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Machines and Manpower [and Discussion]

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POWER ON THE FARM

Machines and manpower

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Agriculture in the western world has become more and more mechanized with fewer and fewer farm workers. Farming is thus becoming a capital intensive industry characterized by larger sized farming units, mechanization, crop specialization and high productivity per worker. Capital requirements encourage corporate farming with integration of production, processing and marketing functions.

The technological base exists for larger and more nearly automatic machines for which the operator would monitor only the machine functions rather than do the traditional guidance. Power applied per unit of land will continue to increase as long as the overall economic payoff exists. Improvements in tillage, planting and harvesting can be expected and machine changes will adapt to new crop strains. Functions will be combined to reduce travel in the fields.

Popular concern for the environment will impose restraints on agricultural practices which lead to soil erosion and pollution of air and water. Reclamation and/or disposal of agricultural wastes is a growing problem, without a truly economic solution, leading to added costs of doing business. Both the machines and the manpower must adapt to these social pressures.

Machines and men have worked miracles in agriculture. The role of men has been all-pervading, not only in the design and operation of the machines, but equally important in achieving miracles of crop genetics and agronomy which, in turn, have profoundly affected the development of machines. We see an interconnected system of land management, labour and capital inputs in the form of new hybrid seed, fertilizers, chemical protection and mechanization spiralling upward with increasing crop yields and higher land and labour productivity.

To no one of these basic factors or inputs alone can be attributed the remarkable gains in agricultural production. Figure 1 shows that the average aggregate yield of major food crops per hectare increases rapidly with the power used per hectare. If I were a chemist, I might wish to remind you of the productivity index shown in figure 2, which gives the improvement per hectare resulting from increased use of fertilizer. We must, however, recognize the fact that these fertilizer results as well as those for the benefit of power used do not exclude the effects of other farm inputs such as tillage methods and herbicides, for example. With this caveat, let us turn to machines and mechanization.

Motivation for machines

The motivation for mechanization of agriculture differs in various parts of the world. In the U.S.A. and Canada the intensive mechanization is motivated by labour saving to produce high yields per man hour. Concurrent high yields per hectare are more nearly a consequence of efforts to minimize production costs rather than to utilize land to the utmost. In fact, areas for planting have been artificially restricted. In most of the developed world we see agriculture which is capital intensive, labour-saving and with ample arable land.

In the developing areas of the world the motivation for mechanization of agriculture is in marked contrast. For the most part, arable land is insufficient despite the large area of the

Earth's surface which is involved. Although the agriculture may be labour intensive, the essential objective is to achieve increased yields per hectare. The function of machines, then, is timely tillage, planting and harvesting with minimum losses of seed and crop. Abundant labour, using primitive methods, would be less effective than well scheduled mechanized tillage, planting and harvesting. Faster work in the fields can produce and harvest a crop less vulnerable to vagaries of the weather and indeed makes double to triple cropping possible, especially in irrigated areas. Mechanization permits the efficient application of fertilizers, herbicides, and insecticides to utilize fully the potential of the new high yield seed strains. Also, we cannot ignore the significant fact that mechanical power releases cropland otherwise needed for nourishment of animal draft power.

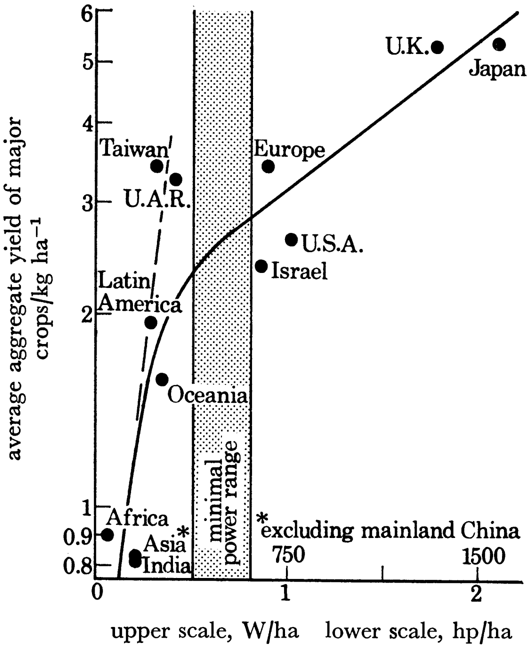

FIGURE 1. Relation between yields of major crops (cereals, pulses, oilseeds, sugar crops, potatoes, cassava, onions, tomatoes) and power used per hectare.

