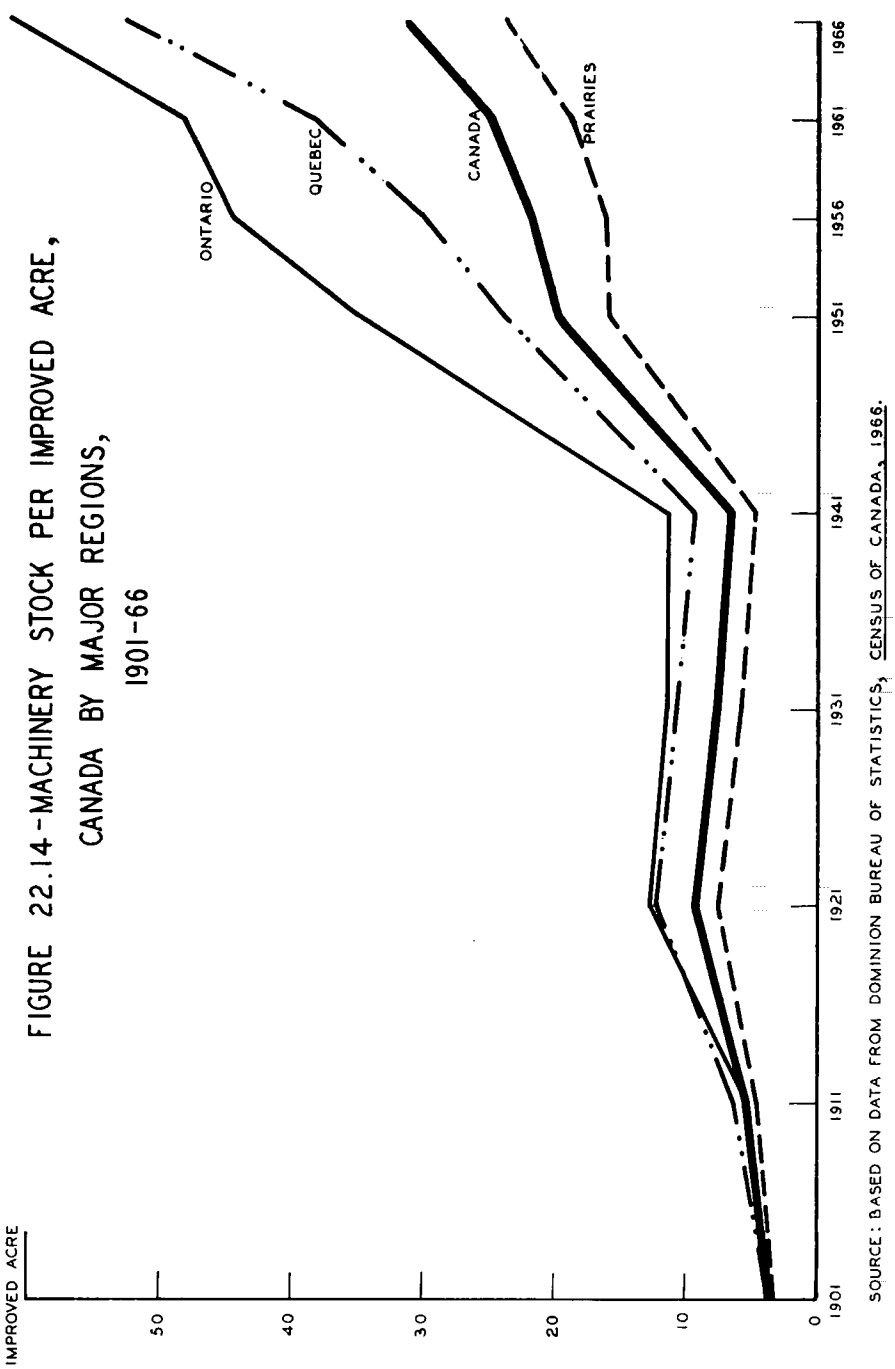


FIGURE 22.14-MACHINERY STOCK PER IMPROVED ACRE, CANADA BY MAJOR REGIONS, 1901-66

SOURCE: BASED ON DATA FROM DOMINION BUREAU OF STATISTICS, CENSUS OF CANADA, 1966.

TABLE 22.1–FARM MACHINERY IN CANADA, BY PROVINCES, 1966

Item	Atlantic	Quebec	Ontario	Prairies	British Columbia	Canada
Number of census-farms	26,393	80,294	109,887	194,844	19,085	430,522
Per cent with trucks or cars	78.7	80.0	91.6	93.4	88.0	89.3
Per cent with tractors	65.5	77.3	86.7	90.8	68.9	84.7
Per cent with combines	8.3	7.4	22.4	63.3	7.9	36.6
Per cent with swathers	0.6	3.6	4.1	55.7	4.6	27.2
Per cent with balers	23.6	30.4	34.3	32.2	19.3	31.3
Per cent with forage harvesters	1.6	4.5	9.9	3.4	7.5	5.4
Per cent with milking machines	23.3	47.3	34.9	9.1	14.2	23.9
Per cent with electricity	94.1	97.9	96.0	79.9	90.6	88.7

Source: Dominion Bureau of Statistics, *1966 Census of Canada, Agriculture* (Ottawa: Queen's Printer, June 1968), Table 21.

Chapter 23

DETERMINANTS OF THE GROWTH IN FARM MECHANIZATION

This chapter attempts to identify the dominant forces for change which have operated in the mechanization of Canadian agriculture. Both pressures which stimulate the growth of farm machinery use and those which might tend to restrain it will be identified.

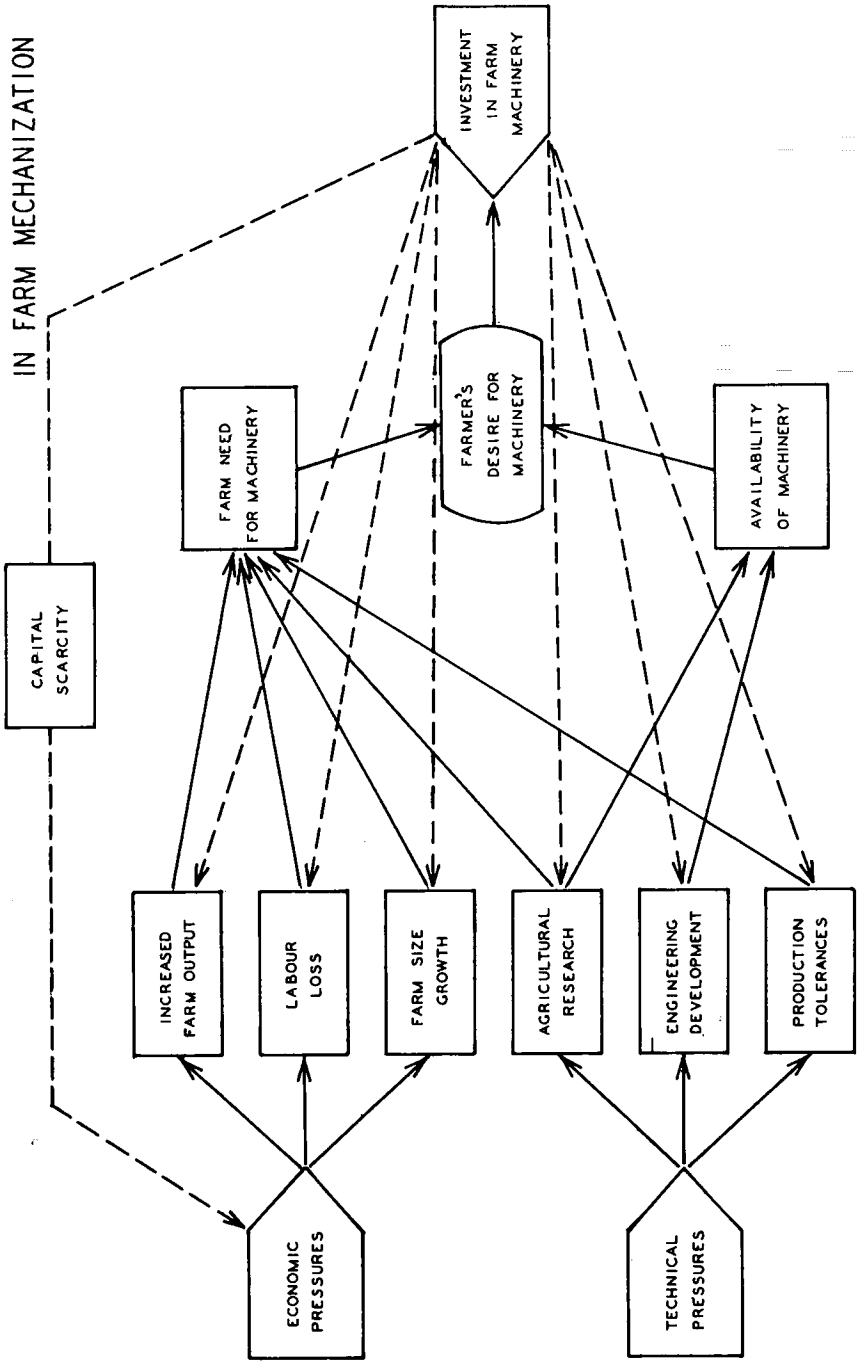
The forces that have led to the development of highly mechanized production in Canadian agriculture consist of a complex of technological, physical, economic and social factors which have perhaps operated separately at times, but usually in concert. Although the relative importance of each of these factors may have varied depending on the time, place, and type of mechanization considered, all have had some relevance to decisions on machinery use. It is largely impossible, therefore, to disentangle completely the farmer's decision process and attribute any particular aspect of mechanical innovation to a specific causal influence. The adoption of any new machine is merely the observed net result of all these influences.

The main elements of the farm mechanization process are depicted in Figure 23.1.

Technological Factors Influencing Farm Mechanization

Machine Technology – The development of machinery technology is the fundamental factor underlying the growth of mechanized production. Sometimes, the development of an implement may be enough to stimulate its adoption simply because it is so superior in use to any alternative. This was undoubtedly true of the moldboard plow and the row-spacing drill. Drawn by horses, they accomplished tasks that could not be as effectively handled by manpower alone. For innovations that perform new operations, or operations that were previously all but impossible, often the mere appearance of the machine provides a strong spur to its adoption. The same may well be true for new machines that are vastly superior to the traditional ones. Thus, the tractor heralded the demise of the work-horse and the combine superseded the binder and thresher.

FIGURE 23.1 - THE PROCESS OF CHANGE IN FARM MECHANIZATION



During recent decades, advances in farm machinery technology have led largely to major improvements and refinements in the basic farm machines, although some totally new machines have been developed too. Engineering and industrial research, most of it not specifically oriented towards agricultural machinery, has resulted in advances in all aspects of mechanical technology which have had important implications for farm machines. Based on these and their own developments, agricultural engineers have designed and offered to farmers a range of farm machinery with capabilities encompassing the whole spectrum of farming activities. Many of these satisfied needs that farmers had long recognized, while others offered facilities for which previously there had been no specific demand. Good examples of this are the refinements that have been added to the basic farm tractor. The modern farmer takes advantage of a reliable and efficient self-starting diesel engine, independent power take-off, three-point linkage and draft control, and the capabilities afforded by the tractor hydraulic system.

As well as having advancing mechanization "pushed" at him by the agricultural engineer, the farmer himself has exerted a "pull" on the machinery firms to develop the implements he requires to satisfy particular needs. The diskers now marketed by most machinery companies grew from the recognition by Prairie farmers of a need for a moisture-conserving alternative to the moldboard plow in large-scale cultivation of arable land. Similarly, the swather originated in a farmer's recognition of the need for a machine which would facilitate combining in areas with a short season. With the larger farms and more intensive production of modern agriculture, farmers are increasingly conscious of the difficulty of accomplishing cultivation and seeding operations within the critical time period. As a result, they have demanded more powerful tractors to pull wider implements–a demand that the manufacturers have shown themselves ready to satisfy.

Other Technology – Progress in the non-machinery technology of agricultural production has also been an important causal factor in the growth of farm mechanization. The benefits of research into fertilizers, herbicides, and pesticides could never have been exploited had not the appropriate machines for their application been developed by machinery companies, and adopted by farmers. The widespread use of fertilizer distributors and sprayers stems directly from these advances in agricultural chemistry. Other examples of agricultural research creating pressures for the development of a particular type of machine, and for its subsequent adoption by farmers, can be quoted: the breeding of monogerm seed in beet crops, the results of experiments into fertilizer placement in potato production, and the advent of ensilage for fodder conservation, have encouraged agricultural engineers to develop machines that could exploit these new production techniques.

The availability of a technological advance does not always imply an automatic and parallel growth in mechanization. The operation of increasingly complex machinery requires new skills on the part of the farm labour force, and the maintenance of these machines demands technical competence and facilities of a

high order. Where these skills and facilities are not available, or grow at a slower rate than the availability of sophisticated machinery, their absence acts as a brake on the rapid or widespread adoption of advanced mechanization. The immediate take-up of new machinery has in some instances been impeded by machines being marketed before they were fully tested or appropriately tailored to their intended task. In addition, farmers' lack of information concerning the capabilities and reliability of a new machine acts as a deterrent to its use, thus causing a lag to arise between the introduction and subsequent general adoption of new machine technology.

Despite this, however, it is clear that technological developments themselves have provided an important element in the pressure towards mechanized farming methods. This implies a great tribute to the ingenuity, skill, and inventiveness of farmers and engineers.

Production Risks – Another factor that has spurred the adoption of farm machinery arises from the increasing level of risk confronting the farmer, and the potential ability of machinery to reduce, or in some cases largely eliminate, some of these risks. With the growing commercialization of agriculture, higher yield levels, and larger holdings, the individual farmer is handling a greater value of output each year. Given the vagaries of the weather and the uncertainties inherent in a biological production process, the farm's production represents many thousands of dollars which are virtually under constant risk right up to the time the output is harvested. In many ways the modern farmer can look to his machinery to provide an important measure of insurance against output uncertainties.

For example, the level of yield for many crops is largely dependent on seedbed preparation and planting being completed by an early date in spring. When weather delays these operations, the available time for the task may be very short if planting is to be achieved at the optimal time. The larger acreages under each farmer's control worsen this problem, leaving him little alternative but to mechanize his operations and utilize large-capacity machines to attain the necessary rate of work. Even if planting is completed in time, the full growth potential of the crop subsequently requires an adequate level of fertilization, spraying, and weeding–operations which rely on a high level of machinery use. Similarly, the level of harvested yield is dependent on harvesting being accomplished within a short and very critical period after ripening, or losses from shelling and spoilage can radically reduce profits. The short time available for harvesting, and further uncertainty surrounding the availability of suitable operating conditions within this period, induce farmers to acquire an ample machinery capacity to ensure that the crop can be gathered with reasonable certainty.

In livestock production, too, there are many instances where the effort to reduce variability in output leads towards mechanized production methods. In dairying, an early example was the milk cooler, which minimized the risks in milk storage. Currently, the newer forage equipment such as the hay conditioner and the

forage harvester are being adopted to bring more certainty into the production of good quality conserved fodder.

In many other ways, the susceptibility of farm output to the uncertainties of weather has led the farmer to look to mechanization for some insulation from its effects. Thus investment in grain-drying facilities can compensate partly for wet harvest conditions, and the installation of irrigation equipment can provide some insurance against drought. As in all cases of insurance, however, the reduced uncertainty only comes at an additional cost. But, with the narrowing of profit margins and the large amount of capital at risk, levelling out fluctuations in output becomes a consideration of major significance.

Physical Factors Influencing Farm Mechanization

Labour Loss – The growth of farm mechanization and the reduction in the agricultural labour force have been clearly associated during recent decades. While the number of persons employed in agriculture has halved since 1946, the stock of machinery on Canadian farms has almost doubled in constant dollars over the same period. On empirical as well as logical grounds, therefore, it is not unreasonable to look on labour loss as an important factor in the process of mechanization, both on the individual farm and in agriculture as a whole. The direction of causality between these changes is not immediately obvious, however. Has the loss of agricultural labour forced farmers to mechanize, or have workers been forced out because farmers found it advantageous to replace them by machines? Probably both types of pressure have been operating.

Although it is impossible to specify the number of farm workers who leave agriculture of their own free will, it is clear that voluntary out-migration is an important element in labour loss. Studies have shown that the "pull" of higher off-farm earnings is a significant factor in attracting workers away from the land.[1] The family labour component of the aggregate farm labour force also tends to decline as the tendency towards longer education makes farm children unavailable for work on the family holding; further, it changes their outlook, and many of them look elsewhere for employment.

Over time, the steady flow of labour into the non-agricultural sector, whatever its cause, means that an important input in the production process has been lost. If output is to be maintained, some alternative must be found. Fortunately, the possibility of utilizing machines to do the work formerly done by man has been increasingly open to the farmer. He has been able to substitute for the lost manpower, by investing in more and larger machines, so avoiding reduction in output. Part of the decreased labour input has been offset, too, by the exploitation of advances in non-machinery technology, in the form of improved seed varieties, fertilizers, chemicals, and better production practices.

[1] K.G. Cowling and D. Metcalf, "Labour Transfer from Agriculture: A Regional Analysis", *The Manchester School*, Vol. 36, No. 1, March 1968, pp. 27-48.

The extent to which a shortage of labour will induce further mechanization will depend on a variety of factors, particularly the type of farming and the products produced. This is because machinery is not a perfect substitute for labour in all cases. Some machines, such as the complete potato harvester, the side rake, or the milking machine, can be regarded very largely as a direct substitute for labour use. Other forms of mechanization may either augment the efforts of human labour or perform operations that were not previously attempted since they were not feasible using manpower alone; the plow, the hammer-mill, and the grain-dryer fall into this class. Other machines, especially the more recent ones, combine into one unit the operations previously conducted by several machines and thus substitute for the older types of machinery as well as for labour. The combine harvester and the potato planter are good examples of this latter type. Many machines currently available to the farmer will have all three of the above characteristics, and as a result it is virtually impossible to attribute a proportion of the observed growth in farm mechanization specifically to the reduction in labour use. On the individual farm the impact of labour loss on further mechanization will depend also upon the size of the farm, the remaining labour force, the level of mechanization already achieved and the available capacity that can be exploited.

In summary, it is unlikely that agriculture could have withstood the dramatic decline in its labour force had it not been able to compensate by increased mechanization; conversely, it is questionable whether mechanization would have reached its present level were it not for the presssures of labour loss.

Output Expansion – Agricultural production has not only been maintained in the face of a declining labour input, but has actually shown a steady increase over the past decades. From 1942 to 1967 the physical volume of output from Canadian farms rose on average by slightly over 2 per cent per year. This expansion in output itself has given rise to pressures for further mechanization, in order that the growing volume of farm production could be handled. Similar pressures were exerted in the earlier years of this century when Canadian agriculture was experiencing its "expansion phase". As the area of settled improved land in farms grew, agriculture required a growth in both its labour force and associated machinery in order to cope with the expanding production base. Now, even with a declining labour force, the expansion in farm output has been maintained, and so too has the need for increased machinery capacity to handle it. Thus, even if the size of the labour force had remained constant, the observed growth in output alone over the past 30 years would have been sufficient to explain a significant part of the growth in farm machinery use.

Farm Enlargement – The amalgamation of holdings and the increase in average farm size is closely associated with the decline in the labour force, and has important implications as a determinant of mechanization. The very fact of amalgamating two holdings implies that one complete farm family leaves the land–that is, the agricultural labour force loses a farm operator and his associated family labour (unless they transfer to the hired labour force). From the standpoint

of the agricultural industry, therefore, its labour input has declined and potentially will require replacement by alternative inputs. In any individual case it may happen that the amalgamating farmer already had the necessary machinery capacity to handle the additional acres; indeed this may well have been a factor that encouraged him to acquire more land. Over time and for the industry as a whole, however, this cannot usually be the case. Thus, as some farmers react to economic pressures by leaving agriculture, and others by enlarging their farms, a basic stimulus is created for an increased investment in machinery capacity and other complementary inputs. Farm amalgamation may further spur machinery investment by inducing the farmer to reorganize and rationalize his whole production structure and method of farming in order to exploit any cost economies obtainable from larger scale mechanized production.

Economic Factors in the Growth of Mechanization

Advances in machinery technology have been basically permissive factors in the growth of mechanization: continued labour loss, larger farm sizes and higher risk levels have created a potential need for expanding machinery use. But the actual growth in mechanical equipment on farms has only come about because finally the net weight of economic considerations has been favourable to this investment. Thus, given the availability of machines and a useful place for them in the farming system, farmers have been able to increase profits or offset losses by their adoption, and have been able to acquire the necessary capital in order to exploit these gains. While the initial cost of machinery investment is high, the cost of *not* mechanizing has been even higher in terms of economic opportunities forgone.

Labour Replacement – When labour leaves the farm, it need not be replaced by machines, for agricultural output could be allowed to fall as the labour input declined, or it could be maintained by resort to expanded use of non-machinery inputs. In fact, studies have shown that there has been a strong economic justification for using machinery inputs in the place of labour. Econometric analyses of farming in Manitoba suggest, that, at 1966 prices, one dollar invested in machinery expenses could substitute for between $1.20 and $1.50 spent on labour–thus resulting in the same level of output at reduced cost.[2] Consequently, farmers could not only compensate for lost labour but had some economic incentive to actively encourage a reduction in their labour force and replace it by machinery services.

On the other hand, while this indicates that the substitution of machinery for labour is profitable from the industry's standpoint, the strength of this as a determinant at the farm level is less explicit. Much of the decline in the work force has been in the family labour component which does not have an appropriate wage

[2] A.W. Wood, T.D. Harris, J.P. Hudson and F. Tennenhouse, *Effect of Changes in Farm Machinery on Cost and Productivity of Prairie Agriculture, 1945-1966,* unpublished Commission study, 1968.

rate for comparison with machinery productivity. Furthermore, where the decline has comprised farm operators quitting production, this does not represent a conscious farmer decision to substitute machinery for labour–though this may be the final effect.

Machinery Economies – The possibility of per unit cost reductions from larger scale mechanized operations provides an economic basis for the amalgamation of holdings and the move towards larger farming units. Conversely, the autonomous growth in the size of farms actually requires a shift towards machinery-based production for economic as well as for physical reasons.

The analysis of Manitoba farms for 1966 indicated that the return from one extra dollar spent on machinery services, with all other inputs held at a constant level, was about $1.50. This was higher than the return that could be achieved from a dollar spent on any other input except fertilizer. An earlier Manitoba study[3] suggested that the rate of return on further capital invested in farm machinery was of the order of 25 per cent, while studies in the United States[4] have estimated the marginal return on machinery capital at between 15 and 30 per cent. These are, however, average figures relevant to the group of farms studied; any individual farmer is not necessarily able to achieve gains of this order. Furthermore, since he cannot invest in marginal units of one dollar, the profitability of investing several thousand dollars in an additional machine may sometimes be negative. It is clear, however, that regardless of the desirability of increasing mechanization to counteract labour loss or increased farm size, much investment is justified on economic grounds alone. The contribution to productivity of farm equipment makes it a profitable area for farmers to invest capital–if they have it, or can acquire it. The Manitoba study suggested that machinery inputs could rise by as much as 50 per cent and still cover their costs.

Cost-Price Pressures – The underlying economic incentive to substitute machinery for labour, and to utilize relatively more machinery when expanding output, arises from changes in the relative prices received for farm products and paid for various inputs. During the Second World War, the subsequent world food shortage, and then the Korean War, the index of prices received for agricultural products rose rapidly and remained well above the index of prices of commodities and services

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[3] J.C. Gilson and M.H. Yeh, *Productivity of Farm Resources in the Carman Area of Manitoba,* Department of Agricultural Economics, University of Manitoba, Bulletin No. 1, Winnipeg, 1959.

