The Influence of Technical Progress on Agricultural Production

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IN THE complex changes that have affected modern agriculture, technical progress has played a large part. Perhaps it is even the warp of the fabric; certainly it has enormously influenced the whole modern economy. It would be easy to write about the wonders of modern technology, and it would also be easy to curse them as responsible for most of our ills. This article does neither. It attempts a sober appraisal, point by point, of the influence of changes in farm power and equipment, plant and animal breeding, fertilizers, animal feeding, disease control—not only the changes in the past but those in prospect in the near future. These changes affect the whole of our agriculture—methods of production, quantities produced, the manpower needed in farming, capital requirements, size of farm units, the organization of the farm, operating costs, conditions of tenure. It is not too much to say that our destiny will depend to no small extent on our understanding of these factors and our ability to direct them for the service of all our people. The article is based on information prepared for an interbureau committee on technological developments in agriculture.

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TECHNICAL change has had a predominating influence on the progress of civilization during the last 200 years. The invention and perfecting of automatic or partly automatic machines and their increasing use have relieved many of the production processes of their former dependence on human labor. But the effects have not been due solely to an increase in the output per man. Changes in methods of production, growing efficiency in methods of distribution, and the introduction of new products to fill new demands have created an economic world fundamentally different from that of our own colonial times. The products that we buy and use today are as different from those of the earlier period as are the ways in which we make and obtain them. The change goes on at an accelerated rate, and it is the general belief that the future will bring changes still more striking than those of the past.

Technological development has changed the problems of agriculture as much as it has changed the methods of production. A century ago the future supplies of food and fiber for the world were a matter of grave concern. Today, with the world population approximately doubled, the problems created by excess production in agriculture are more troublesome, in the United States at least, than are those arising from scarcity. The problem of employment for the people is more significant for the present than that of increasing the production of food.

The transition from a self-sufficing agriculture, in which the farmer produced not only his own food but also much of his clothing and equipment, to the present specialized commercial type of production is the result of a combination of developments within agriculture and economic forces outside it. The development of the railroads and accompanying improvements in transportation and communication created new outlets for farm products from the interior regions of the United States. New equipment and new methods of production transformed agriculture from a primitive to a highly complex industry. The cotton gin, horse power, the steel plow, the reaper, and the threshing machine initiated a change that is now accelerated by the tractor and associated equipment such as the combine harvester, the corn picker, and multirow tillage equipment. Before agriculture has been able to adjust itself to these changes, a mechanical cotton picker, beet lifter, or cane stripper may be forcing new adjustments between labor, capital, and production on farms.

Increased production per unit of land has followed the development of new, better adapted, or more productive varieties of crops. The increased use of fertilizers and improved rotations and tillage practices still further increase the potential production of food and fiber. Improved breeds of livestock and a widespread knowledge of superior methods of feeding and care lead to more effective use of crops in the production of livestock and livestock products. All of these new developments promote efficiency in production and are directed toward the ideal of obtaining more products either from the effort expended or from capital expenditure made.

The aggregate influence of these developments in the United States may be readily grasped if we consider the decrease in the proportion of people now engaged in agriculture and the increase in the produc-
tion of those employed. The proportion of workers engaged in agriculture decreased from one-half of all workers in 1870 to one-fifth of all workers in 1930. During the same period the average agricultural production per capita in the United States increased 22 percent. Thus those engaged in agriculture in the United States not only have been supplying food and fiber to more people but have actually increased the average amount of agricultural products per capita of total population.

Because social and economic adjustments are initiated by technical change, agriculture is faced with the necessity of further adjustments. With present techniques, production of most farm products exceeds the quantities that domestic and foreign demand will absorb without depressed prices and lower farm income. It is true, also, that known techniques and practices are not utilized fully. As the known practices come into general use and as new developments are made available, increases in production may be expected. The release of workers in agriculture as the result of the introduction of labor-saving equipment and the inability of these displaced workers to find employment in industry pose a serious labor-replacement problem. Thus technical developments that increase the production of farm products or that tend to displace workers in agriculture may lead to important economic and social maladjustments.