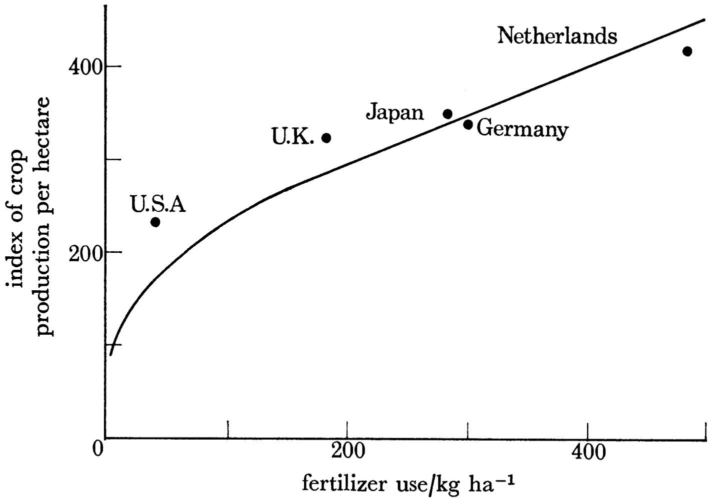

FIGURE 2. Relation between fertilizer use and crop production, 1961–3.

We can expect mechanization of agriculture in the developing countries to be an essential element of economic growth, but national priorities will dictate how much of their scarce foreign exchange may be allocated to the purchase of farm machinery or importation of critical components to supplement local procurement. Moreover, the potential migration of farm labour to the cities and its social impact looms large in the minds of national planners and, thus, will tend to retard the spread of agricultural mechanization. I will leave to the sociologists the resolution of the man–machine relationship as it occurred in the western world and will occur elsewhere – Do machines drive workers to the cities, or do the industrial opportunities of the cities attract the farm workers and thus create a need for agricultural machines?

Agricultural labour

The curve of numbers of agricultural workers in the U.S.A. through the 1955 to 1970 time span, shown in figure 3, suggests the growing dependence on mechanization. Moss (1971) points to a similar trend for England and Wales. We can unhappily expect a future in which many of the small fruits and vegetables we have enjoyed but which do not lend themselves to mechanization will disappear from the markets except as luxuries because of labour shortages.

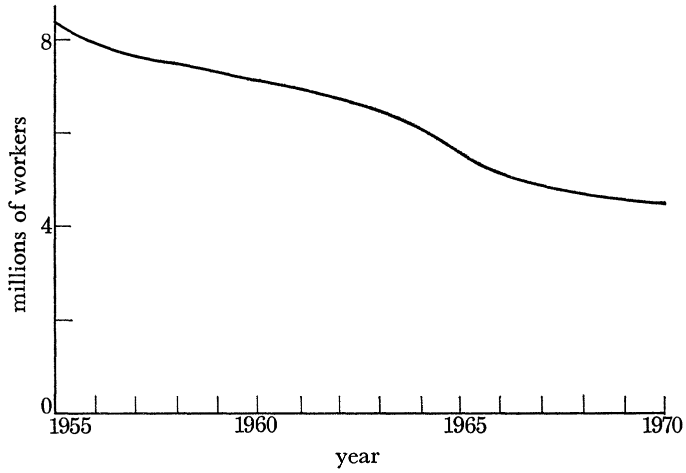

Figure 3. Numbers of agricultural workers in the U.S.A. from 1955 to 1970.

Another economic influence on farm labour is the availability of work off the farm.