[4] E.O. Heady, *Productivity and Income of Labour and Capital on Marshall Silt Loam Farms in Relation to Conservation Farming,* Agricultural Experiment Station, Iowa State College, Research Bulletin No. 401, Ames, Iowa, 1953.
E.O. Heady, *Resource Productivity and Returns on 160-acre Farms in North-Central Iowa,* Agricultural Experiment Station, Iowa State College, Research Bulletin No. 412, Ames, Iowa, 1954.
E.O. Heady and R. Shaw, *Resource Returns and Productivity Coefficients in Selected Farming Areas of Iowa, Montana, and Alabama,* Agricultural Experiment Station, Iowa State College, Research Bulletin No. 425, Ames, Iowa, 1955.
E.O. Heady and E.R. Swanson, *Resource Productivity in Iowa Farming,* Agricultural Experiment Station, Iowa State College, Research Bulletin No. 388, Ames, Iowa, 1952.

used by farmers, with both indexes on a 1935-39 base (see Figure 23.2). This more favourable cost-price ratio encouraged an expansion in farm output, and, as the figures quoted earlier indicate, an increased farm machinery input was a profitable means of achieving this. In addition, the relatively high incomes earned provided a useful source of funds for machinery investment. After 1951, however, the level of agricultural prices started to fall from its high point, while input prices continued to rise. By the mid-fifties, the product price index had started to rise again, keeping pace for a while with the increasing input prices. In 1961, farm product prices faltered again, and have since been inflating more slowly than costs. Thus, since the early fifties, there has been an increasing "cost-price squeeze" operating on the farmer, creating a pressing need to improve agricultural productivity in order to maintain adequate farm incomes.

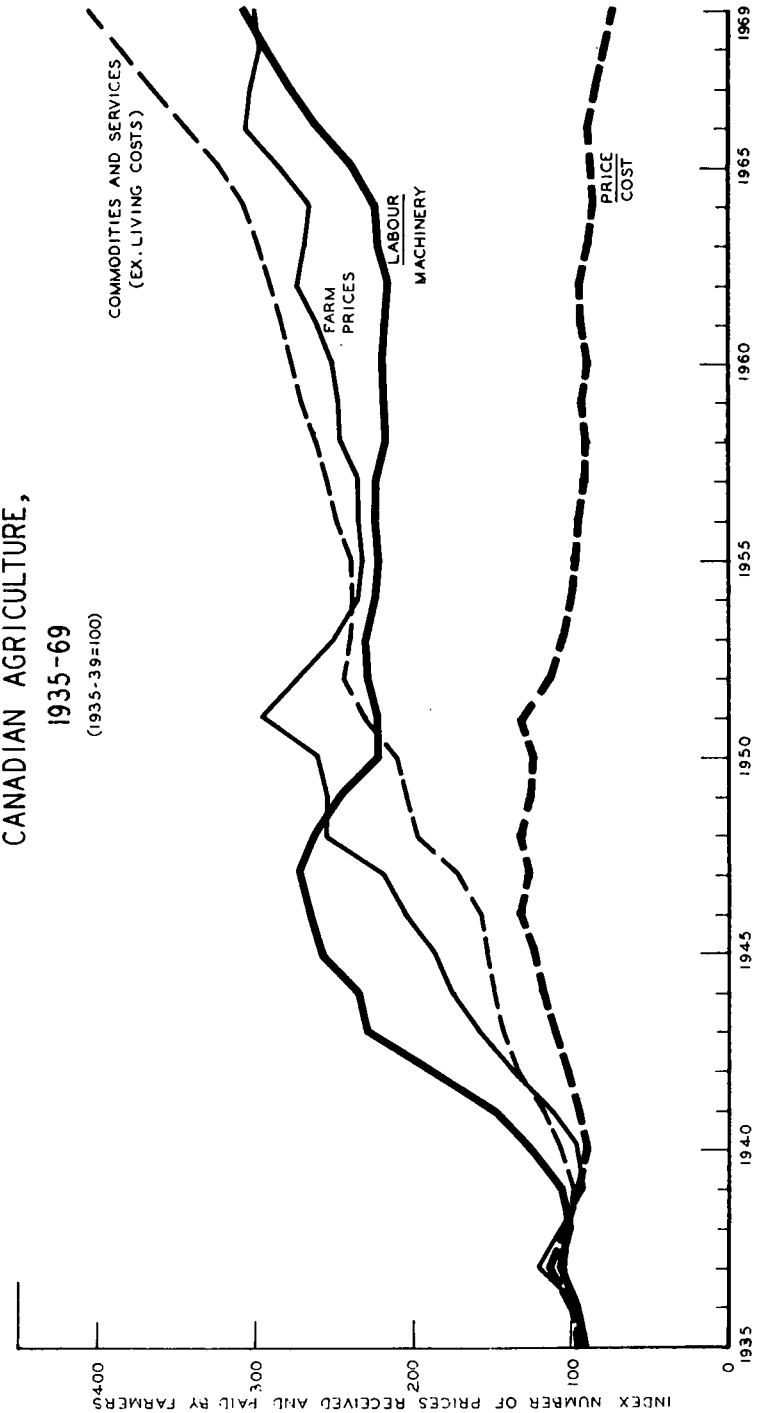
Productivity can be increased by high-cost inputs being replaced by lower-cost inputs, or substituting high-productivity production factors for low-productivity ones. Much of the economic incentive to replace labour by machinery has arisen from this source. Although the price indexes of both these inputs have risen since 1935, the index of wage rates grew much faster than that of machinery prices until 1947. During this period the ratio of farm wage rates to machinery prices rose from an index of 100 in 1935-39 to 270 by 1947, indicating a strong pressure to reduce costs by substituting machinery for labour. Since 1950, however, both indexes have increased at virtually the same rate, so on the basis of price levels alone there has been no distinct advantage in substituting machines for men. But price indexes may not measure fully the economic difference between the inputs–their productivity per unit cost. The contribution of $1 worth of machinery to farm output has been greater than that of $1 spent on labour (as the Manitoba figures show), and for this reason farmers have found it advantageous to combat the cost-price pressures by shifting to higher levels of mechanized production.

With narrowing per unit profit margins, higher levels of output are necessary to provide an adequate aggregate farm income, and for the individual farmer, this in turn implies intensifying production or expanding the acreage farmed, or both. With an increasing scale of operation, about the only means available to the farmer for cultivating more acres, and handling the growing output levels, has been to achieve a high level of mechanization. Furthermore, the pressure on prices (both domestically and internationally) and costs has resulted in a need for a consistently high and uniform quality of product–whether it be the final output such as grain, or a farm-produced input such as fodder. This can only be ensured on large acreages by utilizing a full complement of equipment to accomplish the necessary growing and harvesting operations within the limited and critical time periods available. All this has led to a growing investment in farm machinery.

Unlike fertilizer, which can be purchased as it is needed, the acquisition of new machinery represents an investment of a medium-term nature. In production economics terminology, it is a flow input; its stock of services is purchased in advance and is given off more or less uniformly over time. These services cannot be

FIGURE 23.2-PRICE-COST RELATIONSHIPS, CANADIAN AGRICULTURE, 1935-69

(1935-39=100)



SOURCE: BASED ON DATA TAKEN FROM HISTORICAL STATISTICS OF CANADA, THE MACMILLAN COMPANY OF CANADA LTD., 1965; SELECTED STATISTICAL INFORMATION ON AGRICULTURE IN CANADA, OCTOBER 1969, AND CANADIAN FARM ECONOMICS, APRIL 1970, CANADA DEPARTMENT OF AGRICULTURE.

stored for future use if not exploited at any given point in time (if a combine's harvesting capacity is not used in August these same services are not available for use in December, nor even the following August); thus the value of the investment depreciates over time, whether it is used or not. Furthermore, the investment requires additional expenditure (in the form of repairs and maintenance) in order to ensure that the full potential stream of services is gained.

Thus, although machinery may readily substitute for labour in a functional sense, and may be economically justified in terms of lowered annual production costs in the future, the immediate economic effect on the farmer may make the investment less obvious. To take a very simple example, investing $16,000 in machinery with a life of eight years may enable him to reduce his labour force by one man earning $3,200 annually. In one sense this represents a cost saving of $9,600 over eight years. In another sense, however, he is effectively having to find five years' wages in advance in order to acquire the machine.[5] This means substituting a lump-sum cost at one point in time for a very much smaller flow cost which could be paid out of the income that is generated on the farm during the succeeding years. The difficulty of acquiring this necessary initial capital sum may deter the farmer from making the investment.

Farm Income Level – The availability of capital for medium-term investment is an important determinant of farm mechanization. For some farmers, current or accumulated profits may provide a ready source of funds and such "plowing back" of profits can often finance a significant part of a farmer's purchases of new machinery. This is particularly true where farmers trade in major equipment items every year or two so that the net payment required each year is small. In addition, the amounts charged to depreciation of machinery are an important source of finance over time. For the twenty-year period from 1949-69, depreciation against machinery amounted to around 90 per cent of the value of new machinery purchases.

Nevertheless, for new entrants and for farmers who are expanding their operations in a major way, the availability of capital may still be a major constraint. Net income per farmer remained fairly static throughout the late fifties and if this series is divided by the price of farm machinery, the purchasing power of the farm operator's income for machinery has declined continuously since the end of the Second World War.

The problem of capital availability for mechanization has been aggravated by the fact that land and machinery are, in a sense, complementary inputs. Pressure to mechanize production and to increase farm size often go hand in hand. So, with land and machinery being competitive in their demands for already scarce farm capital, and the pressure to increase farm size being perhaps stronger than the

[5] This simple comparison disregards operating and repair costs on the machine. In addition, of course, discounting procedures should be used to obtain the more valid comparison. If the savings on future wage costs are discounted at an annual rate of 7 per cent, however, the savings from machine investment still amount to $3,133 over eight years.

pressure to mechanize further, it may often become increasingly difficult to find the funds essential for machinery purchase as capital is committed to the acquisition of land. Both credit availability and taxation policy affect agriculture's ability to acquire new farm machinery. However, the impact here is mainly at the individual farm level and will be discussed in some detail in Chapter 25.

Social Factors Influencing Farm Mechanization

Farmers' Attitudes – Some of the attitudes that can influence the process of farm mechanization may be a reflection of the fundamental values of society. Great stock is often placed on individual achievement and on the material gains that are considered to be the reward for hard work. Since the possession of farm machinery is one visible means by which status or achievement can be judged, the acquisition of farm machinery may have a competitive element. Mechanical equipment may be a symbol by which status is indicated–just as size of land holding and numbers of livestock have been in older and less-developed communities. Still, given the evidence that investment is profitable in any case, there is no clear evidence that prestige factors alone are important.

Over time, attitudes to machinery have changed. Machinery has become widely accepted as a major part of farming, and one that is attractive to many farm people. Extension personnel have observed that the presence of machines is often the one thing that is effective in persuading young men to stay on farms. Whether there is some psychological satisfaction in the noise and motion of a big machine, or some pleasure in seeing a good job well done, does not seem to have been explored. On the other hand, it is certainly true that all kinds of farm machinery are not only accepted but relied upon. When tractors first became widespread in the 1930s, they were on trial. Although the number of tractors increased at that time, the number of horses did not begin to decline rapidly until almost a decade later. Little of the same caution is evident in more recent times. Once a machine is shown useful and effective it is usually introduced as soon as economic pressures permit.

On the other hand, the recognition that increased mechanization is associated with changes in the way of doing things, and with the passing of a familiar mode of life, can lead to an adverse reaction to machines. The fact that increased mechanization leads to the movement of people out of farming may cause some resentment to be felt toward it. Since the rural-to-urban transfer causes many stresses both in those who leave and those who stay, the social connotation of expanding mechanization may not be a pleasant one. When it is remembered, too, that machines can have injurious physical and health effects, it is not surprising that the reaction in some cases might be one of distrust. To the extent that this feeling does exist, it must tend to work against the increase of mechanization.

External Influences – A positive attitude to machines and equipment is fostered by the imagery and ethics of the modern world of science and technology. Thus, the present-day farmer can identify–in terms of his tools, equipment, and expertise–with those involved in the construction, manufacturing, and transport

industries, and all have given a ready acceptance to technology which involves a commitment to continuing change.

Part of this new imagery is the acceptance as a "norm" of an urban standard and mode of life. Consequently there seems to have developed an increased leisure preference among farmers, together with an expanding demand for domestic capital goods to take some of the drudgery out of farming. An example might be seen in the expansion of materials-handling equipment on farms. The greater demand for household consumer durables, on the other hand, by competing for scarce capital, might operate as an opposing force.

Risk Effects – Other pressures operate to resist or slow the rate of mechanization. On the management side, new technology often requires new knowledge. The learning process takes time and effort, and a shortage of either may impede the progress of mechanization. In the same way, new machinery may require new operating and maintenance skills and these, too, have to be developed. Where the farmer is an owner-operator, this means that competence has to be developed in two separate areas before a mechanical innovation can be fully exploited. Though the acquisition of this ability can be facilitated by formal training, the shortage of training facilities may be a limiting factor.

Uncertainty may also place a real restraint on innovation. Confronted with a new situation, the farmer's reaction may be simply one of fear of the unknown. In addition, the fear of not being successful in the adoption of a new technique can provide a strong disincentive for innovation. Alternatively, if mechanization is considered desirable, the possibility of failure associated with not adopting the new technology may have an offsetting effect.

A similar restraint on the progress of farm mechanization may be imposed where capital investment is required. Often medium-term credit has to be used for the acquisition of new machinery and there may be an unfavourable attitude to the use of this type of credit. To some extent this is a holdover from unfortunate experiences of the 1930s. To an even greater extent it is a reflection of the strong values held concerning sovereignty of the individual, and particularly of the authority and freedom of action which it is considered are lessened or lost by being in debt. A Commission study has shown that the main concern of farmers with regard to credit is not the amount available, but the terms and conditions on which it is available.[6] The same study revealed that many farmers felt that credit was too readily available. In so far as these attitudes reflect a reluctance to use credit where it is profitable to do so, they are likely also to inhibit the growth of farm mechanization.

Such attitudes may have their basis in the risk considerations associated with borrowed capital and its effect on equity. Uncertainty can be directly related to the

[6] A. Segall, *Farmers' Attitudes to Farm Machinery Purchases,* Royal Commission on Farm Machinery, Study No. 4 (Ottawa: Queen's Printer, 1969).

size of investment, in that the potential loss is greater for a larger investment as is the possible gain. In general the cost of a decision error is higher. But the risk involved in investment may be increased by changing equity proportions. As the amount of capital borrowed increases so do the charges related to it. These costs are fixed, in so far as they are not related to seasons or farm output. Consequently, as the proportion of borrowed capital rises the fixed costs increase directly and the possibility of a loss is heightened. In other words, increasing risk accompanies decreases in equity. Since bankruptcies are irretrievable, the spectre of vanishing equity haunts small farmers and businessmen alike, and more so in situations where output is uncertain. For many, the effect may be a deterrent to investment and so to increased mechanization. In spite of such negative pressures, however, the mechanization of agriculture has proceeded apace.

Chapter 24

IMPACT OF MECHANIZATION ON AGRICULTURE

What has been the impact of mechanization on the nature of agricultural production, on its levels of input and output, and on the rural environment as a whole? What benefits have accrued to the Canadian economy, and the agricultural sector in particular, and what have been the costs? This chapter will review the mechanization process in terms of its effects in the wider context of the agricultural industry. The following chapter will discuss in more depth the adjustment problems created at the individual farm level by a highly mechanized production structure.

Impact on the Technology of Farm Production

In Chapter 21 it was concluded that technological advance can ultimately be viewed simply as the availability of new or better inputs in the production process. This definition applies to all new technology, whether in the form of innovations (that is, distinctly new inputs or production techniques) or merely improvements in the quality of existing ones. In so far as farm mechanization has been an expression of technological change, it will be reflected as a shift in the input structure and hence an alteration in the technology of agricultural production.

More specifically, the rapid growth in the use of machinery on Canadian farms in recent decades has meant that: (a) a variety of new inputs, in the form of mechanical innovations, have been applied to agricultural production; (b) with continuing advances in machinery technology there has been a progressive improvement in the quality of these machinery inputs; (c) along with the new equipment have grown improved production practices and methods of utilizing the traditional inputs; (d) the rise in the absolute importance of machinery inputs, and their substitution for other types of productive resources, has materially altered the proportions in which the different farm inputs are used.

Individually, each of these four effects implies a modification of production techniques; collectively they amount to a radical transformation in the technology of Canadian farming. As a result, agriculture has taken on many of the characteristics of an industrial production process with a strong orientation towards the exploitation of mechanical power.

Power Inputs – Foremost in the development towards "power farming", both in terms of importance and the time sequence, was the emergence of the tractor as the basic power unit and its rapid and widespread adoption. Having been released from the constraints imposed by the speed, power capacity and stamina of the farm horse a whole new approach to farm operations was open to the farmer. Even in the early days when the tractor was little more than an engine on wheels, the new possibilities were extensive. No longer was the size of the job and rate of work tied to that of a horse team. No longer was the length of the working day determined by the stamina of the horse, but rather by that of the operator. This potential lengthening of the working day (coupled with the reduction in time spent tending horses) and the increase in the speed of operation had far-reaching implications for farm work.

A further step towards increased power use came as the supply of electricity spread into rural areas. The electrification of the farmstead, as well as providing domestic benefits, enabled many of the daily farm chores to be more rapidly and effectively accomplished. This alone resulted in substantial savings of time and effort, and greatly improved the efficiency of many localized operations. Although in its early stages as yet, the widespread availability of electric power promises a new era in the mechanization of livestock production.

New Machinery Inputs – The appearance of the tractor as the basic farm power source provided the spur for further changes in the technology of agricultural production. As it was refined and developed into a versatile unit with a high capacity and reliability, a new generation of equipment evolved around the tractor to exploit its capabilities. On the one hand, this meant larger implements (and the feasibility of larger implements has in turn led to a demand for even larger tractors). But it has also fostered a new breed of machines, dependent not on the draught power of the tractor unit but on its stationary power output via the power take-off and hydraulic system. By this means the tractor has become a mobile power unit which can be coupled to a wide variety of equipment that was formerly not available, or at best had to be self-propelled or ground-driven.

New Operations – A new range of machines has enabled a whole new set of operations that were previously either impossible (such as hay-baling, feed milling or rotary cultivating) or could not be easily and effectively accomplished by traditional methods. Subsoil plowing, land drainage and all forms of loading and lifting are operations greatly facilitated by mechanization. Coupled with this, the ease of operation afforded by the three-point linkage and hydraulic lifting of implements, plus the precision of automatic draft control have allowed major advantages in cultivation work.

The farm tractor developed not only in sophistication and refinement but also in size and power rating. The advent of the rugged crawler tractor made the task of land reclamation and improvement far more feasible, and much of the more recent expansion in the total farmland area and improved acreage in Canada stems from this development.

The net result of the adoption of these new and continually improving machines, and the new farm activities they engendered, has been to transform farming as a productive process. From an occupation conventionally characterized by the steady plodding of a cart-horse, and whose pace and sequence were almost totally governed by climatic and biological considerations, farming can now claim to have changed its image. The modern farmer controls an almost industrial process, utilizing large sources of mechanical power and machinery for accomplishing operations with speed and a large measure of independence of climatic phenomena.

Labour Inputs – The primary impact of mechanization has been to adjust the technology of production towards a power- and machine-oriented process. This is reflected in a complete change in the whole input structure of farming. Concomitant with the expansion in machinery use has been an increase in such associated inputs as fuel oils, lubricants, tires, baler twine, and in accessory power inputs–notably electricity.

In contrast, the labour input in farming has declined markedly in quantitative importance, both in absolute terms and in relation to the level of output. This reduction in labour use is reflected in the fact that in 1966 one man's labour was applied to 200 improved acres. This compares with one man per 70 improved acres in 1921 and per 43 improved acres in 1901. Mechanization has thus allowed agriculture to accept a steadily declining labour force without suffering any contraction in the size of the industry.

On the other hand, the quality of the farm labour force has greatly improved. The farm worker must now possess a wide range of machine-operating skills and a high level of technical awareness if he is to use effectively the equipment under his control. He has almost become an indispensable accessory to the machine rather than a primary input in production.

Input Mix – Table 24.4 below shows how the mix of inputs used in Canadian farming has changed over the past few decades. The decline in labour input is evident, while machinery use, fertilizers and purchased feed have all shown significant expansion as farming technology has changed. Much of the growth of purchased feed can be explained by an increasing specialization within agriculture, with less of the livestock feed being transferred within a farm but sold instead through the market for use on other farms.

As well as bringing to agriculture new inputs directly associated with machinery use (such as fuels and oils), mechanization has had an impact on the introduction of other new resources. Thus the rise in inputs of fertilizers, of herbicide and pesticide chemicals has, of necessity, been closely associated with the increased use of farm machinery. With the advent of the hammer-mill, farm-produced and -prepared feeds became a major new input in livestock production. Barn-dried hay and dried grass are further new products (and new inputs) which were only made available by the advances in machine technology.

Further changes in the technology of farming have taken the form of new methods of applying inputs and improved techniques of production. In crop production, an array of new methods have been based on machinery innovations. An early example was the combined cutting and threshing of grain via the combine harvester; or similarly, the combine drill which allowed fertilizer to be more effectively used by placing it, simultaneously with the seeding operation, in the root zone. There were also developments in mulch tillage to control wind erosion and more effective disease and weed control in the growing crop through the practice of spraying. Alternatively, the exact placement of fertilizer and the ability to handle germinated seed in the planting operation can be cited as greatly improved techniques of potato production emanating from the introduction of the appropriate machines.

Many advances in the techniques of livestock production and fodder conservation stem almost entirely from developments in machinery technology. Hay conditioners promote rapid drying, balers enable faster and more convenient handling of hay, forage harvesters and self-unloading trailers speed silage making and make possible the technique of zero grazing. A variety of highly intensive systems of livestock production, from broilers to beef cattle, have been developed using buildings and machinery fully integrated to permit virtually automated production methods.

In general, the progressive advances in machinery technology and its ready availability to the Canadian farmer have been significant factors both in exploiting new ideas on farm production methods and in initiating a modification of traditional techniques.

Mechanization has also improved the work capacity on farms and the rate at which essential tasks can be completed. Much of this result derives from the growth in the use of the tractor as the basic farm power unit. The ability to go faster, both when pulling implements or travelling between jobs, the capacity to operate with much larger units of equipment, and the possibility of working for many more hours in a day when the occasion demanded, meant that many farm operations could be accomplished in a much shorter period of time than previously.

Many other new machines, whether relying on tractor power or not, have also had a significant impact on work capacity and the rate of work. Having been largely relieved of manual exertion, being required instead to provide the less physically tiring effort of machine operation, the farm worker can work substantially longer hours in any day if the occasion demands. Many modern machines combine into one operation what was formerly two or three separate tasks. This integration of activities often results in significantly increased working rates. As a result, the work capacity on an average farm today greatly exceeds that available in the days of labour-based production; the capacity of the machinery complement can be equivalent to that of a very large labour force, while being superior in terms of the speed with which jobs can be completed. Coupled with the enhanced productivity

of other farm inputs, in the form of fertilizers, chemicals and improved management practices, mechanization has bestowed on Canadian agriculture the ability to produce a growing volume of food each year. Without these advances the output expansion that has been experienced over the last three decades could not have been achieved or effectively handled.

The ability to work faster and for longer periods means that critical operations in the production cycle (such as cultivating and seeding, or harvesting) can be accomplished closer to the optimum time, or with less disruption due to unfavourable conditions. With cultivation techniques which guard against soil erosion and (in some cases with the aid of irrigation equipment) ensure more favourable moisture states for crop growth, plus spraying and fertilization practices, crop yields can be higher and more uniform. Fodder conservation for livestock can be completed more rapidly and effectively with modern machinery, minimizing quality loss through rain damage. In consequence, all areas of agricultural production, and particularly crop production, should be less susceptible to weather disturbances in an era of mechanized farming. Farm output as a whole should show less variation from year to year as production approaches a controlled process.

From an examination of the evidence, however, the achievement of such gains is not readily apparent. While mechanized methods lead, in theory at least, to output stability, the year-to-year variations in output now seem as marked as 50 years ago. This is especially true on the Prairies which, being a dominantly crop-oriented region, could logically be expected to have benefited most. But for advanced mechanization, the low-output years might have been even worse. Or perhaps the larger farm sizes that are more common today make the problem of output control more difficult.