'In 1970, for the first time, off-farm earnings of U.S. farmers exceeded farm earnings. Off-farm income totaled $17 billion; total net farm income stood at $15.9 billion. Among farmers with less than $2,500 in farm product sales, off-farm earnings accounted for nearly 90 per cent of total income. But larger operators depended heavily on off-farm earnings, too. In 1970, farmers with $10,000 to $20,000 in farm product sales received more than a third of their total income from off-farm earnings. Economists say the nation's rapidly growing non-farm economy, which provided an abundance of good paying jobs, was a strong stimulant to off-farm employment for farmers in the 1960s.' (The *Furrow*, 1972.)

One thing is clear, Agricola, as we knew him in our Latin school books, is vanishing and farming as a way of life is being displaced by farming as a business.

Tractor power trend

The power used per unit of agricultural land is related to the productivity as was shown in figure 1. Japan and the United Kingdom have the highest value of power applied – about 1500 W (2 horsepower; hp)/ha. The aggregate crop yield is correspondingly high – about 5000 kg/ha. The United States employs approximately 750 W (1 hp)/ha and 1 ha yields about 2500 kg. Again, you are reminded that in these data, other farm input is not constant.

In order to focus more sharply on the object of this discussion, trends which may indicate the future of machines and men in agriculture, let us limit the scope to the more advanced countries with which we are familiar.

An immediate observation is the steady annual increase in tractor power employed. Although the number of units sold per year appears to have levelled out, the power per tractor has risen steadily.

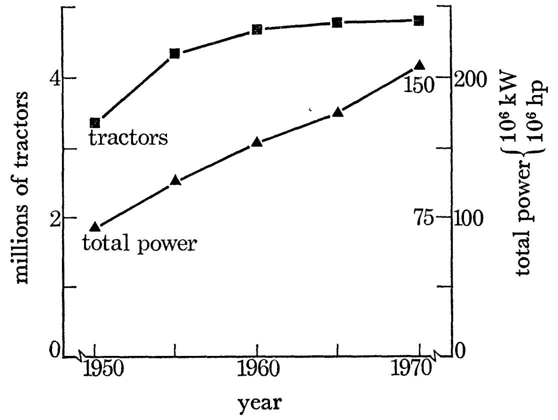

Figure 4. The number of tractors on U.S.A. farms and the total power represented.

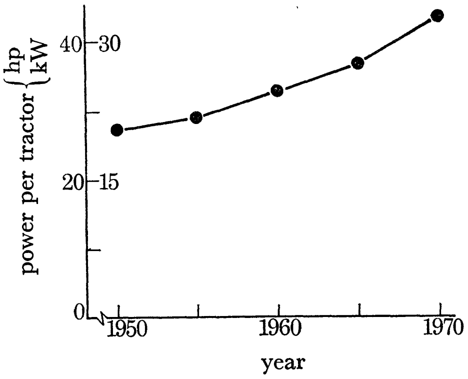

Figure 5. Power per tractor.

Figure 4 made from U.S.D.A. *Statistical Bulletin* no. 233 (1971) shows the number of tractors on U.S.A. farms and the total power represented by these machines. The derived curve, figure 5, of power per tractor illustrates the steady increase from an average per unit of 20.4 kW (27.4 hp) in 1950 to 32.8 (44) in 1970.

Moss (1971) illustrates this trend in a graph of the number of tractors in use in England and Wales from 1940 to 1970. In the United States, we read, for example, in *Implement and tractor* (1972) 'In 1965, 2.3 out of every 1000 tractors sold were in the 100 and over pto horsepower category; in 1971, 25 out of every 100 tractors sold were in this size range – from 2.3 to 25 per cent of the market for the big ones in seven years with a 6 per cent leap in 1971 alone!'

Figure 6 repeats the total U.S.A. tractor power curve and relates it to the total farm labour hours used per year.

Concurrently, with the increase in unit power, the weight of the tractor per unit power has decreased by some 3 % each year. Immediately apparent advantages are more nimble performance and higher operating speeds through the fields. For increased traction at reduced speeds, the weight of the tractor may be increased by the usual ballasting methods.

Despite the higher power trend, we manufacturers were not advancing as rapidly as some of our more progressive farmers were demonstrating to us by replacing original engines in the latest model tractors with higher horsepower engines from other sources to create 'up-powered' machines. New & Spaid's paper (1971) reported their experience with a John Deere Model 5020 repowered with a Detroit Diesel engine rated 237 kW (318 hp), roughly twice the original power. They stated: 'Timeliness of field operations is very important when you're in the business of producing corn in Iowa. By repowering, we have attempted to provide farm power resources which provide sufficient surplus engine power, tractor operating speeds and overall field machine capacity so that our corn planting operations can be completed rapidly between 15 April and 5 May. This permits us to achieve maximum corn yields regardless of weather conditions. . . . In 1971 we planted 850 acres of corn at the rate of 100 acres a day.'

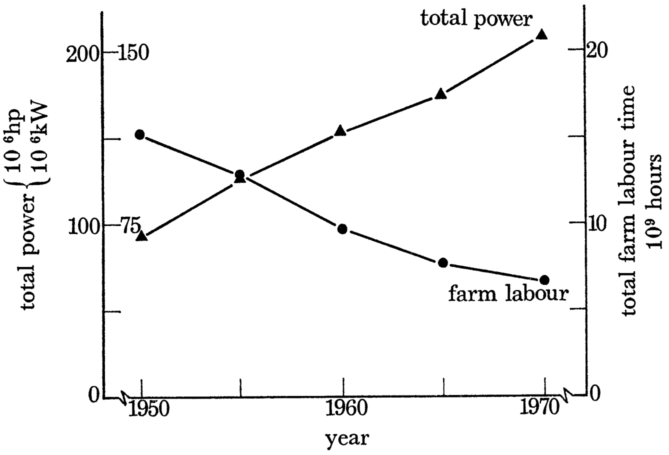

FIGURE 6. Relation of total U.S.A. tractor power curve and the total farm labour hours used per year.

USE OF INCREASED POWER

The field use of high power tractors has been developed empirically by farmers who have determined, for individual conditions, the best practice for high productivity. The broad choices are: to pull a wider spread of implements at usual speeds, pull a tandem set of tools for single pass tillage and planting, or draw normal tools at higher speeds.

The motivation for this higher productivity is, of course, to cut the labour and capital cost per unit of land cultivated and to achieve timeliness of planting. Elsewhere in the developed world this trend toward higher power is occurring limited by areas for cultivation by one operator which are large enough to justify the large machines. Co-ops, state farms, custom or contract operation, joint ownership or other arrangements permit mechanization beyond the boundaries of land ownership.

Higher power, however, is not without some penalty. Unless a substantial portion of the tractor power is delivered through the power take-off (p.t.o.) the weight per driving wheel must be high to develop full tractive effort. This may cause compaction problems in the wheel track. Four-wheel drive machines are a partial answer, but even these may require dual tyres with correspondingly wide tracks.

Another proposed solution is to accept compaction and drive repeatedly in established tracks with the tilled ground between. General acceptance of this scheme is unlikely although the method suggests the possibility of automatic guidance by wire or laser beam techniques.

Self-propelled machines

Higher power and productivity also mark the trend in harvesting equipment. Usage tends to favour the self-propelled combines, forage harvesters and windrowers rather than the pull-type, and the area harvested per operator day is on the increase. Again, as with large tractors, large farms or land combinations are the basis of profitable operation of harvesting equipment. A limit to the tonnage of crops harvested per hour now lies in the ability of trucks or towed wagons to take the crop from the harvesting machine to a receiving terminal or temporary storage while maintaining productivity of the harvesting machine.

Current studies in harvesting methods suggest changes for the future. Corn for grain, for example, now is harvested largely with a combine equipped with a corn head. In 1960, 80% of the corn crop was harvested by a mechanical picker. In 1970 the combine-corn head machine harvested 70% of the crop. Much of the crop is now harvested earlier at a higher moisture content. As a result, the use of artificial drying has increased substantially to prevent spoilage in storage. An alternative to artificial drying is chemical treatment to inhibit mould growth using proprionic acid, for example, a well-known food preservative. Such mechanization gives the farmer greater latitude in his operations.