Certainly mechanized farming can introduce new and additional elements of risk with respect to output levels. For example, it is usually felt that grain has to be much more mature, hence left standing longer, for straight combining as compared with binder harvesting.[1] This raises the chances of loss from shelling or sprouting in the ear in wet seasons. Pre-cutting by swather, to obtain earlier and more even maturing, leaves the grain far less protected from birds and the elements than when it is stooked or left standing uncut. The practice of highly mechanized intensive livestock production eliminates the frequent and traditional watchful eye of the stockman in the care and feeding of his animals, thus raising the hazard of unnoticed wasting or disease. Finally, the almost total reliance of production techniques on the co-operation of machinery means that a mechanical breakdown at some critical period can leave the farmer almost powerless to carry out his necessary tasks–and time lost in waiting for equipment repairs can have a very high opportunity cost.

[1] In fact there is field evidence available which shows that combine efficiency can be increased by harvesting grain earlier, at a mature but pre-ripe and moister stage. To be successful, however, this practice necessitates the use of a grain dryer.

Impact on the Physical Structure of Farming

Mechanization has also had a profound impact on the basic structure of the agricultural industry and on many physical aspects of farm production. Inputs, outputs, techniques and the entire rural environment have changed as a result.

Crop Yields – One area where the effects of mechanization should be evident is in crop yields. By allowing more timely operations throughout the year–in seeding, in summerfallowing and land preparation, in haying and harvesting–potential yields should be more nearly achieved. Some growth in yields has in fact occurred as was observed earlier (see Figure 22.5). However, it is not clear how much of this can be attributed to the use of more and improved machinery.

During this same period, significant improvements in the yield potential and disease resistant properties of crop varieties were achieved; fertilizer use became common; herbicide, fungicide, and pesticide chemicals were developed and adopted; and the technical status of farming practice as a whole advanced on a broad front. All of these factors were themselves output-increasing in nature –indeed it is perhaps surprising that crop yields have not risen by more than they have.

However, if mechanization cannot rightly claim credit for any specific proportion of this yield increase, it can undoubtedly claim to have been an essential ingredient. For much of the yield-raising technology, in the form of improved varieties, fertilizers, chemicals and better production methods, has been dependent on farm machinery for its effective exploitation. Furthermore, the innovation of many of these advances was initially stimulated by the availability of the appropriate items of equipment.

Downing[2] has attempted to assess the contribution of machinery use to the higher crop yields, and concludes that, among the cereals, oats have probably benefited most from the advantages of mechanization. Increases in yield of potatoes is closely associated with the adoption of new machinery which permits the more effective use of fertilizer, and with advances in cultivating, planting and harvesting equipment.

Product Quality – Mechanized methods have also assisted greatly in producing a higher quality end product. Several examples can be cited. Current hay-making and conditioning machinery maximizes the possibility of achieving a product of high feed value; barn hay-drying and grass-drying aid further in producing high quality fodder. Modern dairy equipment ensures that milk quality is maintained at a high standard. Pre-cutting and swathing of cereals prior to combining hastens ripening and produces a more uniformly mature sample of grain; grain drying further guards against deterioration of quality during storage. The sporadic growth of potatoes, resulting in tubers of irregular size and shape which are not so salable

[2] C.G.E. Downing, "Mechanization" (paper given at a *Resources for Tomorrow* Conference in the early 1960s).

can largely be prevented by the use of irrigation equipment at times of soil moisture deficit. In many such ways the quality-improving effects of mechanization have yielded important benefits.

Expansion in the Production Area – The replacement of the farm horse by the tractor released vast areas of land, previously employed in maintaining the horse population, for use in commercial food production. It has been estimated that in Western Canada 10 acres of land were taken up in providing food for each horse. If this is so, then 20 million acres have been made available since 1921 by the displacement of the horse from Prairie agriculture. The land requirements were apparently less in Eastern Canada, being some 3.5 to 4 acres per horse; nevertheless, the demise of the workhorse has released an estimated 4 million acres in Ontario and Quebec.

The "tractorization" of farming, then, had the effect of increasing the size of almost every farm. Mechanization has further expanded the productive area of farms by enabling farmers to utilize the acreage of their holdings more effectively, making it feasible to cultivate the more marginal areas and fields more distant from the farmstead. This partly explains why the total area of improved land and the acreage under crops have increased by over 20 per cent since 1941, while the total area of farmland has remained virtually constant.

TABLE 24.1–AVERAGE FARM SIZE, CANADA AND MAJOR PROVINCES, 1921-66

(Acres)

	Canada		Quebec		Ontario		Prairies	
	Total	Improved	Total	Improved	Total	Improved	Total	Improved
1921	198	99	125	66	114	67	344	176
1941	237	125	117	59	126	75	405	221
1951	279	155	125	66	139	85	498	288
1956	302	175	130	70	141	89	545	326
1961	359	215	148	82	153	99	617	382
1966	405	251	161	95	162	109	685	437

Source: Dominion Bureau of Statistics, *Census of Canada, Agriculture,* various years.

Farm Sizes – The general progress of mechanization has not only raised the effective acreage on each farm, but has also played a significant part in the move towards larger farming units (see Table 24.1). Agricultural economists are not fully agreed on what has been cause and what has been effect in this process. Does increased farm machinery use derive from larger farm units or did it initiate the move towards bigger holdings? One thing is clear, however. The mere fact of farm operators leaving agriculture in response to the attractions of non-farm work, and farmers' sons declining to take over the family farm, results in both a contraction in the labour force and the availability of their holdings on the market. The high capital requirements on entry into modern farming perhaps deter many would-be

new farmers from taking over these holdings as individual units. In consequence there is strong tendency for these farms (particularly the smaller ones) to be amalgamated with existing holdings. This is entirely feasible where the amalgamating farmer has the available machinery capacity, or can readily acquire it, to farm the additional acres.

Thus, mechanization represents an important enabling factor in the process of farm amalgamation. For with modern equipment, one man can handle increasingly large acreages. Further, many farmers who are already well mechanized may find that they can farm additional acres within the capacity of their existing machinery stock.

The other side of the argument is whether mechanization functions as a fundamental determinant in farm-size growth. The answer to this lies in the validity of two hypotheses: (a) that farmers (especially on smaller units) are induced to give up their holdings because small-scale mechanized production is no longer economic, and (b) that many farmers, in investing in a wide complement of machinery, often cannot help but become "over-mechanized", and thus are compelled to expand their production base in order to utilize their available machinery capacity efficiently. But on these two aspects the evidence is far from conclusive.

The basis for these hypotheses is that items of equipment, coming in relatively large units, cannot always be ideally matched with a farm's available land area. Secondly, contemporary mechanization reflects a growing importance of integrated machinery systems rather than merely the mechanization of particular tasks. Consequently, in order to conduct farming methods efficiently based on a low labour input, extensive machinery investment is required. It is plausible that these pressures operate on the very small farm holdings and induce farmers either to enlarge their farms or to leave the industry. But it is difficult to associate these problems with farms up to 640 acres in size—many of which have been subject to amalgamation on the Prairies.

Whatever the truth of the above arguments, mechanization has undoubtedly had a major influence on farm-size growth by being the *sine qua non* of large-scale production.

The Rural Environment – The coming of the machine age in agriculture has brought with it an inevitable impact on the rural scene. Although providing transportation, machinery requires transportation too, and the rapid transfer of equipment from one area of work to another requires an infrastructure of good roads and wide field gateways. Large machines operate less efficiently in small and irregular-shaped fields. Consequently, fences are rooted up, ditches filled, lone trees felled, gates and roadways widened—gradually modifying the rural environment. These incursions on the natural order, coupled with the other more dramatic effects of modern agricultural technology, often evoke deep feelings of nostalgia for the more varied rural scene of a by-gone era.

Economic Impact of Changing Machinery Technology

The mechanization of production is, in the last analysis, undertaken on the basis of economic criteria and as a part of the economic evolution of the farm business. Accordingly, one would expect that the accelerated mechanization of Canadian agriculture has had a profound impact on the economic structure of the industry and the individual farm units that comprise it. Some of these changes will be reviewed here.

Commercialization of Farming – One of the more noticeable changes has been a distinct "commercialization" of agricultural production, witnessed by a marked rise in the proportion of farms identified as "commercial farms" in the Census of Canada.[3] In 1951 only 38 per cent of all census-farms produced sales of $2,500 or more, whereas by 1966 this proportion had risen to 64 per cent. This would seem to represent a genuine growth in the size of many remaining small farm businesses, rather than merely the disappearance of non-commercial holdings as separate farming units; for although the total number of farms fell by 192,569 over this period, the drop in non-commercial farms was much more at 234,314. Nor can this be explained merely in terms of the small physical output of previously non-commercial farms rising in value to exceed $2,500, for farm product prices rose by only 3.4 per cent over this period. Although much of this growing preponderance of commercial farms must lie in the disappearance of the smaller holdings and their amalgamation into larger units, there obviously remain many holdings which have not changed in acreage size but have expanded their sales above the $2,500 limit. The fact is further supported by the growth in the actual numbers of farms defined as commercial (these rising from 235,090 in 1951 to 276,835 by 1966) despite the decline in total farm numbers as a whole.

The figures in Table 24.2 portray certain other interesting features in this context. There has been a noticeable shift in the scale of output of all remaining commercial farms. Holdings having less than $5,000 of sales have declined markedly in number, while those having sales in excess of this figure have increased both in absolute numbers and as a proportion of total farms. This is especially true of the larger units selling over $10,000 of product, appreciable growth being demonstrated in all categories above this level. For example, whereas in 1951 some 13 per cent of total sales of agricultural produce came from farms in the class exceeding $15,000, this proportion had risen to over 48 per cent in 1966.

Much of this change is associated with the growing size of farms, but the economics of adopting mechanized production methods have supplied an additional and independent incentive. For example, machinery inputs must be purchased from the non-agricultural sector, which means cash payments must be made. As more farming inputs emanate from outside agriculture in this way, there has been an inevitable shift away from self-sufficiency towards production for sale. This

[3] A "commercial farm" is currently defined in the Census as one with sales of agricultural produce not less than $2,500 annually. Prior to 1966 the borderline was set at $1,200 of sales.

changing emphasis is evidenced by the fact that in 1930 about 67 per cent of total gross income was derived from cash sales of produce, whereas this proportion stands closer to 90 per cent today.

Part-Time Farming – Another facet of this growing commercialization of agriculture is seen in the rise of part-time farming. Of the reduced number of non-commercial units, by far the majority are now classed as part-time holdings. Compared to 1951 when part-time farms formed only about one-third of the non-commercial farms, by 1966 they had risen in both absolute numbers and proportions to represent 85 per cent of all non-commercial units–and an over-all 30 per cent of all farms in total.[4] Obviously many of the smaller farmers, preferring not to leave the industry altogether, but unable to operate their holdings economically under modern conditions, have been forced to resort to off-farm sources in earning some of their annual income.

Investment Level – Being a capital input with a working life of several years, the acquisition of new equipment requires a capital investment. Total sales of new machinery were valued (in wholesale prices) at $82 million in 1946, while by 1967 this figure had risen to $432 million. Over the period 1960-67 an over-all $2,493 million of new machinery purchases were made. As a consequence the value of machinery and equipment assets on Canadian farms rose from $650 million in 1931 to $3,709 million in 1967. This rise had been part of the general growth in farm capital of all types, for over the same period the total value of agricultural assets increased by almost $16 billion, the value of land and buildings increasing from $4.1 to $14.9 billion and the value of livestock and poultry from $0.5 to $2.5 billion.

For real estate assets, much of this increase in value is neither new investment nor even a capital transfer within the economy, but simply a paper revaluation, reflecting the rising price of farm land. These high land values are, however, real enough to the individual farmer entering the industry or planning to enlarge his farming operation by land purchase. High prices have also increased the investment in machinery and in livestock and poultry.

Capital Structure – As the aggregate level of farm capital has grown, machinery capital has become an increasing proportion of farm assets, rising from 10 per cent in 1921 to 17.5 per cent in 1967. This share has, in fact, been declining in recent years as the inflated land values have been lending more prominence to real estate capital. Real estate assets now occupy 70 per cent of total farm capital, having increased from 58.5 per cent in 1951, but it is still some 7 per cent less than in 1921. Livestock capital had increased its share to 21 per cent in 1951 but by 1967 it was only 12 per cent of the total, very similar to its share of 12.8 per cent in 1921.

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[4] Because of a change in census definition the data are not fully comparable, but the general order of magnitude of the change is beyond question.

TABLE 24.2–CHANGES IN THE SIZE STRUCTURE OF CANADIAN FARMS, AS MEASURED BY LEVEL OF SALES, 1951 AND 1966

	1951			1966		
	Farms			Farms		
Annual Sales	No.	Per Cent	Percentage of Total Sales	No.	Per Cent	Percentage of Total Sales
Over $10,000	21,243	4	22	95,032	22	65
$5,000 – $9,999	69,019	11	27	96,856	22	21
$2,500 – $4,999	144,828	23	29	84,947	20	9
Total commercial farms	235,090	38	78	276,835	64	95
Non-commercial farms	387,309	62	22	152,910	36	5
(Part-time farms, included above)	(65,135)	(10.4)	–	(129,565)	(30)	(18)
All farms[1]	623,091	100	100	430,522	100	100

[1] Including institutional farms.

Source: Dominion Bureau of Statistics, *Census of Canada, Agriculture,* 1966.

With the growth in both total and machinery capital and the reduction in farm numbers, the level of capital measured on a per-farm basis has increased substantially. (See Table 24.3.) The current value of assets per farm has risen almost eight times since 1941. Much of this rise, of course, can be attributed to the revaluation of the existing land rather than the growth of new capital in any real sense. Nevertheless, the average value of machinery on Canadian farms, standing at $8,858 in 1967, is nearly ten times higher than 25 years ago. This component of farm capital has grown faster than any other, and is clearly a result of modern machine-oriented production techniques. Coupled with the high price of purchasing land, this gives a striking indication of the level of capital required to commence farming today.

TABLE 24.3–AVERAGE CAPITAL INVESTMENT PER FARM, BY TYPE OF CAPITAL, CANADA, 1921-67

(Thousands of dollars)

	Total	Land and Buildings	Implements and Machinery	Livestock and Poultry
1921	9.2	7.1	0.9	1.2
1931	7.2	5.6	0.9	0.7
1941	5.8	4.1	0.8	0.8
1951	15.2	8.9	3.1	3.2
1961	27.4	17.9	5.3	4.1
1967	50.6	35.7	8.9	6.1

Source: Canada Department of Agriculture, Economics Branch, *Selected Statistical Information on Agriculture in Canada,* 1969.

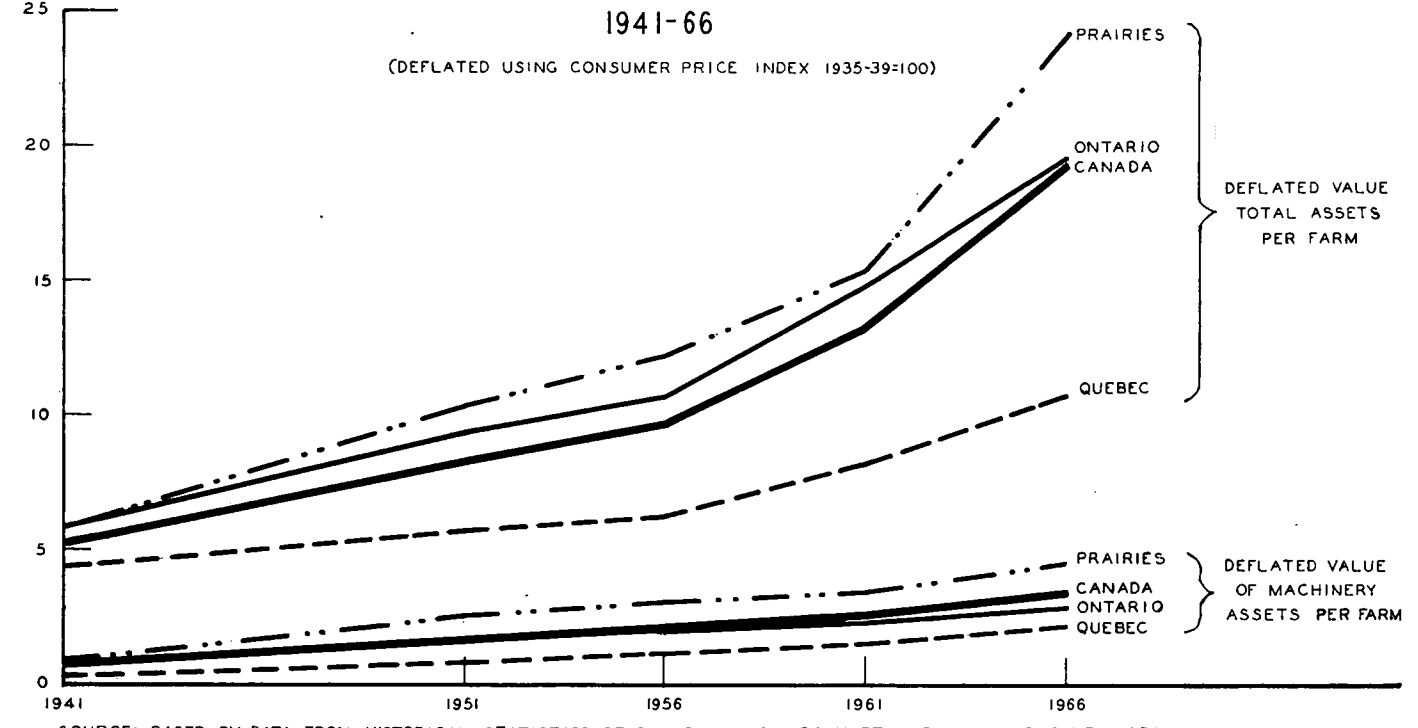
This capital requirement does vary depending on the region and the type of farming, being highest in the Prairies. There, the combination of large farms and crop production, perhaps the most strongly machine-oriented type of farming, results in $10,450 of machinery investment per farm. Ontario farms averaged $6,727 of machinery investment in 1966, while the corresponding figure for Quebec was $5,111.

Census data on machinery capital by size of farm suggest there are scale economies in the use of machinery. Thus, investment in machinery per acre declines steadily and dramatically as the size of farm increases. For example, in 1966, farms in the size range from 10 to 69 acres had an investment in machinery of $118 per acre, farms from 240 to 399 acres an investment of $37 per acre, and farms of 1,600 acres and over an investment of only $21 per acre.

Expressing capital values in current dollars over-dramatizes the growth in farm assets. For current dollars reflect rising prices as well as the growth in real values. Applying appropriate deflators and measuring farm-asset values in constant dollars, a more realistic picture of the growth in agricultural capital, both in aggregate and on a per-farm basis, emerges. The real rise in capital stock, though apparent, is considerably less as seen from Figure 24.1. Nevertheless, it is clear that

FIGURE 24.1 - VALUE OF ASSETS PER FARM, CANADA AND MAJOR REGIONS, 1941-66

(DEFLATED USING CONSUMER PRICE INDEX 1935-39=100)



SOURCE: BASED ON DATA FROM HISTORICAL STATISTICS OF CANADA, M. C. URQUHART AND K. A. H. BUCKLEY, EDS., TORONTO, MACMILLAN, 1965; DOMINION BUREAU OF STATISTICS QUARTERLY BULLETIN OF AGRICULTURAL STATISTICS, CAT. NO. 21-003, AND DBS 1966 CENSUS OF CANADA, AGRICULTURE.

as a result of progressive mechanization in agriculture the asset structure has undergone considerable change, and the capital requirements of operating an up-to-date farming business are sufficiently high as to impose a formidable barrier both to new entrants and to further farm-size enlargement.

Debt Commitment – From the farmer's point of view, funds must be found for new investment when he wishes to expand his stock of machinery and equipment. Investments can be financed out of current earnings or by borrowing. With farm incomes subject to a cost-price squeeze, farmers have increasingly had to resort to loans when purchasing new equipment. Recent estimates suggest that as much as 60 per cent of new machinery sales are currently financed by credit from a variety of sources.

Not surprisingly, therefore, mechanization has brought with it an increasing debt commitment on the part of Canadian farmers. This higher level of loans has been extended further by the necessity to borrow increasingly large sums for land purchase as operators have sought to expand farm size in the face of rising real estate prices.

On the basis of a survey conducted by Mooney and Rust[5] it is estimated that the outstanding debt on farm machinery in 1964 amounted to $308 million, representing some 11 per cent of all farm indebtedness.[6] The Prairie farmers carried a major proportion (64 per cent) of this, since both the pace and the level of advancing mechanization have shown consistent growth in these provinces. Some 20 per cent of the machinery debt was owed by Ontario farmers with Quebec's share being about 13 per cent. There is little doubt that the indebtedness arising from machinery pruchases has risen appreciably since 1964.

Farmers' Equity – If the investment in farm machinery is economically justified then it is quite rational to borrow funds in order to achieve these advantages, rather than forgo them to avoid debt. The increased indebtedness is not bad *per se,* and may, in fact, be an indication of sound economic progress. But a higher debt commitment carries with it a potentially increased risk. Under heavy loan commitments a farmer's equity position can easily become precarious–a situation which will, however, steadily improve if the investments achieve their budgeted economies, but, conversely, may lead to an increased risk of bankruptcy if they do not.

The equity ratio of Canadian farmers has declined to less than one-half of its 1951 value, signifying an appreciable increase in farmers' liabilities in relation to their net worth. Despite this decline, farm debt outstanding was still only about 18 per cent of the value of farm capital. Thus, the over-all debt position of Canadian farmers must still be regarded as conservative. However, for many individual farmers, engaged in a planned expansion of their farm size and mechanization level, equity considerations could be potentially critical.

[5] F. A. Mooney and R. S. Rust, *An Investigation of Farm Credit on Commercial Farms,* Canada Department of Agriculture, Economics Branch, Ottawa, 1968.

[6] R. Harris, *Farm Machinery Finance,* unpublished Commission study, 1969.

Farm Cost Structure – Adjustments to the physical mix of resources used, as production technology changed, have brought a corresponding modification in the cost structure of farming. Differential rates of price change for different inputs further alter this pattern. Consequently, as shown in Figure 24.2 the increased significance of machinery inputs has given a growing importance to their associated elements of cost–depreciation, repairs, fuels and oils. Other cost items, characteristic of modern production technology, such as fertilizers and chemicals, have also grown in size. Despite the fact that labour inputs have fallen as machinery inputs have taken their place, the total cost of labour has risen with the large increases in wage rates.