Hay handling is currently undergoing change. The older method of forming large stacks was largely displaced by mechanical baling for better transport and storage. Now we see a rather rapid swing away from bales to stacks with the introduction of mechanical stack formers and stack movers. One man with a tractor can pull a stack former which, when filled to proper density, deposits the stack on the ground. At a later time a stack mover can gather the stack onto its platform for transport to a desired location on the farm. The cost of handling and storing hay with this new system is less than by baling.

Current nutritional studies show that the whole corn (maize) plant has high feed value for beef production in addition to the grain value and roughage. Consequently, we can expect to see modifications of combines which can deliver kernel corn, chopped forage or any combination of these for immediate cattle feeding or silage for storage and later use. The entire corn plant can be utilized.

An increasing demand on harvesting equipment arises from the trend toward high plant populations – in maize, for example, 90000 to 100000 plants per hectare in some parts of Europe. The plants must, of course, be of a strain which is tolerant of crowding. The resulting crop even if relatively dry represents a tremendous throughput of material for a combine moving through the field at 5 or 6 km/h. High power is needed and the loads on all parts of the machine are very demanding.

Along with the growth of machine in size and sophistication comes the requirement for reliability, better controls, monitoring of machine functions, and improved environment for the operator. This leads almost inevitably to cabs or operator cabins with roll-over protection, ventilation and air-conditioning, isolation to produce tolerable or legal noise levels at the operator's ear, all without loss of essential visibility. Our Roman friend, Agricola, would be impressed!

Tillage and planting

Agricola would also be amazed at the variety of tillage tools and methods of tillage employed today to meet the varied needs of soils and crops. Mouldboard ploughs, chisel ploughs, disk and tooth harrows, crust and clod breakers, sweeps and rotary hoes, all serve particular needs.

For some, power may be applied directly to the tool as well as through the tractor draft link. In fact, we may see a trend toward more power applied to the tool for rotation, oscillation or vibration with less of the tractor engine power acting through draft. Numerous studies of powered or vibratory tools seem to lead to the general observation that power on the tool can reduce draft or modify the seed-bed, but the total power requirement for a given tillage task remains essentially unchanged. However, power to the tool would be advantageous in reducing the necessary weight on driving wheels and achieving better control over the quality of the finished seedbed. We can expect more exploitation of available tractor power through powered tools rather than solely through brute force traction.

We can expect changes in seed planting to achieve more rapid seeding, accurate spacing, uniform depth of planting and proper pressure to assure good soil contact with the seed without leaving a top crust which would interfere with emergence. Continued experimentation with seed types will establish plant population densities for optimum crop yield. At the same time experimental work continues on broadcast seeding which promises to reduce planting costs. To date, this method has few adherents. But, if this seeding technique succeeds, changes in tillage methods and in harvesting machines will follow when row cropping is not practised.

Tillage practices are undergoing change as experimental work demonstrates the advantages and limitations of minimum tillage. The range of trials is from zero tillage to full trash burial by deep mouldboard ploughing. The motivation may be simply less field working or to achieve a balance of incorporated and surface crop residue to minimize wind and water erosion. In fact, rising public concern for the environment may restrict the use of erodable land or at least require methods of tillage which will conserve the top soil. At the same time, assurance is needed that unincorporated crop residue will not encourage the spread or persistence of crop diseases and pests.

Trends in agriculture

Agriculture in the future, at least in our part of the world, will rely more on machines and less on manpower. Farming units will be larger and crops more specialized. Similarly, the labour economies resulting from mechanization of poultry and meat production will lead to more large units for these purposes. Dr Walter Carleton of the Agricultural Research Services, U.S.D.A., pointed out recently that large-scale operations have already demonstrated that only 200 of our largest feedlots could supply the U.S.A. market for beef; 10000 dairy farms could supply the U.S.A. requirement for dairy products; 5000 farms could provide all of the pork; 300 farms or 'egg factories' could suffice for egg production; and 3000 farms could supply the U.S.A. market for broilers.

Such farms would be highly mechanized, particularly in materials handling. A fully integrated unit would grow its feed crops, process and store its feed, process and package its meat or poultry products and even market the products through retail outlets owned or controlled by the same 'agribusiness' corporation. Some parts of this integrated system are now in operation by a few corporate conglomerates. Growth of this concept is viewed with considerable alarm by independent farmers. Already the small operator is beginning to experience difficulty in marketing his products and is being encouraged to join cooperatives or contract his production in advance.

Optimum use of machines

New machines and improvements on more conventional types will add substantially to the capital investment in a farm. At present the U.S.A. investment for each agricultural worker is estimated to be $56000. It is important to the farmer to have an optimum combination of machines for his operation. Recently computer programs have been developed which include such parameters as farm size, machine productivity, type of crop, labour rates, interest rates, depreciation and maintenance charges, and a timeliness penalty for late planting. A combination of tillage tools, tractor, planting and harvesting equipment in proper sizes will be selected by a computer to give the lowest production cost per unit of land farmed. Thus, in choosing a new machine a farmer can be assured that he is getting the properly sized unit to go with the equipment he now has and the crop specialization he plans to follow. In the future we can expect more of such objective selection of machines. Agricola will have come of age as a businessman.

Restrictions and constraints

The future will bring restrictions and constraints on agriculture. Soil surveys by land, air and satellites will be a basis for land use management.

The National Research Council in 1962 created a Committee on Remote Sensing for Agricultural Purposes. The report of the committee, published in 1970, observes: 'Remote sensing has the potential for revolutionizing the detection and characterization of many agricultural and forestry phenomena. Recent studies indicate the remote sensing techniques can be used in the ultraviolet, visible, infrared, and microwave regions of the electromagnetic spectrum to collect data that give a measure of the reflectance, emittance, dielectric constant, surface geometry and equivalent black-body temperature of plants, soils and water. With a minimum amount of ground sampling, these data will permit: (*a*) identification and area measurements of the major agricultural crop types; (*b*) mapping of soil and water temperatures; (*c*) mapping of surface water, including snowpack; (*d*) mapping of disease and insect invasion; (*e*) mapping of gross forest types; (*f*) mapping of forest-fire boundaries; (*g*) assessment of crop and timber stand vigour; (*h*) determination of soil characteristics and soil-moisture condition; (*i*) delineation of rangeland productivity; (*j*) mapping of areas of high potential forest-fire hazard; and (*k*) mapping of major soil boundaries.'

Cropping practices will be recommended, if not required, to achieve best land use. Preservation and improvement of the environment will be high in popular priority implemented with regulations to minimize air and water pollution and achieve water and soil conservation. Crop specialization and concentration of meat, poultry and dairy production will occur, but under carefully regulated conditions consistent with preservation of the environment.

Yet, even without further concentration of meat production, the existing large feedlots now create non-trivial problems of waste disposal. Pollution of air, land or water will be an increasingly important consideration which can limit the size, location and economy of feedlots. Substantial study has been given to this problem with no generally satisfactory solution emerging. Ultimately, return of animal waste to the land through safe incorporation in the soil will probably be the only acceptable solution. Economically, this procedure is no trade-off for chemical fertilizer and the cost of such disposal must be reckoned in the overall cost of doing business. Furthermore, at present not enough is known about the quantities of waste material a given amount of land can tolerate without short- or long-term deterioration.

RESEARCH NEEDS

These and other considerations lead to an appraisal of what is needed in research – broadly interpreted – for present and future mechanized agriculture. The U.S.A. Farm and Industrial Equipment Institute in 1972 made a survey entitled, 'Frontiers of basic and applied research', involving field equipment and livestock equipment. The input was from member manufacturers. Note that the research needs relate to machines and do not include such important areas as agronomy and plant and animal genetics. Figure 7 gives the concensus for field equipment. Note the definitions of applied and basic research in this context. Your attention is directed to the three major areas of farming which call for substantial basic research: tillage, planting and cultivation; chemical utilization and insect control; and harvesting and processing.