Obviously, however, the steady inflation in the economy causes all costs to rise and obscures the true changes in the relative importance of the different cost components. The impact of mechanization is more clearly revealed when the relative proportions of the various cost items are examined, as in Table 24.4. Here it can be seen that machinery costs became increasingly important in farm-operating expenditures throughout the 1940s and 1950s, but have stabilized since then and even declined moderately. Labour incurs a declining share of costs, while interest payments, as might be expected from the growing farm indebtedness, have recently assumed a growing proportion. Regional differences in mechanization are reflected

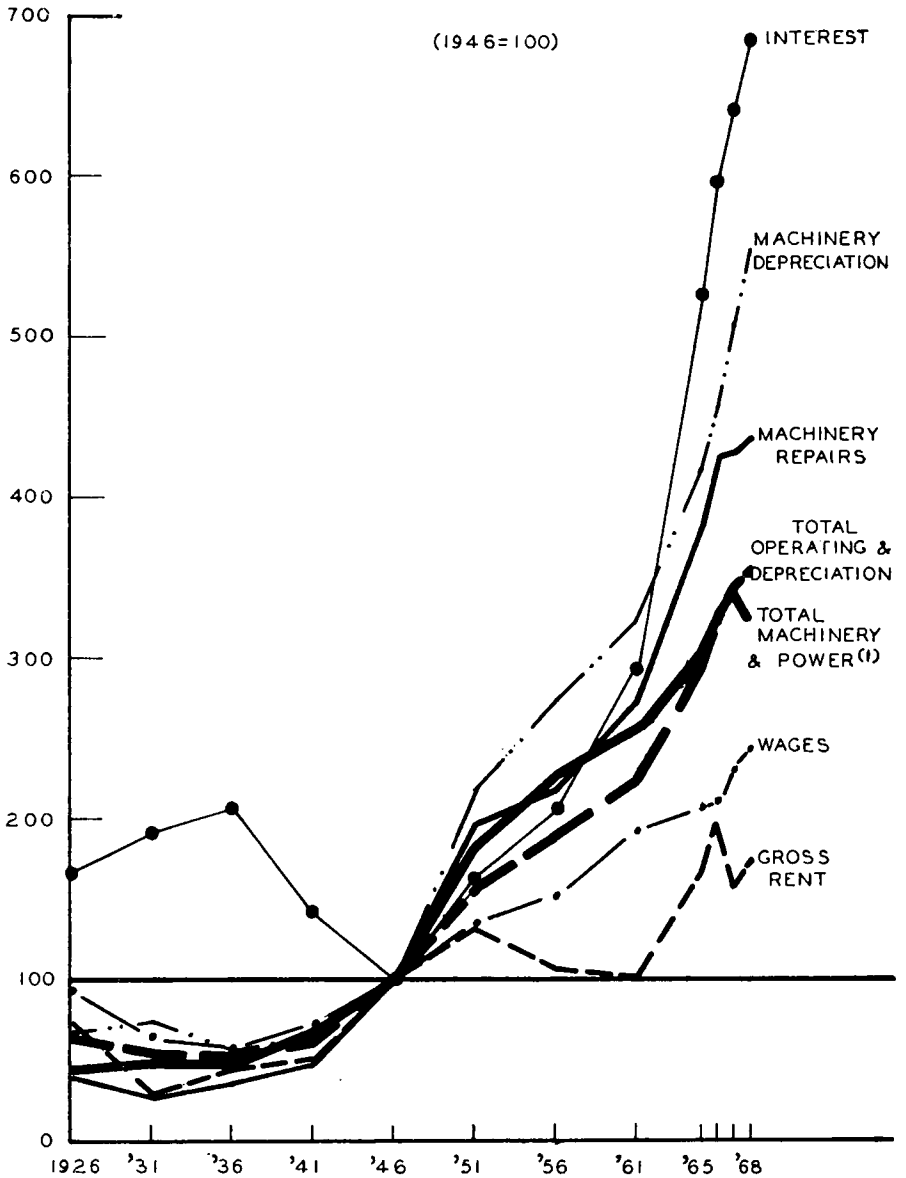
TABLE 24.4–ANALYSIS OF OPERATING EXPENSES AND DEPRECIATION, CANADIAN AGRICULTURE, SELECTED YEARS, 1927-67

	Per Cent of Total Operating and Depreciation Expense			
	1927	1947	1957	1967
Taxes	8.1	5.7	6.2	4.8
Farm rent	9.7	7.9	3.8	4.2
Wages	18.4	12.3	10.9	8.7
Interest on debt	10.1	3.8	4.4	7.4
Machinery expense	12.5	16.9	21.0	16.1
Machinery depreciation	9.9	8.8	13.7	13.1
Total machinery depreciation expense	22.4	25.7	34.7	29.2
Fertilizer and lime	0.9	2.7	3.1	6.1
Other crop	4.0	3.4	3.6	3.4
Feed[1]	10.5	24.7	16.0	17.4
Other livestock	–	1.3	2.0	3.1
Repairs to buildings	3.0	3.2	3.2	3.2
Electric power	–	0.3	1.5	1.2
Miscellaneous operating	4.1	4.1	5.3	5.5
Building depreciation	8.8	5.0	5.2	5.7
Total operating and depreciation	100.0	100.0	100.0	100.0

[1] Includes feed purchased through commercial channels only.

Source: Dominion Bureau of Statistics, based on *Handbook of Agricultural Statistics*, Part II, Cat. No. 21-511, and *Farm Net Income*, Cat. No. 21-202, various years.

FIGURE 24.2 - INDEXES OF MAJOR FARM OPERATING EXPENSES, CANADA, 1926-68



(1) ELECTRIC POWER AND TELEPHONE EXPENSE NOT INCLUDED IN YEARS PREVIOUS TO 1951.

SOURCE: BASED ON DATA FROM HANDBOOK OF AGRICULTURAL STATISTICS, PART II, 1962-65, AND FARM NET INCOME, 1968 ANNUAL.

by the fact that fully one-half of farm costs arise from machinery use in the Prairie Provinces, whereas the proportion is closer to one-quarter for all other provinces.

Off-Farm Payments – As a result of these changes, agriculture has become increasingly dependent upon inputs emanating from the non-farm sector of the economy, and a growing proportion of expenditures are paid to non-agricultural sources. In 1965 some 46 per cent of farm operating expenditures were for inputs from outside agriculture, compared with 29 per cent in 1926. Despite the benefits from the use of such resources as machinery, fertilizers, chemicals–and investment capital–this development leaves the farming community with less control over the acquisition, supply price and availability of the bulk of its inputs.

Economic Security – The terminology of production economics traditionally differentiates variable costs–those that vary directly with the output level, such as fertilizers, seeds, machinery operating expenses–from fixed costs; these latter are fixed in the sense that they do not alter in the short run with changing output levels. The rapid growth of machinery use has resulted in increased depreciation expenses (a fixed cost) which have risen more than the associated variable machinery operating costs. Similarly, annual payments on machinery debt and farmland mortgages are fixed costs. In consequence, there is a tendency for mechanization to shift the balance of costs towards a structure more heavily weighted with fixed costs.

Such a development can represent a situation of increasing risk in so far as farms have a higher proportion of costs, already increasing, which are inescapable. Whether output is high, low, or average, these costs must still be met. The risk in this lies in those years when outputs are below average–perhaps because seeded acreage was low due to poor climatic conditions or when output cannot be sold. Faced with a reduced level of returns and high inescapable fixed-cost payments, severe incursions are made into any expendable surplus. It may even mean that further debt must be incurred, or the farmer's own capital has to be invaded in order to meet these payments and continue operating, with the hope of more favourable years in prospect.

Thus, though mechanization may claim to have reduced many uncertainties of agricultural production in a technological sense, it can at the same time, by virtue of its tendency to raise farm debt and the over-all level of fixed costs, give rise to circumstances involving higher levels of economic risk.

Fortunately, the growth in fixed costs consequent upon increased machinery investment has been countered in large measure by a reduction in expenditures on labour, another predominantly fixed cost item. As a result, fixed costs[7] have only marginally increased their share of total costs, representing 48.3 per cent in 1968 as opposed to 45.9 per cent twenty years earlier. Indeed, this is a highly favourable state of affairs compared to 1928 when rent, wages and interest were vastly more

[7] Taxes, farm labour, rent, interest, building repairs and depreciation, and machinery depreciation.

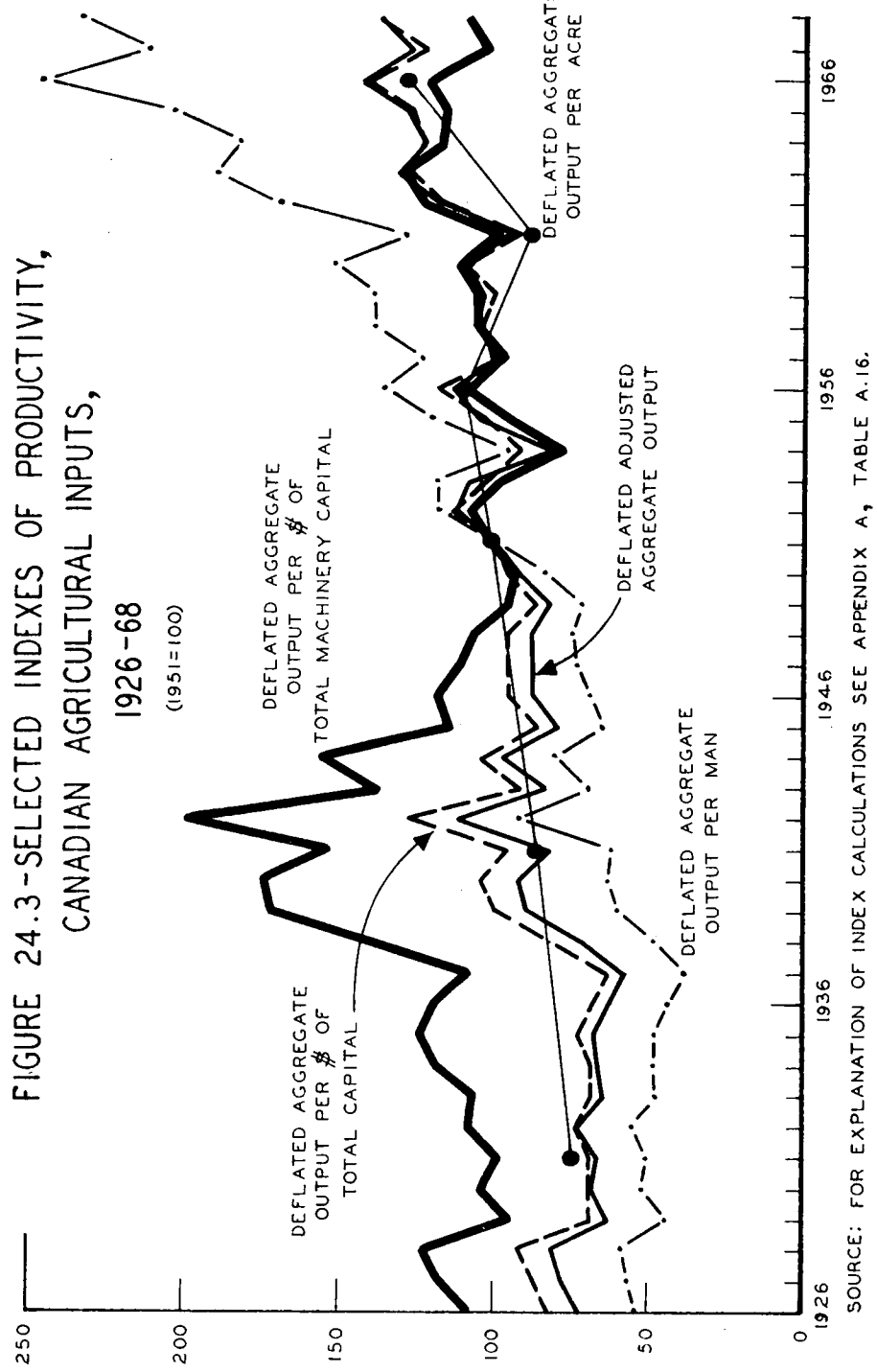
significant expenditures; fixed costs at that time amounted to 67 per cent of total farm expenditures!

Nevertheless, the growth in the level of fixed costs on farms, of which machinery depreciation is a major part, means that on the average Canadian farm an annual sum of about $3,750 per farm has been incurred before any physical production commences from which financial returns may be earned.

Resource Productivity – The combined effect of this spectrum of economic changes stemming from increasingly mechanized farming may be summarized in terms of shifts in the productivity of agriculture's resources. Objective measures of resource productivity, unfortunately, are notoriously elusive, since the calculated productivity of any single resource is but a partial measure being interdependent with the available levels of associated inputs. Consequently, if an increase in output is achieved by expanding the use of one resource (say, capital) while leaving all other inputs at a constant level, the measured productivities of these other resources will all, by definition, rise. But the productivity of capital may, as a result, show a corresponding fall, leaving an assessment of the change in the over-all productivity pattern somewhat indefinite. The nature and extent of economies of scale is all-important in this situation–if major economies exist *all* resource productivities may rise. Where constant or diminishing scale returns are present a mixture of opposing productivity changes will be experienced.

It is not surprising to find that the combination of an increased output from a greatly diminished labour force has conferred major increases in labour productivity in Canadian agriculture. The acreage handled by one man has risen, on the average, from 135 to 320 acres since 1931, while output per acre has doubled over the same period; as a result the real value of output per man in 1966 was almost five times greater than in 1931. Investment in capital goods is the traditional path to increased labour productivity in any industry, and these increases in output per worker and per acre emanate from the outstanding growth in agricultural capital. Total capital per improved acre now stands at $196 in Canadian agriculture, or alternatively at $38,945 per man. Though much of this is represented merely by the higher value of real estate capital, there has been a true growth in capital inputs in the form of machinery and equipment. Machinery investment per improved acre in constant (1949) dollars has risen from $9.4 in 1941 to $23.1 in 1967, and on a per worker basis the respective levels are $804 and $4,576.

While enabling a growth in productivity per man and per acre, these injections of capital have not come at the expense of greatly diminished capital productivity. Figure 24.3 reveals the progress in various resource productivities in Canadian agriculture since 1926. From this it is clear that in the early days of machine-oriented production all resource productivities showed steady improvement. During the mechanization boom of the late 1940s and early 1950s, which initiated the sharp rise in labour productivity, the productivity of machinery capital suffered a sharp drop. Since then it has remained fairly steady, while the growth in labour productivity has continued apace. The productivity of total agricultural capital has shown a fairly consistent upward trend since the late 1920s.



SOURCE: FOR EXPLANATION OF INDEX CALCULATIONS SEE APPENDIX A, TABLE A.16.

Cost-Price Squeeze – It is often asserted that a concentration on mechanized production methods, combined with rising prices for machinery inputs, has contributed to a growing cost-price squeeze in agriculture. Certainly there has been a narrowing of the margin between the index of farm product prices and the corresponding price index of commodities and services used by farmers (see Figure 23.2), circumstances which many observers view with concern. But whether mechanization is one of the culprits in this situation, or even whether the so-called squeeze is of any real significance, is open to question.

For one thing, the two indexes are independent measures of elements that are, in a sense, unrelated, and there is no reason why they should move together. Secondly, the narrowing of the indexes since the early 1950s is especially noticeable because they initially diverged from about 1940. During the period 1940-50 the index of farm product prices rose much more rapidly than the cost index, and it was the collapse of this "boom" in prices which has given the appearance of a squeeze. It was during the latter part of this period, too, that a major growth in machinery investment occurred, so mechanization as such can perhaps be exonerated as a disadvantageous factor in farming prosperity.

Although the cost index has again risen more than the price index since 1960, does this have any true significance? If the price of farm inputs has risen rapidly, so too has their productivity. The cost index alone is totally uninformative concerning the quality changes that have occurred in agricultural resources. That the relatively high cost index is a superficial measure is reflected by the fact that, despite their rising prices, up until 1966 (the latest year shown) the outputs per dollar spent on labour, machinery and other inputs show no sign of a decline. In fact the reverse is true.

Finally, although profit margins per unit of output may be under pressure, the expendable surplus per farm operator has been steadily increasing. As long as the number of farmers who share agricultural income continues to decline, concern over the prosperity of farming as a whole will be tempered by this growth in income per farm operator.

Impact of Changing Technology on Farm Society

Population Balance – One of the most spectacular of recent changes in the farming sector has been the reduction of the farming population, by half, in less than 20 years. While mechanization may not be the sole cause of this outflow it has contributed very substantially to it.

The social side effects of this change have been numerous. The fact that not only are there fewer people left in farming, but also that the proportion of the total work force employed in agriculture has declined from 30 per cent to 7 per cent since 1931, has presumably resulted in a loss of political power, the implications of which may be far reaching. Since the migration has been mainly of people in the younger adult age groups, there has been a change in the age structure of the farm

population—giving a marked proportional increase in the older age groups—which foreshadows further changes to come.

The process of migration may often have been a harsh experience for the individuals involved. First there is the economic hardships associated with being slowly squeezed out. Depending on how long those involved try to hold on, this may affect many other aspects of their life such as children's education and both the physical and mental well-being of adults of the family. It results, too, in the break-up of families, and creates the need for new relationships to be forged. In this context, those who leave the farm are confronted with the many hardships and uncertainties created by the rural-to-urban transition.

Accompanying this population shift there has been an increase in the number of non-farm people indirectly employed in farming. The substitution of capital for labour has effectively increased the service force employed in maintaining farms fully operable. This force includes mechanics and repairmen, technical specialists, an expanded sales force, advisory officers and additional administrative staff. The reduction in the farm work-force has been partially substituted for by an increase in the amount of custom work and specialized contract work done on farms. No longer can the total labour input into agriculture be ascertained by counting the number of adult males resident on farms. Apart from the custom work that is done, the increase in the number of part-time farmers effectively invalidates a simple count of farm-based personnel.

In view of the movement of people out of farming, two changes which have occurred appear anomalous. The first is that many small towns and villages in rural areas have actually increased in population. This is essentially an effect of mechanization in that with more cars, trucks and run-abouts farmers can live in the towns and commute to and from their farms. The second is that, according to the published statistics, the number of adult males employed per farm has actually increased. This effect is caused by the development of certain intensive operations, particularly involving livestock, and by the disappearance of small farms that employ only the owner-operator. A corollary is that the number of farms large enough to need employed labour has tended to increase. On the other front, there is also more town-country integration, with the relative disappearance of a separate and different farm way of life.

All of these changes can, of course, be associated with increasing farm mechanization. Even though mechanization may not be an important determinant of some effects, it is, nevertheless, an identifiable feature of the times and may therefore be held responsible by association. Many of the changes that occur in the process of agricultural adjustment create upheaval and uncertainty. Thus, for many farm people, the experience of the times is disconcerting. A feature of modern farming is that mechanization and the costs related to it are increasing, and this sometimes results in machinery and machinery companies, rightly or wrongly, being blamed for some of the problems that arise. Though there are some real issues

involved, it may be this reaction, more than anything else, that has lead to dissatisfaction with the companies and to the demand for official enquiries into their operation. If the farm machinery industry were to recognize the significance of this involvement by association, and to take some action to offset it, they might avoid repeated public investigations.

Physical Welfare – A more direct impact of expanding mechanization has been that on the physical well-being of farm people. A Commission study has shown that the adverse effects are both acute, in the form of accidental injuries–and chronic, in the form of health damage.[8] Statistics on fatalities in Canada show quite clearly that fatal accidents directly related to farm machinery are increasing at an alarming rate (see Figure 24.4). Not only are they increasing in proportion to the size of farm population but in absolute terms as well. The victims are in all age groups, but particularly they are the very young and the aged as seen from Table 24.5.

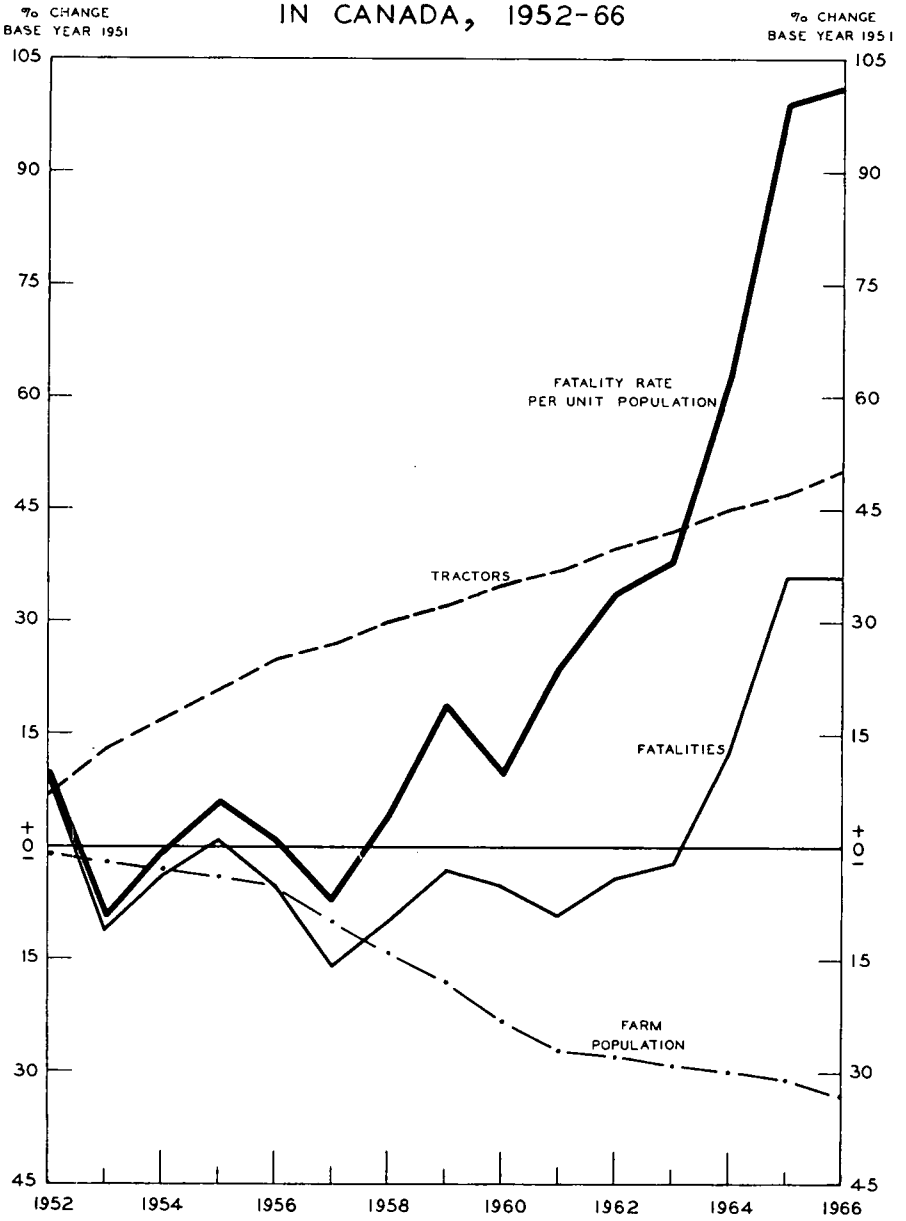
Statistics on disabling and temporary injuries are, unfortunately, less complete than might be desired, but such evidence as does exist suggests that they are becoming more frequent, as are fatalities. There are also some indications that injuries sustained in farm machinery accidents are more severe than other categories of farm accidents. These effects suggest some change within the man-machine relationship on farms. Though there are clear indications that changes concerning the man, machine and environment can all contribute to the creation of an accident situation, the most obvious changes are those including machinery. The rise in fatalities would seem to be unnecessary when it is known that the modification of machinery design would effectively reduce a large number of them. Others could be avoided by increased awareness and care on the part of the farmer.

The chronic effects include hearing loss due to noise, various ailments caused by exposure to heat, cold, wind and dust, and physiological effects due to jolting and vibration. Although the statistical evidence is incomplete, these too seem to be on the increase. They differ from the acute effects in that these affect almost exclusively the operator, and not bystanders or those working nearby. The onset of these effects are insidious since they are usually cumulative over time, and the causes may not be recognized until their impact becomes acute. Again, most of these effects could be lessened by improvements in machinery design. To some extent they might also be reduced by increased awareness of their nature and by taking action to ameliorate their impact.

Overall, these adverse welfare effects appear to exceed those that are beneficial. By doing jobs faster and with less human effort, machines might be expected to benefit directly those who use them. To some extent they do. There can be little doubt that most farm operations can be done with less exertion than at

[8] G.F. Donaldson, *Farm Machinery Safety*, Royal Commission on Farm Machinery, Study No. 1 (Ottawa: Queen's Printer, 1968).

FIGURE 24.4 - CHANGES IN FARM MACHINERY FATALITY RATE, FARM TRACTORS AND FARM POPULATION IN CANADA, 1952-66



SOURCE: G. F. DONALDSON, FARM MACHINERY SAFETY, ROYAL COMMISSION ON FARM MACHINERY, STUDY NO. 1 (OTTAWA: QUEEN'S PRINTER, 1968).

TABLE 24.5–FARM MACHINERY FATALITIES IN CANADA – ACCIDENT TYPE AND AGE OF VICTIM, 1962-66

Age in Years	Over-turned	Crushed by Tractor	Run Over Operator	Run Over Bystander	Run Over (Other)	Servicing	Caught PTO	Caught Other	Miscel-laneous	Total	Percentage
1– 4	5	4	–	49	6	–	–	3	2	69	12
5– 9	9	2	8	13	5	–	–	4	5	46	8
10–19	46	15	6	2	11	–	3	2	14	99	17
20–29	20	4	–	1	3	1	6	3	5	43	7
30–39	23	1	1	–	3	2	1	6	6	43	7
40–49	35	5	3	–	5	4	2	6	15	75	13
50–59	36	8	10	–	9	5	5	8	10	91	15
60–69	31	3	4	–	12	3	5	3	12	73	12
70+	25	1	5	1	9	3	2	1	12	59	10
Total	230	43	37	66	63	18	24	36	81	598	100
Percentage	39	7	6	11	11	3	4	6	13	100	

Note: Percentages may not add to 100 due to rounding.

Source: G.F. Donaldson, *Farm Machinery Safety,* Royal Commission on Farm Machinery, Study No. 1 (Ottawa: Queen's Printer, 1968), Appendix II, Table 2, p. 91.

one time was necessary. Nor is there any question that many operations can be done more speedily. This latter advantage, however, has not always been obtained as a direct gain. Very often the extra capacity resulting from a higher rate of work has been used to cover a larger acreage in order to increase economic gains. In this regard, the transition from the horse to the tractor has often increased the length of the working day. Whereas the horse team had to be spelled at regular intervals, and could only be used for a limited number of hours at a time, the tractor has no such limitations. It can theoretically, and sometimes in practice, work for almost 24 hours in a day—and an operator must work with it. The prolonged hours of work that are possible tend to aggravate the chronic health effects mentioned above, and through fatigue, may be a prime cause of certain accidents. In these various ways the impact of expanding mechanization of farm people can be severe and unfavourable.

Chapter 25

ADJUSTMENTS RELATED TO CHANGING TECHNOLOGY ON FARMS

Adjustments in Farming Organization

At the level of the individual farm, mechanization has exerted far-reaching effects on all aspects of the farming organization. It has affected the size structure of farms, the farm's use of labour and capital, and the pattern of organizations supplying farm services. This section examines these changes in some detail.

Farm Organization – A predominant change has been in the acreage size of farms. As already shown, the average size of farms has increased in all parts of Canada, mainly through amalgamations. Expanding mechanization has accompanied this increase in acreage per farm, and has undoubtedly facilitated it by allowing the extra acres to be farmed with approximately the same labour force per farm. There has accordingly been a concurrent drop in labour used per acre cropped. *A priori,* there seems no reason why mechanization as such should be a determinant of this change–yet this is a widely held belief. It is frequently argued that there is much under-utilization of equipment on farms, and that in order to overcome this problem farmers seek to buy additional land.[1] [2]

This argument, in its simplest form, assumes that farmers are either unable to purchase a machinery system to suit their size requirements, or that they irrationally purchase equipment that is too big for their purpose. The first of these propositions seems unlikely to hold, once it is recognized that there is a very wide range of machinery sizes on the market–including more than 10 different sized tractors–and that the used equipment market forms a continuum of sizes in terms of price-capacity considerations. Consequently, there seems no reason why a farmer should not be able to select a capital outlay as small as is required. The second point seems illogical, in that it implies that an irrational machinery buyer subsequently becomes a rational land buyer. Though in some cases farmers will undoubtedly over-estimate their machinery needs or, because of insufficient

[1] Anon. "Agriculture in the United States", *Current Affairs Bulletin,* Vol. 44, No. 2, June 1969.

[2] Province of Saskatchewan, Royal Commission on Agriculture and Rural Life, *Mechanization and Farm Costs,* Report No. 2 (Regina: Queen's Printer, 1956).

information, may make a wrong capacity decision, it seems unlikely that these mistakes would all be in the same direction. It seems more likely that this over-mechanization is purposeful—in other words, that farmers wish to expand for various economic reasons, and that the increasing level and scale of mechanization enables them to do so without changing their labour base. It may also be appropriate where increased mechanization will reduce production risk and where part-time custom work is a feasible income-earning activity.

Such a purposeful build-up of equipment may be a vital part of the mechanism of farm amalgamation and may help to explain the high prices paid for farm land. These prices would seem insupportable on the basis of any realistic assessment of its average agricultural productivity. An existing operation can expand its machinery base over several years, taking advantage of favourable taxation deductions and incurring only minimal increases in production costs. In association with this under-utilized stock of machinery capacity, a farmer can find the marginal cost of operating further land to be very low—being merely the extra expenditure on seed, fertilizers, and fuel. The net marginal returns from additional acres can therefore be at a correspondingly high level which, when capitalized, might appear to justify a high price being paid. There may, of course, be increased production risk involved until such time as the machinery complement builds up again.

As the process of farm growth by amalgamation has occurred, however, there has also been some polarization in the range of farm size with the maintenance, and in some areas an increase, in the number of small farms. This is a reflection of a trend toward part-time farming. Part-time farms have long existed near forestry areas, and are increasingly found in proximity to oil wells, and even near metropolitan areas, notably on the Niagara Peninsula. By enabling the operation of the farm with fewer working hours per acre, increased mechanization has made part-time farming more feasible.

The amalgamation of farms has many and widespread side effects. It frequently changes the form of tenure, as can be seen from the increasing number of farms that have some rented land. Often this represents land owned by other members of the same family, but the incidence of land owners renting their land to larger scale operators, sometimes selling them their own labour as well, is increasing.

Farm amalgamations often lead to a fragmentation of land holdings as well. For when farms are amalgamated they are rarely adjacent to one another, though usually nearby. This creates a need for more mobility, such as higher-speed road gears on tractors to expedite travel between farms. There is a related advantage in having implements either mounted on pneumatic tires or on the tractor itself. There is also a demand for mobile farmstead equipment. Fragmented farms often mean multiple and scattered buildings and therefore there is a need for handling equipment such as elevators and augers, and even for hammer mills and grain dryers, to be mobile. Storage and field operations scattered in this way increase the

amount of handling and transporting of both production inputs and outputs. This has encouraged the increase in trucks, pick-ups and dual-purpose vehicles on farms.

Increased travel, in turn, necessitates the better maintenance, if not the formation, of roads and access routes. Often this requires specialized equipment. In addition, bridges, culverts, wider gateways and generally improved access are often required. The larger machines that are bought encourage an increase in field size, the removal of fences and in some cases removal of trees, in order to increase the efficiency of their usage.

Labour Use – Adjustments in the labour force on farms are closely related to changes in farm size and in the ownership pattern of farms. The number of persons employed per farm in Canada has remained virtually constant during the last two decades even though the total farm labour force has declined by one-half. During the same period there has been a decrease in the hours of labour employed per acre in any one year, and an even greater reduction in the hours of labour used per unit of output.

Accompanying this there have been changes in the structure of the farm labour force, both in terms of age and quality. Many of the smaller farms tend to be operated by older men, and there has also been an increase in the number of women farm workers since 1951. Accordingly, the trend in mechanization is toward easier operation of machines and the growth of handling equipment which reduces heavy lifting. There is also a higher incidence of accidents in the over-50 age group. The employed labour on farms tends to be of increasingly higher quality in terms of working skills and responsibility. This type of employee can command high wages both in and outside farming. Consequently his services have to be used effectively and this means having efficient and large-sized machines.

Since the employee is very often no longer a "farm type", he can move relatively freely from farm to town employment. Accordingly he can demand and get not only wages and housing conditions comparable to those offered in towns, but also comparable working conditions–hours, leisure, and comfort and safety. Even when farmers' sons are employed in the family business today, they have better alternative opportunities and, more often than not, a higher level of training than those of their parents. Consequently, they, too, are interested in improved rewards and working conditions. It is this aspect that seems to underlie the tendency for purchasers of new machines, particularly the bigger models used on larger farms, to be interested not only in operating capacity and efficiency, but also in adequacy of control, comfort and safety features. Employed labour of "competitive quality" cannot be made to make do with inadequate equipment, nor be relied upon to improvise in order to maintain operation.

With increasing mechanization and the increasing complexity of new machines, the skills required in operation and in repair and maintenance tend to be continually increasing. This has two effects–the trend toward employing higher-skilled, more competent farm staff, and increased reliance on off-the-farm services.

These trends are reinforced by the changed labour situation on farms. The surplus off-season labour which had a low opportunity cost no longer exists. Younger members of families tend to be off to school or training courses of some kind. The paid labour is not cheap and must be used to best advantage in the most productive activities. The spare time that was once employed on the farm is now diverted to leisure pursuits. As a result the time for activities other than specifically farm operations is limited. Thus the use of off-farm services increases.

These specialist technical services are not the only ones to be increasingly used. The shortage of surplus labour means that many traditional off-season jobs are being done by tradesmen. The erection of new buildings and building repairs are examples. In this case, too, the improved specification desired often necessitates specialist skills. The economic advantage of mass-produced buildings, and the equipment that is effectively part of them, means that the erection process has to be mechanized. Once specialist machinery is required, it is frequently profitable to import services to the farm. The same applies to a variety of jobs that can be mechanized, such as drainage, fencing, and other irregular or small-volume jobs. By employing specialist labour on these jobs, the amount of labour employed on farms is clearly increased, though this change never shows up in the census.

Capital Use – Changes in farm size and in the level of mechanization on farms lead to corresponding adjustments in the level and structure of the capital stock of farm businesses. The effects of these changes are reinforced by increases in the intensity of animal-stocking rates and by increases in the value of land. All of these factors combine to make the increase in total capital per farm a striking feature of the change in farming structure. Some measure of the increase that has occurred in land values can be gained from the fact that the proportion of farm capital that is represented by machinery has recently declined. This, in spite of the fact that the actual investment in farm machinery has expanded, and that more and larger machines are much in evidence on farms.

The same general pattern of expanding capital investment in land and machinery, with a concurrent decline in the relative importance of machinery capital, is a feature of all sizes and types of farms in Canada. Overall, the smaller farms tend to have a larger proportion of both total capital and machinery capital relative to their output. This probably reflects the economies of scale that might be expected (although, if the small farms are run as part-time farms, they may quite rationally have a higher volume of machinery than there is on farms with full-time farmers).

Associated with the larger capital stock of machinery there have been changes in the purchasing decision. Annual purchases have increased both in number and value, and as each investment outlay has enlarged so has the complexity of the decision involved. The larger outlay means that the cost of decision error is increased. Because larger machines are more complex, the choice between alternatives becomes more difficult. The fact that even small pieces of equipment

may have complex interrelationships with other items in a machinery system further increases the problem. Thus the process of investing in farm machinery is one which receives increasing attention, and which is viewed with increasing concern by farmers. But, of course, changes in farm mechanization do not affect only the structure and management of farms–they necessitate adjustments by suppliers as well.

Service Pattern – Over the last 30 years farm machinery dealerships have become fewer and larger. As a result the relationship between seller and buyer has become less personal. The farmer may not personally know any of those serving him, and this can contribute to the uncertainties surrounding machinery. On the other hand, the larger dealer operation can afford to employ specialists in various aspects of servicing and repair, and can often maintain better stocks of salable goods and replacement parts.

As the dealerships have grown in size they have tended to serve a larger area, mainly because the growth of larger firms has been at the expense of the smaller ones. Thus, the distance farmers have to travel when bringing machines in for service, or when seeking replacement parts, has increased. This can be expensive in terms of both direct costs and lost time, though to some extent this is offset by the better service and fuller stocks of parts that are often provided. The distance factor has also been offset by the use of mobile service units, often radio-controlled, which provide field service particularly during busy seasonal periods.

Another feature of this changing dealer pattern has been the increased complexity of the operation. A large dealership tends to employ a number of highly trained and skilled personnel–not only in the repair shop. Often these staff attend training schools run by the manufacturer, in addition to their basic training. The skills they develop are complemented by a variety of specialized tools and equipment used both for effecting repairs and for making regulatory adjustments on complicated mechanisms. As the relative complexity of machines has increased, there tends to be less farmer maintenance and increased dependence on the dealer service.

Several aspects of the dealership's responsibilities have been extended in recent years. The increase in user dependence on specialized service is one of them. But the expansion of farm mechanization has increased other obligations too. These include some responsibility for operator training, and for safety education. In some instances this onus is passed on from the manufacturer and reflects his liability for the performance and safety of his product. The dealer also has to accept the duties associated with the warranty and service agreements that have become an accepted part of farm machinery packages. As the package becomes increasingly complex, there is growing pressure for the dealer to provide some guidance to farmers in machinery selection and in other aspects of machinery management, including its finance. This expanding role of the dealership is a reflection of the increasing interdependence of different sectors of the economy, and the same trend affects other institutions as well.

Government departments and agencies have had to adjust their policies, too, in order to fit in with a more mechanized agriculture. On the positive side, this has involved the development of appropriate taxation policies, the organizing of financing and loan arrangements and, in a few all too rare instances, of instituting special programs such as that operated under the auspices of the Agricultural Machinery Administration in Saskatchewan. Various governments have also brought in laws regulating the operation of the farm machinery companies, and they have from time to time investigated general aspects of the impact of mechanization on farms.

Various other institutions have also taken action to meet the changing situation, sometimes with governmental support. Research stations and advisory services have investigated and tried to anticipate various changes. The universities have oriented their teaching programs to meet the needs of the mechanical revolution on farms. Though the adjustments of all such organizations often seem to have been too little and too late in terms of the massive changes required, they have nevertheless been purposeful adjustments which have aided the harvesting of the fruits of farm mechanization in most cases. Inasmuch as these changes have been constructive, they provide a basis for the type of activity that might purposefully be fostered in the future.

And as has been described in more detail elsewhere in this Report the machinery manufacturers themselves have had to make extensive changes as mechanization has proceeded.

Changes in Machinery Investment

Of the many farm adjustments that have occurred in response to greater mechanization, changes in the investment pattern are perhaps the most significant. For these changes affect the management and business aspect of farming and the adjustments required lead to further changes in all aspects of farming. Since management involves adjustment to change, it is the management side of farming that in the final analysis reflects the full magnitude of the changes that are taking place.

Investment Pattern – Though the consistent increase in farm machinery investment that has taken place since 1945 has been caused partly by larger and more complex farm machines, there has also been an increase in the total number of machines. More and more farm operations are being mechanized. In order to achieve this, new equipment is required. For example there are herbicide sprayers, new forage harvesting machines and hydraulic lifting equipment. The operation of these new items necessitates additional units of more commonplace machines including tractors and trailers–and these accordingly have begun to multiply. Thus the increase in machine numbers includes both new and existing types of machines. At the same time there has also been an increase in the size of the more traditional equipment. In particular there has been an increase in the horsepower of tractors

and subsequently in the implements that they pull. Often the increase in implement size has not been proportional to the increase in horsepower, as some power has been diverted through more sophisticated transmissions which give greater flexibility and effectiveness of control, but with slightly lower efficiency in mechanical terms.

This increased complexity, and the higher technical quality that is essential to it, represents another way in which the capital cost of machinery has tended to increase. The shift from gasoline to diesel engines has had a similar effect. The latter are cheaper to run, have lower repair and maintenance costs, but also have a higher initial cost.

Another feature of the investment pattern has been caused by the emergence of "systems". Machines are rarely bought separately but as part of a matched system. The full effectiveness of many pieces of equipment is dependent on the adequacy of auxiliary items that form part of the working system. Thus, the replacement of a combine with a larger-capacity model provides little benefit unless storage facilities and handling equipment all have sufficient capacity to permit its effective operation. The use of handling equipment is a component of increasing significance in these modern machinery systems. In addition, sophisticated equipment needs to be kept under cover when not in use, so that machinery buildings add to capital requirements. To the extent that new machines are repaired and serviced on farms there is a need for specialized tools and devices to facilitate this, as well as a workshop or other place to carry out the service operations. All of these items add to capital investment related to mechanization.

Farming Operations and Constraints – The whole process of farm mechanization is tied up with changes in farming operations, particularly husbandry. Very often new varieties of machines are necessary to permit the effective mechanization of a process, as was true of tomato harvesting. New machines may be required to facilitate the introduction of a new farming method. Thus, mechanical sprayers are essential to allow the use of "minimum tillage" in cereal growing. But apart from these direct influences, many other shifts in farming practice have indirect effects on the pattern of machinery investment. The increased use of fertilizer generally has the effect of increasing yields from crops. In some cases, too, the use of chemical fertilizer permits the more frequent cropping of suitable areas. The use of herbicides to control weed growth enhances this possibility. This means that rotations can be shortened and a larger proportion of farm acreage cropped in any one year. In some cases irrigation can be effectively used to enable even more intensive cropping. Machinery itself contributes by such changes as precision seeding, and by permitting more freedom in the spacing of plants, particularly in corn growing. At the same time breeding programs provide more disease-resistant and better-yielding crop varieties, and all of these changes tend to increase the volume of output per acre.

The increase in the volume of output expands the time required to complete seasonal operations. The continuing increase in acreage cropped per man, due both to tighter rotations and larger-sized farms, further aggravates this problem. Because of the timeliness constraints on farming operations, this persistent trend causes a continuing adjustment in many aspects of farming, including mechanization. The time available for any field operation is determined by the prevailing weather conditions and the biological tolerances of the variety being grown. At seeding time in Canada, seed-bed preparation cannot begin until the ground thaws and sowing can commence only after the soil has reached a certain temperature. A very brief period exists during which seeding conditions are optimal. Before this period a loss of yield occurs due to the soil conditions. This loss is higher the earlier the seeding date is before the optimum. Similarly, the yield obtained begins to decline progressively after the optimal period has been passed due to the shorter growing period that is available. Though the length of the optimal period will vary from year to year, it sets an effective limit on seeding operations.

At harvest a similar but somewhat less rigid set of restraints is met. The start of harvest is determined by the time of ripening of the crop, and this in turn depends upon the date of seeding, the growth characteristics of the crop variety, and the weather conditions during the growth period subsequent to seeding. The time available for harvest is influenced by weather conditions that prevail once the crop is harvest ripe, and is restricted by the grain losses and loss in quality that occur in the standing crop. As with seeding, this final constraint is not rigid, but after a brief optimal harvesting period the time taken can be extended only by accepting a progressively greater loss of yield and grain quality. The rate of this loss is again determined by the weather conditions that prevail at the time, and these vary from year to year and from place to place. In some cases even small changes in location can give very different constraints. The acreage of crop that can be handled, at both seeding and harvest, is therefore determined on any one farm in any one year by the extent to which the restraints can be overcome by better technology or husbandry practices.

Capacity Requirements – Within the varying time available, the acreage of crop a farmer can grow is primarily determined by the rate at which he can complete the sequence of operations involved. Before the introduction of tractors he was limited in this mainly by the walking speed of a working team (about 2.4 m.p.h.), by the width of machines this team (of usually six to eight horses) could draw, and by the number of hours they could effectively work in any one day. Thus the acreage of crop sown on any farm was effectively restricted.

At harvest, the restraints were somewhat less absolute. The rate at which harvest proceeded was limited in part by the weather, and by the rate of work of the horse-drawn mower or reaper and binder. In general, however, the time available could be extended almost indefinitely, to accommodate annual variations in the volume of crop and in harvesting conditions. Providing the crop could be cut, it could usually be placed in stooks or carted and stacked, by enlarging the casual

labour force to meet the needs of the season. In a big crop year, or a late harvest, threshing could go on well into winter should it be necessary to do so; though the cost, in terms of grain losses associated with the length of time the crop was standing, and with all the handling involved, was undoubtedly high under such circumstances.

With the introduction of the tractor the situation initially was changed very little. The first tractors did little more than substitute mechanical power for draft power. Each tractor was regarded as being approximately equal only to a horse team. Since it pulled the same implements, the rate of work could be increased very little without loss of quality and effectiveness in operation. To some extent the tractor was less flexible than the horse team it replaced; it became bogged down in places where horses might have carried on. The one restraint effectively removed by the tractor was the number of hours that could be worked in a day. The tractor needed neither to stop for a spell nor did it tire as the day went on. The hours worked were limited rather by the fatigue of the operator and the changing working conditions during the day.

As time progressed the tractor improved, and new potentials became realized as machines were developed to suit the tractor rather than the horse team. Though eventually there was to be a whole range of new and specialized tractor-operated equipment–from redesigned cultivation implements to power-operated harvest equipment–the most significant change was in the size of the implements and equipment that could be pulled. This began steadily to increase.

Capacity-Acreage Effects – With this increase in machinery capacity the farmer was able to plant an expanding crop acreage. This had in turn to be harvested, and thus pressure increased for the harvest to become more fully mechanized. At this time, the combine, or its forerunners, which had been in limited use for some time, became widely used. The processes of harvesting and threshing became virtually a single operation. As such it was greatly expedited, but because of the nature of the machinery involved, harvesting was no longer an open-ended final operation whose vagaries could be encompassed by extending the labour force or the time taken. It became a fully mechanized activity.

This increase in harvesting capacity in turn permitted a further increase in acreage cropped, and presumably created a demand for more machinery capacity for soil preparation and seeding operations. As this was achieved, by even larger tractors and implements, the sowing operations again ceased to be the major constraint on acreage of crop per farm, so that there was a further demand for expanded harvesting capability. It is conceivable that in this way, over many decades, mechanization has progressively facilitated the growing of an increased acreage of crops on individual farms.

To the extent that it has done this, farm mechanization has been a determinant of the growth of crop acres per farm, and of farm size adjustments and the related land price movements. Such an argument assumes, of course, that either

income effects, risk aversion, or some other factor, causes farmer's goals to be oriented toward increasing their land base providing they can handle it. That such a goal is held, by some farmers at least, is well known. Thus this explanation is not wholly unacceptable. It seems considerably more likely, or at least more plausible, than the simpler notion that larger machines are bought that provide unused capacity, and that this encourages a growth in farm size in order to spread overhead costs.

Capacity-Time Effects – The increased capacity that has been achieved, however, has involved many changes apart from the growth in machinery size. Since increased capacity can be obtained by either doing the job involved more expeditiously or by extending the available operating time, there have been developments that have endeavoured to do both. By selecting crop varieties (and breeding new ones to select from), and by spreading seeding dates as widely as possible, the length of the seeding and the harvesting periods was extended as far as the biological tolerances would allow. The time available for soil preparation and seeding was utilized more effectively by the introduction of the disker, which allowed seeding directly into the stubble of the previous crop. Similarly, the harvest period was extended to some extent, and shelling losses somewhat reduced, by the practice of swathing. The use of the swather to cut and windrow the crop permitted grain to ripen more evenly so that combining could begin earlier. Since shelling losses were reduced, the length of the harvest period could be extended without the same cost involved through grain losses. Since it could put two cuts into one windrow, the swather also speeded the rate of combining in some cases.

Other innovations contributed, too, including the introduction of integrated systems. As larger and faster combines enabled larger acreages to be harvested in less time, severe handling problems arose. Hence the use of bulk handling was necessary to facilitate faster unloading and speedier removal of grain from the field. More recently the advent of grain dryers on the Prairies has shown promise of allowing harvest to begin even earlier, and of permitting more days to be used for combining when grain would previously have been too damp. When the rate of work that can be realized is dependent on all of the stages involved in an operation, there is a need for the stages to be integrated into a system. Mechanization seems likely to continue along these lines as the farm operator battles to extend his control of the production process.

Capacity-Cost Effects – Such changes in farm machinery capacity have significant cost implications. The choice of a particular capacity system is effectively a choice of a particular level of investment. Since machinery is a flow resource this investment is translated into an annual cost. Within the production year it becomes a fixed part of the unit cost. Given any one level of output, a different investment will give a proportionally different unit cost. Thus unless there is a proportional increase in the volume handled, a larger capacity system is likely to involve higher unit costs. Although this may occur, however, it may be offset by a more reliable output. A specific aim in using larger and more complete

machinery systems is the reduction of risk. Thus a smaller profit margin with greater reliability might be preferred to a sometimes higher but more variable one. The decision as to what amount of risk to accept will be determined by the financial position of the individual farm, and the attitude of its manager.

The process of mechanization generally involves substitution of overhead costs for operating costs. For instance, cereal harvest mechanization has substituted overhead costs of the swather, combine, transport and storage bins, augers, and grain dryers (all with some component operating costs) for the operating costs of stooking, loading, stacking, threshing, and so on. In view of this increased overhead component in the unit cost of the operation, it might be expected that the nature of the unit cost will be altered. This is to say that, when used over larger levels of output, the overhead costs for any given machinery system will be spread further and will thus give a lower average cost per unit of output. It is sometimes also argued that this will hold for a series of machinery systems, and that economies of scale will exist. A Commission study of seeding and harvesting costs on the Prairies shows that successive-sized systems have minimum cost levels over a narrow range of acres, and that the minimum cost varies little from one system to the next.[3] In other words, except for very low acreages when the overhead costs have not been spread (and when either custom work or a used machine would be cheaper), the unit cost of the operation for the most suitable-sized system is comparable for all scales of operation—provided the minimum cost alternative is being used.