In figure 8 which relates to livestock equipment the two areas which call for the most basic research are 'solid waste management and pollution abatement,' and 'pollution control (air)'. Feeding and disease control also demand substantial basic research.

The modern combine does the whole job of reaping and threshing. Manpower has been reduced to a minimum. Further combine development will probably be in increased productivity, reduction of losses and improved cleaning. As mentioned earlier, a current limitation in combine productivity is in the transport of the grain from the combine. Various container concepts are being explored which would eliminate the operation of unloading a combine grain tank into a transport vehicle.

We could imagine a guidance system for a combine which would eliminate the operator. However, without a rather elaborate remote control system a man would probably be needed on the machine to monitor its various functions and performance. The future may bring novel methods of threshing and separation as well as machines specialized for a particular crop. Yet, as a general purpose machine for a variety of crops, the modern combine will be difficult to displace.

Changes in the value of straw, stalks and other parts of the plant for new uses on or off the farm may require design changes in the combine which could be accommodated within the scope of existing technology.

The future may bring more complex machines which perform more of the operations now done out of the fields or off the farm. For example, one can imagine a cotton picker which picks, cleans, gins and bales as it goes through the field. Several of the conventional steps from plant to textile mill would be eliminated. Ultimately, the overall economics of the machine and the processing would determine the acceptance of the scheme, assuming that the quality and form of the baled cotton is acceptable to the mills.

We have seen the agricultural labour force in the developed countries shrink as mechanization has increased. Already the labour cost of the farm product may be reaching a level which suggests that the cost incentive for further labour reduction becomes less compelling. The machine then substitutes for unavailable labour. Attention will be directed toward simplification or elimination of links in the food and feed processing and marketing chain. 'Factories in the field' may become more numerous than they are today.

But, whatever the man–machine relationship will be as determined by economics, we can expect external constraints and regulations designed for the protection of the land and the environment. The machines and man's use of them in agriculture in the future must recognize these added social values.

● APPLIED RESEARCH

▮ BASIC RESEARCH

	CORN	SOY BEANS	SMALL GRAIN	HAY & FORAGE	FRUIT & VEG.	COTTON	WASTE PROD. UTILIZATION	HIGH-SPEED FARMING	SOUND ATTENUATION	HUMAN FACTORS & ENVIRONMENT	MARGINAL LAND UTILIZATION	RURAL DEVELOPMENT	WASTE MGMT.
PRIME MOVERS	●	●	●	●	●	●	●	▮	▮	▮	●		●
TILLAGE, PLANTING AND CULTIVATION	▮	▮	▮	●	▮	▮		▮			●		▮
CHEMICAL UTILIZATION AND INSECT CONTROL	▮	▮	▮	●	▮	▮		▮		▮	▮		▮
HARVESTING AND PROCESSING	▮	▮	▮	▮	▮	▮	▮	▮	▮	▮	●		●
POLLUTION, SOIL CONSERVATION AND ECOLOGY	●	●	●	●	●	●	▮	▮		▮	●	●	▮
CONSUMER AND ECONOMIC RESEARCH	●	●	●	●	●	●	●	●	●	▮	●	▮	●
SAFETY	●	●	●	●	●	●	●	▮	▮	▮	●	●	●
SYSTEM DEVELOPMENT	●	●	●	●	●	●	●	▮		▮	●	▮	●
COMMUNICATION	●	●	●	●	●	●	●	●	●	▮	●	▮	●
LEISURE TIME				●						▮	●	▮	
DRYING AND PROCESSING	▮	▮	▮	●		●		▮	●	▮			▮

FIGURE 7. F.I.E.I. survey 1972 – field equipment.