This finding is in keeping with those from another Commission study which showed that apart from the small-farm-size groups, where scale diseconomies were measured, there was a plateau of farm sizes over which no economies or diseconomies of scale were observable in the aggregate sample.[4] Such an adjustment would be in keeping with the increasing capital investment and resultant overhead costs on these farms, a large proportion of which relates to farm machinery.

Some interesting points also arise from a consideration of the marginal or incremental cost associated with using a machinery system to cover an additional acre. From the Commission's study it was found that the marginal cost increased more sharply for seeding operations than it did for harvesting operations (see Figure 25.1). This suggests that the restraints on seeding are more severe than those on harvesting, and that the cost of timeliness is accordingly greater. The less steeply rising marginal cost for harvesting, on the other hand, suggests that timeliness effects, though significant, are not as serious as for seeding operations. The variation in both the unit cost and marginal cost of harvesting, however, showed greater variability from year to year than did those for seeding. Thus, although the

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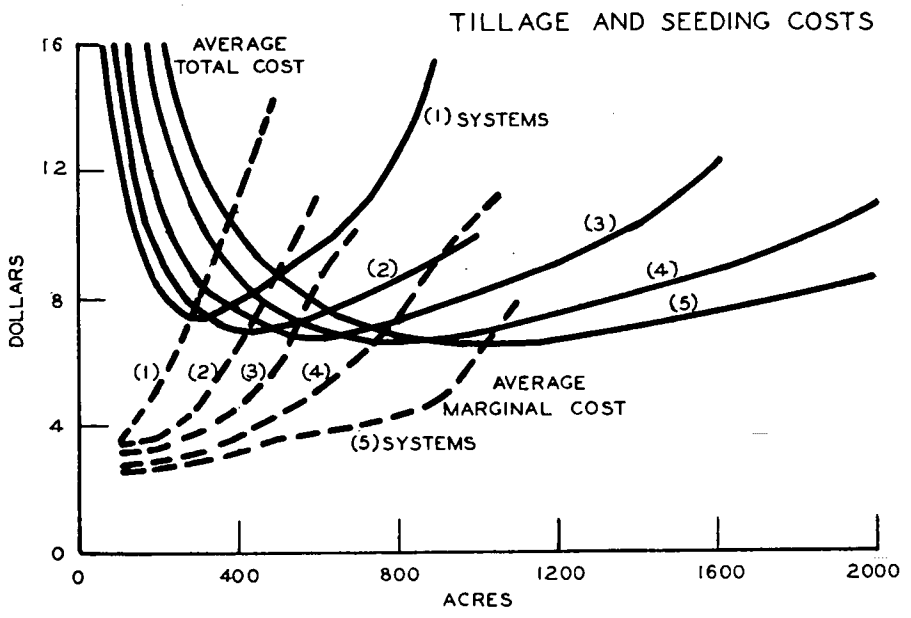
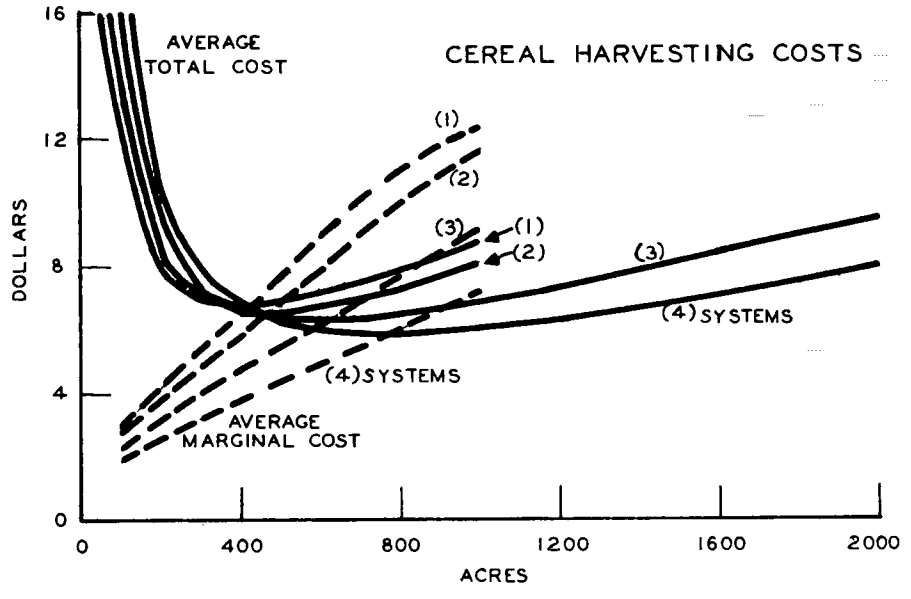
[3]G. F. Donaldson, *Farm Machinery Capacity,* Royal Commission on Farm Machinery, Study No. 10 (Ottawa: Queen's Printer, 1970).

[4]J. S. Sahota, *Economies of Scale in Farming: Analysis of the 1958 Farm Sample Survey* (data from survey conducted by the Dominion Bureau of Statistics), unpublished Commission study, 1969, as summarized in Appendix B.

FIGURE 25.1-ESTIMATED MACHINERY COST CURVES





harvest restraints are less rigid, the risks are greater from year to year. Farmers assert that their production risks are increasing over the years; to the extent that they have larger acreages carrying higher yields obtained through greater production costs (for fertilizer, seed, and other requisites) but with the same number of days and degree of weather variability, this is clearly a real concern.

These effects go some way toward explaining some of the features of the mechanization of these two farm activities. The constraints on the seeding operation suggest a reason for the large range of alternative systems that are available (including more than 10 tractors of different horsepower), since each one is suited to a fairly narrow acreage limit. For harvest operations there are fewer alternatives to choose from, and the emphasis is on additions and modifications to the harvesting system (such as grain drying), that will increase control over the harvest variables. Because of the importance of timeliness as a cost determinant at all times, there is also concern about machine reliability, and this leads to considerations of replacement.

Replacement Patterns – Since farm machinery is a flow resource which yields its services over time, each machine eventually wears out. At this stage, if not before, it has to be replaced by a new unit. Over time, the timing and the pattern of the replacement of farm machines has changed. For instance, data on the stock of tractors on Canadian farms suggest that their average age is increasing. The minimum average age of farm tractors was 5.9 years in 1951, 7.8 in 1956, 12.4 in 1961 and 14.8 in 1966. Though this trend is greatly influenced by the upsurge in purchases in the immediate postwar years, it is nevertheless a sustained trend– and at first a surprising one.

Given that investment in farm machinery has been shown to be profitable, an increase in tractor purchases might be expected. Since there is continual improvement in the level of engineering technology, a more rapid replacement pattern would seem more sensible. In view of the timeliness effects in field operations, increasingly more modern and reliable equipment would seem to be desirable. As the number of hours worked per farm each year has grown, machines might be expected to wear out sooner rather than later. Since the costs of repair parts and skilled labour both continue to rise, it would seem likely that earlier rather than later replacement would be the trend in order to substitute more slowly rising overhead costs for the faster increasing operating costs.

This is, in fact, the case. Beneath the masking effect of the increasing age of machines on farms there are several other changes occurring. First, there has been an increase in the number of tractors per farm–partly because there are fewer farms. Most farms have one tractor and many have four or five. Since there are more tractors, each can work fewer hours and decrease its workload even if the total number of hours worked on the farm were to increase (though this has in fact not happened). Thus, each unit takes more years to work the same number of hours. Second, there has been an increase in tractor substitutes on farms. These

take the form of increasing numbers of self-propelled combines and swathers, electric motors to replace stationary tractor power, and dual-purpose vehicles. The latter are particularly useful when farms consist of scattered blocks so that much road travel is involved. To the extent that jeeps (or their equivalent) and trucks are used for on-farm transport they substitute for tractors. Thus the number of operations for which tractors are used has declined and the hours of tractor work per year has changed accordingly.

At the same time there have been some changes in the replacement pattern which reinforce this hypothesis even more strongly. Although the number of tractors bought each year has declined, thus contributing to the increasing age pattern, the total amount of horsepower purchased has continually increased. Though fewer new tractors come onto farms, many of them are of increased horsepower. In addition, it is very likely that the newer and larger tractors are used in critical field operations. These two effects--tractor substitutes and larger tractors--have combined to cause the number of tractor hours used on farms each year to decrease.

The tractor replacement pattern on farms has not been the same in all regions. The major growth in the number of tractors per farm and of larger (over 80 HP) tractors has been in the Prairie Provinces. In all provinces the number of tractors per farm has increased most where the number of farms has decreased most. The over-all proportional change in horsepower per acre has been about the same in all locations.

The shift to the use of larger tractors has, in turn, created some further adjustments. The very large tractors used for field operations tend to be unsuitable for use as a second or third tractor. Consequently there is a trend toward replacing not only the first tractor with an equally large or larger unit, but also the second or third tractor, with a similar small unit. This adjustment has caused some changes in the second-hand market, with newer, larger units becoming available. It has been shown that, both economically and technically, this presents an opportunity for the increased tractorization of smaller holdings. There is evidence that the existence of a second-hand market in farm machinery is directly attributable to the fact that used equipment is worth more to farmers who use it infrequently, or who have to pay higher interest rates, than it is to those with low rates of interest or high levels of use. Not infrequently the smaller farmer may have both lower usage and higher interest charges. Thus it may pay him to buy a used tractor even though it pays the first owner to dispose of it.[5] Empirical evidence suggests that this is technically feasible too. Data on repair and maintenance costs show a different pattern and are reduced when a machine is transferred from its original level of use to a lower use level. Thus, if a tractor is transferred from a larger to a smaller farm, or from a bigger to a smaller role in the farm business, there will be some gain from the change in technical performance.

[5] W. Candler, "The Rate of Interest and the Second-hand Market for Farm Machinery", *Journal of Agricultural Economics*, Vol. 15, No. 3, June 1963.

In accordance with the changing pattern of tractor replacement, there have been changes in other equipment. Very often the implements pulled by the tractor had a longer life than the power unit–mainly because they had fewer working parts–and thus lower repair and maintenance costs. But with the escalation in tractor size it has been necessary to upgrade the implements continually in order to exploit the increased power effectively. This has meant the introduction of both different and larger implements. As a consequence of this change, more high-quality used equipment has been traded on new implements. Fortunately, the structure of the farming industry, with its many different sized units and the existence of a second-hand market, allows this exchange to take place reasonably effectively and without the cost becoming prohibitive. This alteration is one of many changes in the acquisition pattern for farm machinery.

Alterations in the Acquisition of Farm Machinery

With the growth of mechanization, extra capital has had to be found by all farms in order to stay in business. Given the rate and extent of the mechanization growth, it is hardly surprising that there have been changes in the mode of acquisition of machinery and, where it is purchased outright, in the source of capital used for purchase. Though the evidence available is sketchy, it is possible to detect adjustments in machinery purchase, in co-operative ownership, and in hiring arrangements.

Machinery Purchase – In the period 1951-66, annual purchases on a per farm basis and the stock of equipment on Canadian farms more than doubled. Despite the inflation of money values, this represents a significant increase, from $378 to $968 per farm for purchases, and from $3,102 to $8,250 per farm for machinery assets. Thus a significant proportion of new farm capital has gone into machinery. At the same time, however, there has been a massive growth in the total capital invested per farm, reflecting both the increasing land base of farms by their amalgamation with other units, and the rise in land values.

These two effects have had different implications for farm finance. The increase in investment per farm that is due to amalgamations does not alter the total capital stock of the farming sector, but it does mean that those farmers who do the amalgamating have to find capital for the purchase of additional land. Thus the growth in machinery investment has taken place in a period of capital scarcity.

On the other hand, the upward trend in land values that has been particularly marked in the 1960s causes an increase in the equity of anyone owning land. Thus most farmers will have experienced an increase in their equity base. Since this is a prime determinant of borrowing capacity, the increase in equity provides a proportional expansion in credit access. In so far as credit is used for machinery purchase, the rise in land prices aids mechanization.

Studies have shown that in the past (and particularly in the 1950s), the money used for farm machinery purchases was drawn largely from farmers'

incomes.[6] But, there is some evidence to suggest that credit has grown in importance as a means of machinery acquisition. In the years 1961-66 the capital stock invested in machinery on farms increased by 50 per cent but concurrently the estimated medium-term (1.5–10 years) credit outstanding grew by some 150 per cent. Short-term credit showed a 100 per cent increase in the same period. Since virtually all credit used for machinery will fall into these two categories, it is evident that an increasing proportion of machinery purchases is being made on credit.

Nevertheless, most analyses of demand for farm machines demonstrate a relationship between net farm incomes and purchases in any one year. This is not surprising since all purchases whether for cash or credit have eventually to be paid for out of income. High-income years may allow old loans to be paid off so that more credit might be accessible in a good year, as well as more surplus cash. A year of high income may also have important psychological effects, and may encourage expenditure by increasing confidence. There is also the point that years of high farm income are very often also years of high physical output. Thus some machinery purchases may be more essential in such years. Together, these points may help to explain the relationship found in such demand studies.

Over time there have been changes in the sources of credit used to finance the purchase of farm machinery. In the late nineteenth century, the main finance source seems to have been merchant credit and machinery company loans. As the expanding agriculture became better established the commercial banks provided larger amounts of credit. During the depression of the 1930s all credit sources closed down and there was a credit shortage which led eventually to the introduction of the *Farm Improvement Loan Act* of 1944. Subsequently, the commercial banks, backed by government guarantee, have remained by far the most important single source of farm machinery finance. In 1964 the chartered banks provided 52 per cent of all farm machinery credit, 42 per cent being backed by F.I.L.A. guarantee. The farm machinery companies provided 16 per cent, independent finance companies 12 per cent, credit unions 7 per cent, and the remaining 13 per cent was provided by various other sources. In recent years, as has been described elsewhere, credit provided by the farm machinery companies has increased in importance.

Purchase Incentives – The productivity increasing impact of farm mechanization has been well recognized by governments, with the result that many countries have adopted policies that encourage machinery investment. The precise nature of these incentives varies from one situation to another, but they mostly include: (1) special credit facilities, (2) adjustments in the rate of depreciation allowed for taxation purposes, or (3) direct capital grant arrangements.

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[6] H. G. Diesslin, *Agricultural Equipment Financing*, National Bureau of Economic Research, New York, N.Y., 1955.
A. S. Tostlebe, *Capital in Agriculture: Its Formation and Financing Since 1870* (Princeton: Princeton University Press, 1957).

In Canada, some elements of all three of these devices are used. The nature of the special credit provisions have been previously outlined. There are also favourable depreciation allowances, and almost by accident, a tax-free rebate (which would be removed by the *White Paper*). In general, for taxation purposes depreciable assets are handled on the reducing balance method of calculating annual costs. When this method was introduced, however, farmers were permitted to continue using the simpler but less realistic straight-line method of computing capital cost allowances. Most farmers have chosen to remain with the old basis, though in some ways the declining balance method is more favourable to them. Though both methods can apply equally favourable depreciation rates, the use of the declining balance method gives higher deductions in the early years after purchase and permits the bulk of the cost to be written down more rapidly. The straight-line method, which permits the writing-off of equal amounts over a specified number of years, reduces the bulk more slowly but permits the investment to be fully written off sooner.

It may be for this last reason that the latter procedure is preferred by farmers. The point is that once a capital expense has been written off it can then be sold without the proceeds being taken into account for income taxation purposes. Thus if a combine is sold after five years it can provide a handy tax-free bonus. The new combine can then be depreciated as was the old one. This loop-hole will be closed if the declining balance method is adopted as standard practice—as was recommended in the *Report of the Royal Commission on Taxation*[7] and now in the *White Paper*. As long as it remains, however, this anomaly will have various side effects.

One of these is that because of the tax-free profit on the used machine, farmers may tend to place excessive emphasis on the price obtained for his trade-in. To the extent that he does this, there is pressure for the dealership to meet his demands by raising the price paid for the used machine, and adjusting the purchase price of the new machine accordingly. This may contribute to the high list price for farm machinery in Canada, and for the high dealer margins that are allowed. Similarly the investment policy followed by farmers could be related to this short-run advantage which may not be in the long-run interests of either the individual farmer or the farming industry. It may, for instance, encourage farmers to replace existing equipment when it might be more profitable to mechanize another operation, meanwhile "making do" with the used equipment. There can be no doubt that a policy of earlier replacement is encouraged by the existing arrangement, and it seems likely that this may result in more frequent replacement than would otherwise be profitable. It does, however, provide the farmer with a bonus which, probably more often than not, will be plowed back into machinery purchases.

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[7] *Report of the Royal Commission on Taxation* (Ottawa: Queen's Printer, 1966).

Co-operative Ownership – As the level of mechanization continues to rise, there is obvious incentive for some sort of co-operative ownership, particularly for equipment that is little used. Two forms of joint ownership are commonly found, sharing and syndicates. The more informal arrangement of equipment sharing is common practice in farming areas, and always has been. Very often the sharing is done within a family group, or some other identifiable social group. In many cases the arrangement takes the form of specialized ownership wherein each farmer will own the specialized equipment used in a different operation or enterprise. The sharing arrangement often provides the dual advantage of reducing machinery costs and providing specialist labour. It is, however, an arrangement characteristic of family farming. As such, and as farming becomes more commercialized, it can be expected to decline.

Syndicates are a more formal sharing arrangement. Here the owning syndicate has a corporate identity and the machine users each become shareholders. It has the advantage that not only are machinery costs per farm reduced, but also that the capital borrowed to finance the machinery purchased is not held as a debt against the equity of the syndicate member. Thus, it is a means of obtaining access to capital without direct borrowing. In some cases, special credit provisions are made for syndicates, which further enhance their virtues.

On the other hand, syndicates provide some operational snags particularly in relation to timeliness and maintenance. For operations involving timeliness restraints there are obvious organizational difficulties involved. The machine is perhaps wanted by several people at once and this can result in both economic and social problems. There are often problems, too, with repair and maintenance and general user care in operation. The operating costs of a syndicate-owned machine often exceed those of an individually owned one. For all this, however, syndicates do have financial advantages, and they can be used for specialist and off-season activities. On a larger scale there may also be a useful arrangement when establishing grain-drying and storage facilities, or any other activity that can profitably be centralized.

Hired Facilities – The logical alternative to co-operative ownership is to make use of hired facilities. Again there are two kinds often found–custom services, and machinery rental. Both types tend to exist in a variety of forms, from the highly organized and professional to the disorganized and casual.

A variety of different operations are done on a custom basis, the best organized being cereal harvesting. A much larger acreage than now was so harvested in the 1940s when machinery was scarce. Sometimes this has been done by large operations that move thousands of miles, beginning in Texas and moving northwards. In other cases the work is done by a small local operation, which may have two or three machines. In other situations still, custom work is done by a farmer with surplus capacity–usually for a neighbour. In an industry where capacity requirements vary annually, the existence of this type of contract arrangement is a vital flexible element in the total system.

Custom services have the advantage that they involve no capital outlay (or where they are used in emergency situations, lowered capital outlay). The use of custom services consequently involves no fixed or overhead costs, though they usually come at an increased unit cost. They also have the advantage that, along with the machine, the farmer employs the specialist labour provided.

The great disadvantage of being dependent on custom services is the timeliness factor in seasonal operations. Custom operations are never available when they are most wanted–for the very simple reasons that (1) all other producers in the same area will want them at about the same time, and (2) the time when they will be needed varies from season to season and cannot be predicted more than a few weeks ahead. Their full advantages can be gained, however, in non-seasonal operations and in those seasonal activities that do not have active timeliness restraints.

The alternative to custom work is to make use of machinery rental facilities. Rental arrangements have not been widely available on a formal basis, but they are increasing. For convenience, three different categories may be delineated. Lease-hire arrangements are the first. These are common in industry and likely to increase in farming. The advantages are that it provides a modern machine, at a fixed annual cost without risk of large expenditure due to breakdown. There is usually provision for rapid replacement in case of a major breakdown. No capital outlay is involved and all risk is taken by the vendor. The only disadvantage is that it might be cheaper to own rather than to rent.

Rental agencies are the second category that provide equipment on a rental basis, sometimes with an operator, in which case they are similar to custom services. This type of service is obviously useful for non-repetitive, non-seasonal jobs for which special equipment is necessary. To the extent that a wide variety of specialist machinery is available such services do provide a means of getting access to the best machine for the job.

Machinery dealerships provide the third type of rental. Very often this is an irregular part of their business, but many if not most dealerships will at various times rent machines to their farmer clients in an emergency. Together with the custom work done by neighbours, this forms the safety valve on many seasonal operations. The present trend suggests that dealerships in the future might provide lease-hire and rental facilities as a standard stock-in-trade. For all this, however, the greatest proportion of farm machinery is still likely to be acquired by purchase, partly on credit.

Changes in Management Decisions Concerning Machinery

From the foregoing discussion it is clear that there has been an abundance of adjustment and change associated with the continuing process of farm mechanization. All such change creates effects of its own. Change is the fundamental cause of uncertainty, since many changes and their outcomes cannot be anticipated.

Change is also a prime determinant of the need for decision-making, since, without change, decisions could be taken once only without need for further repetition.

In their management decision-making, farmers are confronted with a burgeoning complexity associated with the progressive change taking place in their farm businesses. The changes concern the over-all operating environment, including the marketing and policy framework; the planning and organization of production, including the choice of enterprises, activities and resources; the control of the business, including purchase and selling arrangements; and the day-to-day regulation of operations within the production process. Mechanization causes adjustments in all of these aspects of farming. As the rate of mechanization increases so the number of decisions multiply, and as the level of mechanization grows so the number and complexity of production decisions expand proportionately.

The multiplicity of decisions necessitated by technological change create a demand for information. Decision-making involves the evaluation of alternatives to permit choice, a process which hinges fundamentally on the availability of appropriate information. As all activities involve decisions, so many phases in farm production and the use of machinery necessitate the acquisition, analysis and assessment of large amounts of information.

Some changes may create a need not only for larger amounts of information, but also for a different kind than has been required in the past. This situation is demonstrated in the case of grain drying on the Prairies. The introduction of artificial grain drying has caused a need among farmers and advisers for detailed technical information on the growth and maturity of plants, on the physical and physiological process of drying, and on the resulting biological and chemical changes in grain qualities, as well as on the operation of dryers themselves. Associated with these relationships there are complex cost, market and price implications that need to be taken into account. In this particular case, the changes affect not only farmers, but machinery manufacturers, government agencies, market authorities, and food processors as well. Therefore, the type of information required is determined by the type of decision involved, the time and level at which the decision is to be made, and who the decision-maker is. Furthermore, the type of information that is useful will depend on the analytical tools available to facilitate the increased accuracy of decision-making.

The extent to which information is useful, in terms of the farmer's changing management decisions concerning machinery, is determined by three aspects of each decision situation: (1) the degree of certainty regarding the outcome of possible alternative courses of action; (2) the economic consequences of choosing other than the best course of action; and (3) the amount by which the information (if available) is expected to reduce the initial uncertainty. Each of these elements can be expected to change over time.

In spite of technical improvements that have allowed better control of many aspects of farm production, the range of outcomes, inherent variability and

resultant uncertainty associated with all the alternative actions has, in a purely physical sense, rarely been reduced. It is only when the technical advance is applied with full knowledge of its implications and information on its range of effects that uncertainty can effectively be lowered. Both the greater variety of feasible alternatives and the technical complexities of producing crop and animal products would seem in every case to have increased. Concurrently the extension of new technology has caused some variable restraints which cause uncertainty (such as the time available for the cereal harvest) to be more fully stretched. All of these adjustments increase the range of uncertainty of alternative actions unless the relevant information is available and used. Such information is, of course, really an integral part of technical improvements.

Similarly, as production yields have grown, and total output and revenue from increasingly larger farms have become greater, the potential loss of income due to uncertain events has progressively enlarged. As production has become more mechanized and capital has been substituted for labour, the level of fixed costs as a proportion of total costs has also increased, and the total expenditure per acre or per livestock unit has expanded. Thus the potential loss from costs incurred in production has grown more serious. Since the consequences of alternative actions must be expressed in relative terms, the potential loss of benefit will vary from one situation to another. However, as the range of possible outcomes is extended, some of the possible economic consequences become more dire. Thus the uncertainty confronting the farmer in his management decisions is increased.