■ APPLIED RESEARCH

▥ BASIC RESEARCH

	BEEF	DAIRY	HOGS	POULTRY	RURAL DEVELOPMENT	ECOLOGY AND ENVIRONMENT
HOUSING	■	■	■	■	■	■
FEEDING	▥	▥	▥	▥		
STORAGE	▥	▥	■	■		■
SOLID WASTE MANAGEMENT AND POLLUTION ABATEMENT	▥	▥	▥	▥	▥	▥
POLLUTION CONTROL (AIR)	▥	▥	▥	▥	▥	▥
LABOUR	■	■	■	■	▥	■
DISEASE CONTROL	▥	▥	▥	▥		
SAFETY	■	■	■	■	▥	▥
NOISE ABATEMENT				■	■	■
POWER	■	■	■	■	■	■
TRANSPORTATION	■	■	■	■	▥	▥
YIELD AND QUALITY	■	■	■	■		
INSTRUMENTATION AND CONTROLS	▥	▥	▥	▥	■	

Figure 8. F.I.E.I. survey 1972 – livestock equipment.

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Discussion

G. PREUSCHEN (*Max-Planck Institut für Landarbeit und Landtecknik,* 6550 *Bad Kreuznach, Germany*). Dr Lindvall gives a very impressive view of the future of U.S.A. agriculture: very big machines with automatized driving systems and a very small number of farmers. If I read the first slide exactly, then the diminution of farming people was 4.5 millions in the last 25 years and the number remaining today is also 4.5 millions. That means that in the 2000s all American farms together will need only one man to operate them and this man can be the Minister of Agriculture!

Bigger machines are used for many reasons: low incomes push farmers to other professions, and neighbours can rent many farms at low costs and they need bigger machinery – that is the situation in the corn belt of U.S.A. Farming people like bigger machinery for development of their social status, salesmen have a better market with more expensive machines – and in many countries there exists no more workers for farm-work (the situation in Germany).

There are technical disadvantages: tyres for high traction are rare, pressure on the soil too high. The use of heavy machines is extremely difficult under wet conditions. May I remind you of the situation in the wet summer of 1970 in Hungary where only one type of heavy combine was used: the loss of cereal was 20 % in many regions.

From the economical point of view, bigger machines have a higher cost per unit of performance than smaller ones, e.g. a 2 t/h combine has lower costs per tonne than a 4 t/h combine; a 2-mouldboard plough costs 25 % of a 6-mouldboard plough. Influence of the farm-size: we have more opportunities to work with a 37 kW (50 hp) tractor than with a 75 kW (100 hp) tractor, but if the 75 kW (100 hp) tractor has to do the same work for which a 22 kW (30 hp) tractor is sufficient, this is expensive. Bigger machinery costs more and higher costs induce the farmer to higher yield: that is the most important reason for overproduction in the E.E.C.

The first discussion speakers of this morning gave an outline of the limitation of all technical factors in the future: we must ask, what do farming people like to do; what is the best standard of life, of health, of working conditions, etc.; do people like odour, noise of 90 dB, handling of liquid manure etc.? Last week I was in Hungary. There exist many big feedlots and dairy farms of 1000 to 5000 cows, but in that country (with underemployed people in the villages!) we do not find enough people who like to work in such large units. Specialization and labour-division? The workers in industry do not want any more specialized working-places – the new Volvo car and the Philips television factories use small groups of workers doing 20 to 40 operations, no longer using a conveyor belt.

We have to respect the fundamental difference between agriculture and industry: industry makes its products by hand and by machines invented by men. Farmers do not make the products; they only help nature to produce them. So we do not have in agriculture a direct relation between input in labour and energy on one side and output in products on the other side. Farming people have to cooperate with soil, plants and animals. This can be done only in supervisible units, but not in agro-industries – we know the disaster of these big units in Russia.

In the future we have also to respect the opinion of the general public more. Agriculture makes the human environment in the outside world – people regard wild nature as an 'enemy', not as a 'friendly' environment. Food production is only one part of agricultural tasks, in many developed countries a rather small part. Maintenance of environment, consumption of CO_2, production of O_2, diminution of noises, dust, gases etc. can be just as important, but this requires more handwork than machinery.

The number of people in agriculture must be sufficient for all these tasks. In many countries we no longer have enough people: in Western Germany we have already 5% of our area uncultivated – a 'destroyed nature'! Agricultural engineering can and must improve living conditions to keep people on the farms!