Despite this general pattern of developments, the actual performance of farm production on individual units has in most cases not demonstrated this variability. This is because the many changes in farm production that might give rise to this potential variability are, in most cases, introduced or implemented only when information about their effects and effectiveness is fully available. This information allows the new technology to be applied in most situations without an increase in uncertainty proportional in magnitude to the physical and economic adjustments themselves. In terms of the third of the three elements specified above, the amount by which the relevant information can reduce the related uncertainty is very great. As a consequence, the acquisition and use of increased knowledge and detailed information is a predominant characteristic of the mode of operation of the modern farmer.

The extent of the adjustment in this aspect of farm life can be observed in the proliferation of communication channels between various sources of information and farmers. The farmer is surrounded with journals, bulletins, and reports; he is bombarded with information at courses and schools, and by individual technical advisers; he is urged to be scientific and efficient through the mass media of radio and television. This network is supported by government agencies with their research centres and advisory services, by universities, colleges and schools, and by commercial firms. These are all in addition to the farmers' associations and the traditional service professions of accountancy, law, and marketing.

All of this activity is facilitated by an expanding professional group of "agrologists" who work in these various organizations, and to a growing extent as private consultants. The continued expansion of these services has been maintained in recent decades even though there has been a reduction in the number of farms. Thus the proportional growth has been much greater than is often recognized. This particular adjustment related to changing technology in the farming scene is perhaps the most easily observed but the least well recognized.

The use that is made of the information is extensive, even though farm practice lags behind precept to some degree at all times. The external channels are effective in reaching most if not all farmers, even though many farmers obtain much of their information second hand from their fellow farm managers. An effective information service does not need to reach all users directly, provided the facts are passed on. The significance of this aspect of farming can be judged from the observable fact that it is often those farmers who are not inclined or able to make use of the available flow of information who find their economic existence in jeopardy.

In view of the special role that farm machinery plays in present-day farming, and of the proportion of farm costs that mechanization represents, information concerning machinery and machinery decisions is of particular value to the farmer. Yet of the total expenditure on all formal scientific information services to agriculture, less than 10 per cent (and probably less than 5 per cent) is devoted to obtaining and distributing information on farm machinery and mechanization. As a consequence, the information that is passed around is imprecise and of poor quality. To a large degree, farm mechanization is the one aspect of agricultural production that remains the safe domain of the non-technical journalist–though this is clearly not always the case. As a consequence, the farmer finds himself on least solid ground when making decisions related to machinery. This cannot only lead to wrong or less-than-satisfactory choices of alternatives, but it may be a determinant of a far-reaching unease and subsequent disquiet among farmers concerning this aspect of their operations. It seems likely that this situation might be a root cause of the type of pressure that has lead to publicly expressed concern about farm machinery problems and to the origin of this Commission.

Chapter 26

IMPLICATIONS OF CONTINUING FARM MECHANIZATION

The adjustment pressures on Canadian agriculture since the end of the Second World War are symptomatic of the process of growth in an economy. As a nation becomes more affluent, the traditional industries, particularly agriculture, though continuing to grow in absolute terms, undergo a decline in importance relative to the rest of the economy. With rising income levels the demand for agriculture's output grows at a slower rate than aggregate demand in the economy, and earns a declining share of the consumer's dollar. As the Canadian economy continues to develop, both in size and in structure, these adjustment pressures will continue to operate on the agricultural sector. And since farm mechanization has, in many senses, come as a response to these pressures, so it can be expected to play an important role in the future adjustments in farming.

On the other hand, perhaps a new phase in the process of mechanization has been, or soon will be, reached. The emphasis in future developments is likely to be on major refinements to already mechanized operations, and on exploiting advanced and sophisticated technology within the existing structure of machinery use. Having reached the stage where machines are an integral part of farming activity, the role of mechanization is now shifting away from mere labour substitution and the augmenting of manual effort. It has now become an indispensable component of farm production, an input upon which the continued operation of Canadian agriculture is dependent. With such pre-eminence in the agricultural sector, it becomes of critical importance that the future advances in farm machines are exploited in such a way that the full benefits are derived, both by the farm community and the nation at large. For this to be realized, a series of problem areas, both extant and potential, deserve examination and attention.

In this chapter an attempt is made to envisage some of the more predictable changes, both in the agricultural industry and in the machines it relies upon, and to anticipate the problems that may develop.

Changes in Agricultural Production

Product Prices and Costs – A comparatively slow growth in demand for agricultural products, coupled with the continually expanding output that has

resulted from the application of improved varieties and new farming methods, has produced continuous downward pressure on farm product prices relative to the prices of farm inputs and prices in other sectors of the economy. This is often referred to as a "cost-price squeeze". The term is not strictly accurate since costs depend on the effectiveness with which inputs are used as well as the prices at which they are purchased.

This relative price pattern has impinged differently on the two major sectors within farming–crop production, and livestock production. In general, prices of livestock and livestock products have been rising more rapidly than prices for crop products. In part, this reflects the fact that demand for meat and dairy products has a higher income elasticity (increases more in percentage terms as per capita income rises) than is true for breadstuffs. In part, too, it reflects the fact that mechanization has been more extensively applied to crop products with presumably greater cost reductions as a result. Indeed, the crop sector of agriculture has already reached an advanced stage of mechanization, whereas the scope for analogous developments in livestock farming is still relatively unexplored.

Future developments in costs and prices are difficult to assess with any confidence. Prices of agricultural products in Canada are strongly dependent on a continually changing world export market. On the input side it seems likely that further increases in prices can be expected. Agriculture's dependence on purchased inputs has been growing, and the prices of these inputs are likely to move more in line with prices in the industrial sector than with the level of agricultural prices.

Labour Loss – An additional facet of agriculture's adjustment to its new role in a contemporary economy is the continual loss of labour to the non-farm sector of employment. Farm wage rates have traditionally lagged behind those in the rest of the economy, and entrepreneurial earnings in agriculture have frequently fallen short of potential earnings in alternative occupations. The effect of these divergences over time has been to draw labour off the farms, until Canada now is approaching a type of agriculture utilizing very low labour inputs. There seems no reason to expect these pressures to cease for some time yet. Many farm operators will continue to be attracted by the earnings, the work, and living conditions of the towns and cities, and the agricultural population will decline as retiring farmers are not replaced by new entrants to agriculture. In addition, a continuing rise in farm wage rates seems likely to provide farmers with an incentive to substitute machinery for manpower.

Thus, future mechanization will see a continuation of past trends. As the labour force declines in size, the stock of machinery in use on farms and new investment in all forms of productive assets will rise. Ultimately, however, there must come a point where this trend will change in character. For the foreseeable future, machines will still require some minimum amount of labour to operate them. In the last analysis, therefore, machinery and manpower become complementary inputs, and continued labour loss will become a constraint on further

mechanization rather than a determinant. Until that point is reached, the continued growth in farm machinery use can proceed unabated. But since there remain few operations which are as yet unmechanized, the main development is likely to be in the form of larger and higher-capacity machines to enable the spectrum of farm work to be accomplished with even less labour. As the horsepower rating of tractors continues to rise, further labour migration will occur.

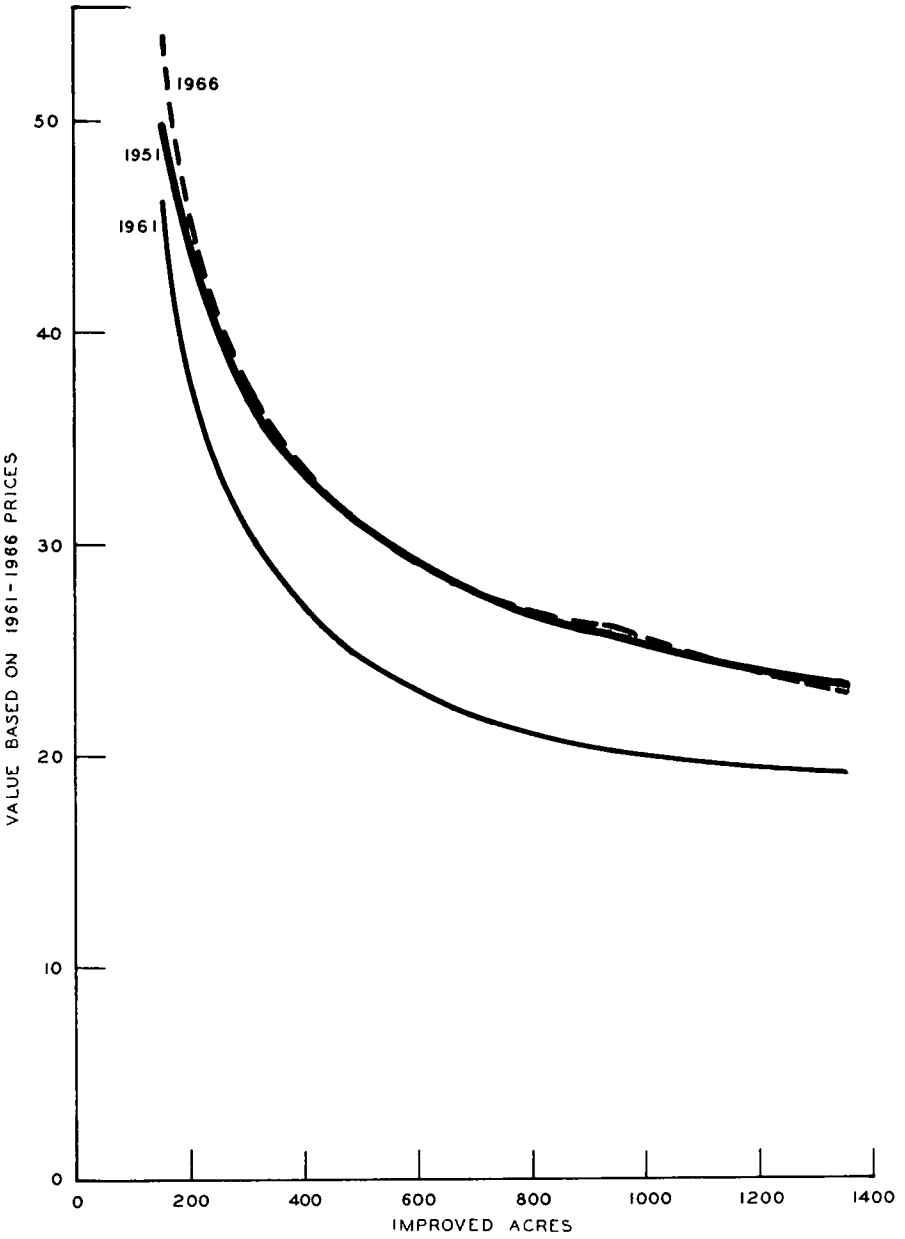
The Commercialization of Farming – Canadian farming will continue to become more commercial. The data of Table 24.2 show clearly that the number of farms that sell more than $5,000 of product annually has increased over the years, despite the reduction in total farm numbers. Furthermore, there is a noticeable growth in the average size of farm business, with more and more holdings moving into the category of sales in excess of $10,000. At the other end of the spectrum, many of the small and previously non-commercial farms are now classified as part-time units and this trend, too, might be expected to prevail into the future.

The commercialization of farming is an understandable development that stems directly from farmers' attempts to survive in an increasingly competitive environment, and from their specific need for cash earnings to purchase essential inputs from the non-farm sector. A study of farm changes since 1951 demonstrates that the dividing line between farms that are declining in number and those that are still increasing lies at the level of $5,000 in annual sales for Canada as a whole. There are also indications that this "survival level" of farm size is gradually rising over time. While this is a fairly neutral method of identifying the forces operating on farm businesses, it does give some indication of the course of change that might be expected in the future.

Farm-Size Enlargement – Although farm size in terms of acres is a significantly distinct concept from size in terms of annual sales of produce, there have been obvious parallels in the change of farm size as measured on both bases. Increases in the average size of farms have been directly associated with the decline in the labour force as farm operators left the land, and the consequent reduction in farm numbers. With further migration of labour expected, the upward shift in the distribution of farm sizes must therefore continue. The indications from a survival analysis of farm changes since 1951 are that farms above 560 acres are the only ones *not* declining in number. Since almost 80 per cent of Canadian farms are smaller than this, the possibilities for further reduction in farm numbers, and hence expansion in farm sizes, seem extensive. Even when this type of analysis is applied on a regional basis, a similar conclusion emerges.

If this trend does continue, its impact on the mechanization of farming raises certain interesting issues. Since farm-size growth and labour loss are directly related, one consequence will be an ever-increasing area of farm land being handled per man. This will require a further expansion of the work capacity of tractors and associated machines in order that the farming tasks can be done effectively. At the aggregate level, the indications are that the growth in the level of machinery

FIGURE 26.1- INVESTMENT IN MACHINERY AND EQUIPMENT PER IMPROVED ACRE, BY SIZE OF FARM, CONSTANT PRICES, CANADA, 1951, 1961 AND 1966



investment may slow down. This conclusion is supported by Figure 26.1, showing that as farm size increases, the machinery stock per acre tends to decline. Similarly, when farm size, as measured by the value of products sold per farm, increases, the amount invested in machinery per dollar of product declines. For farms selling products worth $35,000 or more annually, the value of farm products sold per dollar invested in machinery was, in 1966, $2.78. For farms with annual sales of less than $2,500 the corresponding figure was $0.32.

Capital Acquisition – Although appearing as a trend that is occurring autonomously, farm-size enlargement is such that it may soon give rise to major problems that have not previously been met in the procurement of agricultural capital. When a small farmer decides to turn towards the non-agricultural sector for employment, his holding may remain as an integral unit or may be amalgamated with another farm. Farm size will therefore be enlarged in this latter manner, but in one of two ways. If the farm was previously occupied by a tenant, the tenancy could be simply taken over by the farmer amalgamating the holding with his own. This method has obviously been characteristic of recent years, as witnessed by the decline in the number of farms occupied solely on a tenancy basis, and the rise in part-tenant, part-owner tenure. Conversely, the farmer amalgamating the new land with his own may have to purchase the land in order to bring it in as part of an expanded farm business. In this case, he will require access to sufficient capital to enable purchase. Since the availability of farms that are entirely rented is now quite low, farm amalgamations by purchase will necessarily become more and more frequent, and the high level of land prices will begin to have a more significant impact on farm enlargement than they have heretofore when tenanted farms were more freely available. That this is already occurring is borne out by the fact that the proportion of owned farm land has risen fairly consistently since 1941, with tenanted land becoming an increasingly rare commodity. This trend could be offset if migrating owner-farmers were to make their land available for amalgamation on a tenancy basis. But with the high capital values represented by land assets, the relatively low rates of return on this investment under tenancy, and the understandable desire of the farmer to take his capital with him to aid the transition into the non-farm sector, this seems an unlikely possibility. If capital availability becomes an important factor in farm-size enlargement, it will likewise tend to operate as a restraining factor on further investment in mechanization.

Part-Time Farming – The migration of labour from agriculture can also take the form of farmers assuming a dependence on the non-agricultural sector for the bulk of their income, but retaining their farms for operation on a part-time basis. If this development becomes common, especially among the smaller farms, a series of implications for both national farm policy and continued mechanization are evident. Dominant among these are that the "small-farm income problem" may, in the extreme case, diminish as a cause for concern, since there seems little obligation on society to support the agricultural earnings of an individual who is only minimally dependent on his farm as a source of income, and who perhaps

voluntarily subsidizes his farming activities by off-farm work. Secondly, if part-time farming becomes an established facet of Canadian agriculture, this could conceivably lead to a disproportionate expansion in machinery investment on such farms. Being a type of production that portrays *par excellence* the minimization of labour inputs, it becomes rational–even essential–for a high level of machinery capacity per acre to be maintained.

Developments in Mechanization – Along with adjustments in the nature and organization of farming there will inevitably be many changes in the type and operation of machines used on farms. The nature of these changes will be determined by (i) the role that machines are called upon to play in future agricultural production, and (ii) the materials and components that are available for use in farm machines. These determinants will vary as time progresses in accordance with many other changes–both economic and technological. Consequently, the exact form of future innovations is not known and cannot accurately be predicted. On the basis of trends, however, some indication can be obtained concerning the direction in which developments in farm mechanization will go, at least in the short run.

As indicated previously, the predominant role of farm mechanization has been in substituting for manual effort, and this process will continue. But mechanization has not been acting this way exclusively, as there are many operations now mechanized that would not be feasible without it. In the future, more operations will be in this category as machinery begins to substitute not only for manual effort but for the working skills of the operator as well. In this way, we can anticipate improved control devices, automatic regulation, and even remote control, to become part of the farm scene.

Another change will follow from the march of technological progress itself. It can be argued that since the investment in research and development today exceeds that of any previous era (and this is manifest in the fact that 90 per cent of all the scientists who ever lived are alive today), we might expect the rate of technological change to be increasing. If this is so, then it is likely that new machinery will also substitute for existing machinery, in that new equipment will do existing jobs faster, more effectively, or in a different and preferred way. As this trend ensues, "functional obsolescence" is likely to increase; instead of becoming physically obsolescent through wear and tear, machines may become redundant because the new generation of equipment is superior in function.

The trend in the use of machinery to combat production risk is likely to continue in those areas where it has begun, and to extend to others. As more and more biological processes become understood by man, and thus subject to his regulation, mechanization will be extended to facilitate this control. Concurrently, changing economic conditions will allow existing technology to be extended to more applications. Thus, for instance, the production of various kinds of livestock can be expected to reach the technological sophistication of the broiler industry.

There will also be an extension of measures that offset the timeliness restraints of crop production, including grass and grain drying, the use of chemicals to adjust maturity and harvesting times, and breeding programs to provide cereal varieties that mature in sequence, and fruit varieties that lend themselves to mechanical harvesting. In addition, there are likely to be developments that allow machinery to operate in less favourable conditions–particularly on wetter soils–thus reducing the risk effects of weather on field operations.

The machinery developments that occur in order to fulfil these new functions, and those that substitute for existing machines, will depend on the application of new technology, materials and methods in machinery development and manufacture. The current trend in technical development suggests that there will be increased use of hydraulics both in transmission and in leverage applications. There will also be extended use made of electronic devices. Electronics will permit the monitoring of different operations or systems so that a continuous watch can be kept on performance. Although early uses, such as the grain-loss monitor on combines, will merely permit manual corrections to be made, there is but a short step from this to automatic adjustment–also facilitated by electronics, in combination with hydraulically operated mechanisms.

The use of new materials and methods that are the by-product of space research might also be anticipated. Thus there are likely to be better steels and alloys used in manufacture, and extended use of plastic and nylon materials and anti-friction coatings on wearing surfaces. New technology will also be widely seen in transistorized electrical systems, improved hydraulics and air filtering, better lubricants, the use of design refinements in structural components, and in advanced suspension systems including the use of the hovercraft principle. These various changes will show up in different machines and uses, but obviously some will have greater potential in certain applications than in others. These differences become apparent when consideration is given to potential developments in existing farm operations.

New Applications – In crop production, there will be changes in all phases of production. Seed-bed preparation and seeding will involve essentially the same sequences but different means will be used. Instead of moldboards and disks, increasing use will be made of cultivating tines, which give a better mulching effect. Both low- and high-speed traction might be used, in different situations, with tines designed specifically to suit the working speed. Tines are likely to be coated with anti-friction surfaces, to increase cultivating efficiency. Alternatives to this might be the use of fluid lubrication to ease the passage of the tine through the soil. In some situations, too, it may be possible to use electro-osmosis to achieve the same effect. This is done by using a charge on the blade surface to attract oppositely charged moisture particles in the soil. Another alternative in some situations may be the use of vibratory power–energy in the form of sound waves that may be used to "cultivate" the soil. Given today's availability of adequate power in the form of larger horsepower tractors, there is also the possibility of extending the use of

rotary cultivation, at least in those circumstances where a fine tilth is desired or acceptable. In the subsequent sowing operation, the use of precision seeding will become the rule.

Similar developments can be anticipated in the area of harvesting and processing. Recent developments in the harvesting of forage presage far-reaching changes in that field. In particular, the briquetting, cubing, and wafering of livestock feeds will provide a higher quality product with reduced wastage and easier handling and storage than most other forms of conservation. Thus, one or the other of these techniques is destined to be found on most crop-livestock farms. For poorer quality forage, haying is likely to continue. To overcome some of the handling problems, use will be made of automatic haystacks, by which the cut material is compressed in the trailer by air-blast and is dumped and stored in the field in this moulded form.

The harvesting of cereals and other seed crops is likely to be aided by the use of electronic monitoring and automatic control on combines. In some situations, too, remote control may be used–either for combines themselves or for the bulk trailers used in carting grain from the field. At the storage base, the use of augers and elevators will become even more commonplace, and the movement of grain through pipes by air-blast or pumping devices may be introduced. The harvesting sequence will be regulated by the inclusion of an artificial-grain-drying phase, using the continuous-flow principle and probably incorporating the alternating heat-cool-heat sequence termed "dryeration", that prevents heat damage to grain.

Just as mechanical harvesting has spread from grain crops and forage to sugar cane and potatoes, so mechanical methods will increasingly spread to the harvesting of vegetables such as lettuce, to the stripping of grapes and soft fruits, and the shake-catch harvesting of tree fruits. The harvesting of all crops will be eased by improved handling methods.

Materials handling, though always significant in farm production, has tended to lag in its agricultural applications. Consequently, there is a body of materials handling and storage technology used in industry and commerce that can readily be applied to farming. Thus, we can expect to see materials handled in bulk and loosely packed, together with fork lifts and other mobile units for lifting, stacking, and transportation. In storage, there will be extended use of environment control and irradiation, and of such measures as the chilled storage of grain and the sealed conserving of high-moisture grain for livestock feed.

The livestock industries in particular can be expected to increase their level of mechanization. All buildings will feature better design for environment control –improved ventilation, odour suppression, and perhaps solar heating. Given improved fodder-processing, the relative cost of open grazing losses will soon justify "zero-grazing" policies, where the animals are kept off valuable pasture and the feed delivered to them. As feed distribution becomes mechanized so will cleaning operations and the removal of waste products. This will involve mechanical

sweeping and conveyors for handling manure, or perhaps pumps and the use of fluidization to facilitate ease of disposal. The biggest changes are likely to be in general building design and mechanization to enable efficient materials-handling methods to be used whenever possible.

Some of the more radical changes in all types of farm machinery are likely to be those relating to operation and control. With changing working conditions more design emphasis will be placed on convenience and comfort (and, hopefully, safety) in both operation and servicing. This will be facilitated by the extension of human engineering principles and research. One feature of the change will probably be the use of automatic adjustment made possible by extended use of electronic devices. Applications of this type will range from automatic irrigation control to the automatic balancing of the operation of component systems in complex machines.

Many improvements in control and comfort may derive from massive changes in the configuration of the tractor. Though some changes are already observable, such as the use of four large wheels and a centrally hinged body to permit steering by hydraulic rams, even more dramatic changes are now made feasible by the introduction of the hydrostatic transmission. This removes all advantage from the driver being mounted above the transmission, and means that he might be seated elsewhere–up front, for instance. As such changes occur, the tractor is likely to become unrecognizable in terms of its traditional appearance.

All of these changes will be accompanied by, and will to some extent necessitate, changes in machinery management. Already farm mechanization is based largely on "systems". As the individual machines that are components of an integrated system become more sophisticated, it becomes more difficult to assess and combine the many alternatives to best advantage. It is similarly difficult to develop and tailor a system so that it is adequate to the needs and purpose of a particular farm situation. Consequently there will be increased use made of "systems analysis", and the use of various optimizing techniques, to facilitate the selection and combination of mechanical equipment. Similarly, as the specification of machines is improved and the precision of the operation increased, there will be a need for greater care and accuracy in servicing and adjusting them. There will also be more care required in assessing the optimum time to replace component parts of equipment items, and the component units of machinery systems. This will again necessitate the application of developed management tools. The use of these tools will make necessary a process of evaluation to obtain relevant measurements, and the extension of information systems to permit the data to be effectively used. To a large degree, the management of machines will in future be dependent on outside sources of information rather than inside information and practical insight as at present.

Facilitation of Continued Mechanization

The mechanization of agriculture still has almost unlimited prospects. Many developments are foreseeable. Assuredly, a great many others are not. The

adjustments that will accompany this mechanization may well be as radical and far-reaching as any in the past. The adjustments of the past have caused problems and difficulties that have not been easily or fully resolved. If mechanization continues in haphazard fashion, these less desirable effects can be expected to accumulate.

Thus a program of action aimed at facilitating further progress in farm mechanization seems desirable. Such a program must influence each stage of the manufacturer-dealer-farmer relationship. It would need to take account of their tripartite involvement and shared responsibility in what is an interdependent, co-operative, chain relationship. No change in machine design can be introduced without effects on the dealer and the farmer. No adjustment in farm size can be made without its impact on the dealer and the manufacturer. No change in the organization of dealerships can be without its effects on both suppliers and clients. Yet each link in the chain has its own special responsibilities.

The manufacturers must inevitably remain the largest in size, and smallest in number, of the firms involved in the co-operative process. Their special responsibility concerns the quality of technology, both that in hand and that being developed. Progress in mechanization necessitates new and improved designs as well as changed specifications to meet the needs of the changing farm scene. Thus, it is necessary that they have a continuing program of research and development, and this is both difficult and expensive. Although all manufacturers, large and small alike, undertake some development work, the question can always be raised as to whether they do enough. Small firms producing mainly for the Canadian market can obviously spend less on research and development than larger firms. But larger firms, producing as they do for a world market, can spend only a limited amount on work directly related to Canada. Yet Canadian agriculture has many characteristic features that may justify considerable study of mechanization problems, particularly if Canada is to maintain an agriculture that can sell competitively on world markets.

The second responsibility of manufacturers concerns the maintenance and effective working of the co-operative link between themselves, their dealers, and the farmers who buy and use their products. The manufacturers have a special role in doing this partly because of the dependence that farmers put upon them, since they are the source of a basic input of farm production, and partly because of their dominant size in relation to both dealers and farmers. This responsibility covers not only the supply of equipment, but of replacement parts, finance, specialist services, and information.

This service is usually provided through the dealership. Prior to purchase, the dealership must provide information (including perhaps a demonstration), stocks to ensure availability, and finance or knowledge of how and where it can be obtained. During the transfer the dealer must facilitate the "paper war" involved in transferring ownership and arranging payment and delivery. After sales he must

provide service and other skills needed to ensure effective machine operation. In addition, he has to provide a feedback of information to the manufacturer, relating to sales, field use, warranty, stores turnover and service plans. None of this might seem very difficult, and, in practice, many dealers manage to achieve most of these things very well. In doing so, however, they are dependent on outside sources for basic skills, for information, and for buyer finance. As the level and complexity of mechanization increases, their needs in each of these spheres change accordingly. Although some of these requirements are met by dealers themselves (either individually or collectively) and some assistance is provided by manufacturers, it is questionable whether this is enough. Since education and training, information sources and extension, and credit arrangements are all outside the dealer's control, he needs purposeful assistance and co-operation from outside sources to enable him to function effectively.

The responsibility of the farmer in the progressive mechanization of agriculture includes the acquisition, finance, and utilization of machines. Thus, he has to plan his operation and select machinery to meet the needs of the over-all system he decides to implement. To do this he must use knowledge and information in conjunction with his management skills. In order to get his operation going the farmer has to acquire the equipment involved using either capital obtained from external sources or from internal capital provision by using reserves or diverting expenditure from alternative investment. Where credit is used, the flow of repayments has to be organized. Once the machinery has been obtained the farmer is confronted with the problems of its effective utilization, maintenance, and subsequent replacement. Where the program of the operation is changed (perhaps in response to product price changes, market conditions, or to farm amalgamations) there are the inevitable adjustment problems of re-mechanization. In all of these activities the farmer is dependent on outside assistance, both from the farm machinery industry through the dealerships, and from other sources.

The type of assistance needed most by farmers includes detailed information about production alternatives. For this they are largely dependent on outside services because of the nature of the farm firm. Most farms are run as family units with usually one person, or two at most, involved in management. On this scale there can be virtually none of the specialization in managerial functions existing in all large industrial or commercial firms–such as the farm machinery firms or the larger dealerships. Because of the limited size of the management input, there is a severe limitation on both the time and the skills that can be devoted to decision-making and other managerial functions. This situation has been long recognized, and its recognition has been the basic reason for the initial establishment and subsequent expansion of government-supported farm research and extension programs.

The structure of farming in Canada is, however, changing. The process of farm amalgamation seems certain to continue for many decades to come. But what is also certain is that, even if this process ensues at a very high rate, few if any farms

will achieve a scale of operations sufficient to permit the sort of management advantages that are associated with the division of functions between individuals and development of their specialist skills. This is not to say that we should not anticipate some changes in this direction. It is highly likely, for instance, that larger farms will be able to allocate some resources (more than in the past) to improving management functions, including the analysis of decision alternatives. It is also very likely that the higher cost of decision error associated with larger expenditures and more technically sophisticated operations will make it profitable to do so. Though this may lead to some changes in the nature of management on farms, with farmers themselves becoming increasingly well trained, there is also likely to be a growth in privately operated farm management consulting firms to meet the demand for both analytical skills and reliable information. This development has already begun on a small scale in Canada and is even further developed in other countries including Australia, Britain, and New Zealand. To a very large extent, however, these firms are also dependent on a supply of information from industrial firms, research centres, universities, and government agencies, on which to base their analyses and advice.

Apart from the accuracy of his decisions, the farmer has to worry about finding the capital to finance the expansion or adjustment of his business. A consideration of agricultural change in Canada over the last two decades, involving all aspects of farm structure and technology, strongly suggests that the adjustment to a more efficient agricultural pattern may be mechanization-led. Thus capital funds for the purchase of machinery may be the key to continuing farm progress. Because the purchase of new machinery requires a medium-term investment that must compete for funds with other capital requirements such as land acquisition and working capital, availability of funds may at times be a limiting factor in new machinery acquisitions. Thus there is a need for adequate credit facilities and investment incentives for the farmer.

In view of the significance of farm mechanization for future progress, and of the prevailing conditions surrounding farm machinery in Canada, it is recommended that the government should consider implementing a program to encourage farm mechanization and to smooth its advancement. Such a program should meet five requirements: (i) ensure that sufficient research and development is undertaken in relation to farm machinery in Canada to provide a continuing flow of new machinery technology well suited to Canadian requirements; (ii) provide facilities for measurement and evaluation activity so that adequate reliable information is available to ensure the successful introduction and efficient use of new farm machinery; (iii) endeavour to promote the smooth functioning of a co-operative relationship between manufacturers, distributors, and users of farm machinery; (iv) attempt to minimize the adverse effects of mechanization on health, safety, and welfare of the agricultural community, and (v) provide credit facilities and capital-formation incentives to encourage an adequate rate of investment in farm mechanization.

Each of these requirements might individually be achieved in any of several different ways. Since they are interrelated aims, however, they might best be achieved by one integrated program, rather than a number of isolated ones. Similarly, where there are institutions that can effectively cope with some aspect of these requirements, no new institutional arrangements should be considered necessary. In this regard, the area of machinery finance seems well served by the existing system and no major changes seem necessary. Thus recommendations concerning farm mechanization are as follows:

1. Research and Development – In an earlier section of this Report (Chapter 17) it was pointed out that the benefits that had been derived from improvements in farm machinery technology in the past were extremely large. Indeed, over the period from 1926-66 it was estimated that the net benefits obtained were probably of the order of from $2 to $3 billion annually and might well exceed those derived from all other agricultural improvements. If it could be anticipated that future benefits would be in proportion to past benefits, a case could be made for allocating as much as one-half of all the government's expenditures on agricultural research to the improvement of farm machinery technology. However, such a massive reallocation of the R&D effort related to agriculture could not take place overnight. Accordingly, it was recommended that the Canada Department of Agriculture set as its short-term goal to be reached by 1980 the allocation of 10 per cent of its total research budget to supporting improvements in farm machinery. By 1985 this allocation should be raised to 15 per cent. On the basis of the present research budget, this would imply an annual expenditure of around $4 million by 1980, and $6 million by 1985. Some additional funds should be provided to support the expansion of capital facilities required for an effective research effort. After this goal has been reached, the value of further reallocations towards research on farm machinery technology should be carefully considered before any further goals are established. Reaching this goal need not require a net over-all increase in government spending, since there may be many other areas of government expenditure where potential benefits are very much lower than those for research on farm machinery technology.

A number of guidelines the government might follow in expanding its research program were suggested earlier and these are repeated here. Considerable emphasis should be placed on expanding basic knowledge about farm machinery technology, especially with respect to machines suited to the type of soil, climatic and crop conditions prevalent in Canada. A substantial part of the increased research funds should be allocated to support farm machinery research programs in Canadian universities. There should also be an expanded research effort at the federal government's research stations and experimental farms. While there is undoubted merit in giving individual research workers considerable freedom in choosing their research projects, an effort should be made to allocate funds in proportion to potential benefits. Potential benefits are, of course, difficult to estimate with accuracy. For this reason, some reliance may have to be placed on

fairly crude guidelines such as the value of crops for which the machinery is used or the potential for further replacement of labour. Still, it should always be remembered that potential benefit is the appropriate measure.

A central body should be established to oversee and co-ordinate the use of these funds so they can best meet the future needs of agriculture across the country. To exercise this role effectively, this central body should have a modest research effort of its own to keep it in close contact with research problems in this area. It should also maintain effective liaison with the R&D efforts of the private machinery firms. The governing board of this institution should include representatives from provincial and federal governments, from the farming community, industry and the universities, and should include engineers, agricultural economists, plant scientists, and representatives of other disciplines. While it is not intended to provide a detailed blueprint for such a board, the following might provide an acceptable pattern: university representatives 3, provincial governments 2, federal government 2, manufacturers 3, dealers 2, and farmers 3. The governing board should also include the director of the central research station and perhaps two of his senior staff members.

As was noted earlier many new inventions or ideas for improvement in farm machinery originate with farmers. Typically the farmer has little knowledge of how to patent or market his invention. It is recommended that the research unit described above should be prepared to provide farmers with advice on how to patent their improvements in farm machinery and on how to market them.

2. Evaluation and Information – With the growing complexity of farm machines and the increasing pace of technological change, farmers' decisions about what machinery to buy–in what sizes and types and with what attachments–have become more difficult. Yet with the higher capital costs involved in modern farming, the importance of correct decisions has increased. More information is needed if the farmer is to make intelligent and economic decisions.

The information can come from a number of sources. The manufacturer obtains a good deal of information in the process of developing and testing new machines. Additional information becomes available to the manufacturers from their records with respect to warranty and provision of repair parts and from the analyses they make on the causes of component failure. With the test facilities they have available they could easily record additional data if it seemed desirable. Some data may be recorded on the way machines perform in use on experimental farms or university field stations. Farmers also acquire information about the performance of the machines they buy and use. This could be collected and made more generally available. In some important areas there is surprisingly little information available at any level. For example, data on the working speeds of tillage machinery and the efficiency of machinery at these different speeds is surprisingly hard to obtain.

Recently the larger manufacturers have begun to make use of systems analysis, first applied in the defence, aircraft, and space industries, in the design and

development of new machinery. This approach has been used with some success in upgrading the reliability of machinery with a resultant saving both to the manufacturer and the farmer in the form of lower warranty costs and improved reliability in operation.

Although the manufacturer of farm machines has recognized the systems approach in developing new machines, he has yet to recognize that the machine he manufactures is only part of a larger system including the farmer. Little provision is made for providing the farmer with the kinds of information he needs to make intelligent buying and replacement decisions. Increasingly sophisticated analytical tools are now available to farmers to help make decisions about machinery purchase and use. Yet very few of the measurements recorded by manufacturers are accessible to farmers and, in general, the data they can obtain are quite inadequate to permit effective use of the available tools. How can this deficiency be overcome?

Official testing agencies for farm machinery currently exist in some 29 different countries including Australia, Britain, Finland, France, Germany, Italy, The Netherlands, Sweden, and the U.S.S.R. No such agency exists in Canada, although for several years the Agricultural Machinery Administration operated by the Saskatchewan government conducted a testing program. In the United States the University of Nebraska operates a tractor-testing program whose tests are compulsory for all tractors sold in the state. In fact, almost all the tractors sold in the United States are tested at Nebraska. The Commissioner visited testing stations in a number of European countries and discussed their programs with the officials responsible. In addition, a careful examination of the many issues involved in farm machinery evaluation is provided in one of the Commission's separate publications.[1] The issue of farm machinery testing or evaluation was also discussed extensively during the Commission's public hearings. It received almost uniform support from farmers and farm organizations. In contrast, manufacturers appeared rather fearful of what might be involved, and argued that since their own test programs were adequate any additional government testing was unnecessary. They scarcely seemed aware of the farmer's need for additional information. On the basis of this extensive review of the matter the following recommendations are made:

> (i) The federal government should establish a central agency for the testing and evaluation of farm machinery. The agency should set up such regional stations as appear desirable for an effective program. Although the testing agency would have its own budget and manager, both the testing agency and the research organization would be under the supervision of one senior officer (a president or chairman) and through him to the same governing board.

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[1] G. F. Donaldson, *Farm Machinery Testing*, Royal Commission on Farm Machinery, Study No. 8 (Ottawa: Queen's Printer, 1970).

(ii) The basic goal of the testing agency should be to provide farmers with the kind of information they need to make intelligent decisions in buying and replacing farm machinery. The agency will undoubtedly want to approach its job on a flexible basis. For some machines, the most effective way to provide information may be to devise a set of standard tests which all manufacturers would be required to carry out and publish as a condition for selling their machines. For other machines, the agency may wish to conduct its own tests. A certain amount of in-house testing will be needed to validate and improve the standard test procedures. It may find it desirable to collect information from farmers, on a sample basis, with respect to the operating characteristics of some machines. With such an experimental and wide ranging approach the agency should, in time, discover how to discharge its role most effectively.

(iii) The agency should offer to test prototype machines for manufacturers for a modest fee. The experience of other countries suggests that a service of this kind often produces significant improvements in machines before they are marketed. Such a service might also help smaller firms to keep their machines competitive in quality with those of the larger firms. The mere existence of a testing agency may serve a useful role since it will deter manufacturers from rushing machines to the market before they have been fully tested. The knowledge that deficiencies may be exposed in a government test report can provide a salutary check on the temptation to short-circuit the testing process.

(iv) The size of the testing program is to some degree a matter of judgement. It is recommended that the agency should initially be provided with an operating budget of $1 million. At current wage and salary levels this should enable the agency to employ about 20 scientists and support them with secretarial, technical and other assistance. Budgetary provision would need to be made also for any required capital facilities.

On any assessment of potential benefits, such an expenditure would appear to be fully justified. If better information enabled farmers to save 5 per cent on tractor fuel consumption, the saving would amount to $30 per farm each year. Another $25 per farm might be saved by effecting a 5 per cent saving on repair costs. A further saving, say $45 per farm, might be obtained through better selection of machine size. On the basis of 300,000 commercial farms, a saving of this magnitude would provide an annual saving of $30 million. Even one-tenth of this would be $3 million per year. The total operating budget proposed here for the test agency is less than one quarter of 1 per cent of the farming industry's annual expenditure on new machinery and repair parts. Compared to the amount that other

industries often spend on assessing new investment projects, the amount proposed is very small indeed. For this reason, after a number of years of operating experience, it may be desirable to increase the agency's operating budget to perhaps twice the amount proposed above.

(v) The agency should take whatever steps it deems desirable to ensure that the information it obtains from its tests and in other ways is made available in usable form to the farming community. In this connection, the provincial governments and universities may wish to reassess their advisory service to farmers in order to make sure that they can effectively take advantage of the new information that will be provided by the test and evaluation agency. In this connection it may be helpful to give a comment on the state of affairs in the United Kingdom to the effect that:

> Until recently the number of products of the engineering industry on farms was very limited. During the last 20 years they have multiplied considerably but they will multiply very much more quickly in sophistication and in numbers in the coming decades. However, we still train farmers and advisory officers as if engineering was a trifling part of their future responsibilities. One of the things that is urgently needed in the United Kingdom is a reorientation of education for farm owners, managers and advisory officers. Engineering must take its place as one of the important aspects of their training.

The same may very well apply to Canada.

(vi) The agency should seek the co-operation of existing advisory services and should support them wherever possible.

3. Co-operative Relationships – With farm machines now so important in agriculture, it is highly desirable that all those involved in the supply and use of farm machinery maintain an effective working relationship. This is most likely to be realized where there is good communication on a two- or three-way basis between the farmer, the dealer, and the manufacturer. Too often in the past these relationships have been complicated by various suspicions and a general lack of understanding of the problems faced by other members of this tripartite group. There is reason to believe that the Commission's public hearings performed a valuable role just by enabling farmers, dealers, and manufacturers each to achieve a better understanding of the problems faced by other members of the group. However, the improved understanding obtained in this way may deteriorate in time. For this reason the following two recommendations are made:

(i) Under the general supervision of the governing board proposed above, a small unit should be established whose major role should be to use its "good offices" to help maintain a good working relationship among all those involved with farm machinery.

(ii) It is recommended that each of the provincial governments designate some person with a good knowledge of farm machinery problems to act as an "ombudsman" in this area. He could hear complaints from farmers, or dealers or even manufacturers who felt they had been unfairly treated, investigate them thoroughly and try to achieve a just settlement of the problem. Some provinces already have a person who performs this role. It is desirable that the practice become more general and that all farmers be aware of its existence.

4. Safety and Health – As a study already published by the Commission indicates, farm machinery can have very adverse effects on the safety and health of farmers.[2] Within the past 10 years the fatality rate in farm machinery accidents has more than doubled. In addition, many farmers have been injured more or less seriously and suffered pain and shock and in some instances permanent injury and have incurred medical and hospitalization costs and a loss of working time. Even apart from accidents, there is evidence that farmers suffer significant loss of hearing and other adverse effects from continuous use of large power machinery. Anything that can be done to reduce or minimize these effects will add significantly to the farmer's welfare. The following recommendations are made with these considerations in mind:

(i) Roll-bars with seat belts or safety cabs should be compulsory on all new farm tractors sold in Canada. Within a short time, the requirement should be extended to all tractors. Cabs that do not meet safety specifications should be outlawed for use on farms. The regulation would need to be established in terms of cabs or roll-bars that meet certain minimum engineering standards. The standard currently in effect in Britain and Sweden may prove suitable. Roll-bars now are available as optional equipment from many manufacturers. However, the prices currently being charged appear inordinately high. The Commission obtained from a prominent engineering firm an estimate of the manufacturing cost of the roll-bars currently sold by a major farm machinery firm. According to their estimate, the manufacturing cost is only from 20 to 25 per cent of the manufacturer's suggested retail price. Prices for other firms were roughly comparable. Thus, in introducing this provision, it is desirable that there be sufficient advance notice to allow short-line and other manufacturers to enter this market and keep the price at reasonable levels. Swedish experience suggests that the use of safety cabs or roll-bars on tractors could be expected to reduce the fatality rate from farm machinery accidents by 50 per cent and save some 60 to 70 lives a year.

(ii) The government should sponsor a program of research designed to improve the safety and reduce the health hazards connected with farm

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[2]G. F. Donaldson, *Farm Machinery Safety,* Royal Commission on Farm Machinery, Study No. 1 (Ottawa: Queen's Printer, 1968).

machinery. Specifically, the unit or agency charged with this responsibility should study and possibly make recommendations with respect to the compulsory use of a further range of safety devices including: driving and warning lights, rear-view mirrors, slow-moving vehicle emblems, passenger seats or safety hand grips on tractors, additional brakes, maximum noise emission levels, guards and safety shields. Funds should also be available to encourage research in universities into the safety and health hazards connected with the use of farm machinery.

(iii) The same unit or agency should take the responsibility for initiating an improved program of education on the health and safety hazards related to farm machinery as well as an improved set of statistical data in this area.

5. Adjustment Problems – Over the past few decades the introduction of improved farm machinery has had far-reaching effects on the rural scene. More than any other factor, it has been improved farm machinery that has caused the farm labour force and the farm population to decline by more than one-half since 1945. These improvements are also an underlying causal force behind the decline in the number of farm machinery dealerships and the concentration of sales in a smaller number of much larger dealers. Again, it is improved machinery that has led to the shift to larger farming units and concurrently to the decline in smaller trading centres and the concentration of an increasing proportion of sales in larger centres. And with the many further improvements in machinery that are still on the horizon there is every indication that these trends will continue.

Until recently, the farmers who were forced or induced to leave farming by these underlying forces had to find an alternative occupation and re-establish themselves and their families with little outside assistance. Indeed, governments often scarcely seemed aware of what was happening. The programs for retraining and relocation introduced by the Department of Manpower and Immigration within the past few years have done much to change this picture. Still, people in rural communities may often be unaware of the assistance that is potentially available. For this reason there should be a small research program designed to keep a continuing watch over this problem. Society as a whole and some farmers receive substantial benefits from the improvements in farm machinery technology that are continuously being introduced. It is only fair that the social costs and undesirable side effects that progress imposes, often on the older and less well educated members of the community, should be eased by suitable government measures. The research program envisaged would be small, perhaps consisting of two agricultural economists and two rural sociologists. It might well be located within the research division of the Canada Department of Agriculture.

6. Credit Facilities and Investment Incentives – There can be little doubt that the Farm Improvement Loans Act has done much to make funds available at a

reasonable cost for the finance of farm machinery. Still, there are a number of considerations which suggest that some further encouragement is needed for investment in farm machinery. First, there is the evidence, cited earlier, that investment in farm machinery often yields large returns. Farmers, in effect, under-invest rather than over-invest in farm machinery. Second, investment in new farm machines is often the key element in encouraging the shift to a more efficient size of farm enterprise. Third, new machinery may often be a vital link leading to the adoption of improved farm technology in general. All this suggests a need for reassessing the incentives provided for investment in farm machinery.

A key question is the adequacy of the allowances for depreciation. For income tax purposes, farmers are allowed, if they prefer, to use the straight-line method of charging depreciation instead of the more usual and the more economically suitable declining balance method. The rates in effect under each method for a recent year (1969) are as follows:

	Straight Line	Declining Balance
	(Per cent)	
Combines, hay balers and forage harvesters:		
pull type	10	20
self-propelled	15	30
Sprayers	10	20
Tractors	15	30

Using these rates a new tractor or self-propelled combine would be depreciated to about one-third of its purchase price within three years using a declining balance method. If allowance is made for the degree to which list prices exceed the effective value of new machines—17.5 per cent on the average—this one-third comes closer to 20 per cent. This seems entirely adequate. On the other hand, the straight-line rates appear low and might well be increased from 10 to 15 and from 15 to 20 per cent.

Allowing farmers to depreciate their machinery on the basis of a list price, which is usually some 15 to 20 per cent in excess of the effective price paid by the farmer, is largely equivalent to giving farmers an investment credit, a device which allows charging to depreciation, for tax purposes, an amount in excess of the purchase price. In view of the desirability of maintaining a strong incentive for investment in new machinery this advantage to farmers should be retained. However, it might be preferable to rationalize present practice by giving farmers a straightforward investment credit on new machinery purchases.

To sum up, the proposal set forth above calls for a Farm Machinery Institute with two major divisions each with its own manager and each responsible through a senior officer (president or chairman) to a semi-independent governing board. The National Research Council might be an appropriate model to follow in developing

the Institute's structure. One division of the Institute would be primarily concerned with research, and might well be assigned the responsibility for safety and health problems. The other division would be primarily concerned with the testing and evaluation of farm machinery and the provision of better information to farmers to support their machinery purchase and replacement decisions. It could also be assigned responsibility for maintaining good channels of communication among the various groups involved in the farm machinery problem as recommended above under the heading of co-operative relationships. The manager and one of the senior officers of each division and the President or Chairman of the Institute should be members of the governing board. Beyond this, the membership of the board should represent the various groups involved, including governments and the university community.

Most of the machinery used on Canadian farms is produced by a few very large companies, several of them ranking among the 20 largest corporations in the world, and nearly all of them having their head office outside Canada. If the Farm Machinery Institute is to be able to intervene in the relationship between these firms and their dealers and farmer clients using only its "good offices", it will need to be making a continuing positive contribution of its own. I am confident that with the structure and budgetary support proposed, the Institute should have no difficulty in doing so.