Presumably the adoption of a new process gives some immediate advantage to the individual using it. Why, then, with all the technical developments in agriculture in recent years, has the income of farmers been decreasing? Probably some farmers in some sections have benefited from technical change, but the influence of increased production on prices may have depressed incomes of farmers not in a position to use the improvements. The effect on price may have offset any decrease in cost or increase in production even for those farmers using the new methods. Thus a sequence of developments may have been set up which runs contrary to the objectives of agricultural policy. An understanding of the effects of technical progress may provide a basis for directing the use of new developments in such a way as to fully utilize their benefits and to minimize their disadvantages. Technological developments add to the material well-being of society in the long run, but the pains of adjustment and transition may be acute, especially under the conditions existing today.

Directly and indirectly technological progress affects agricultural production in many ways. The directions and degrees of influence are almost as diverse as the developments themselves. In order to be incorporated into the production organization, particular developments must make some contribution by way of (1) increased volume of production, (2) improved quality of product, (3) lower cost per unit of product, or (4) less fatigue and less tedium in connection with farm labor. The effectiveness of any one process may depend largely on the contribution of complementary processes. The value of an innovation may be derived indirectly from its contribution to other related developments; that is, the contribution that a new process can

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make to efficient production depends in a large measure on the stage of development of related processes and on the relative prices of labor, equipment, and the resulting product. The influence of the tractor is not solely that of a more effective power unit. Its value depends in part upon combining the added power with machinery capable of doing work not feasible with horses.

The flow of technological improvements with their incentive to adjustments in farming is only one of the forces that make agriculture a dynamic rather than a static industry. Changes in the economic situation, the growth and disappearance of markets resulting from shifts in population, the growth or decline of competing areas, the introduction of competing products, and changes in the consuming habits of customers may likewise induce changes in the organization and volume of production in agriculture.

Besides their direct influence, economic factors may also have a marked influence on the rapidity with which technical changes are adopted and hence may speed up or retard the adjustment to new techniques or processes. The fact that there is a lapse of time between the development of a process, its adoption into general use, and the actual making of adjustments to it permits some appraisal of the probable consequences of technical improvement and makes possible the development of programs to facilitate change. Many of the potentially important technological developments are not yet in use but have progressed so far in the experimental stage that some judgment of their economic use and limitations can be made.

FARM POWER AND EQUIPMENT

The change from horses to tractors for farm work, trucks for hauling, and automobiles for travel has speeded up the rate with which work is done and has increased the capacity of the labor force on farms. A natural adjustment to this greater capacity of labor is to increase the size of the business unit and to reduce the use of extra labor on the typical family farm. Moreover, greater power and recent improvements in machine design make possible better seedbed preparation and more thorough tillage. Improved harvesting equipment has reduced losses in harvesting and thus contributes to increased production from a given area. When equipment and land area are properly balanced, these gains are sometimes achieved with little or no addition to the investment in working capital for a given land area.

Changes in Farm Power

Probably no other group of developments has influenced agriculture so much as those related to mechanical power and the equipment that such power brought into common use. The National Research Project of the Works Progress Administration estimated that in 1935 the tractor, motortruck, and automobile saved in agriculture or shifted to industry labor equal to that of 345,000 persons for 1 year. The number of horses, mules, and colts on farms decreased from 26,500,000 in 1915 to 15,182,000 in 1939. This decrease of work

stock in the face of expanding crop production was a direct result of the use of tractors, trucks, and automobiles. It seems likely that the trend to less labor and fewer horses will continue.

The tractor, by bringing more drawbar power to particular operations, has made possible operation at higher speeds and use of equipment of greater working width than is feasible with horses. Larger or more effective equipment can be used for ordinary farm operations. The belt pulley on the tractor provided a mobile source of power for work previously done with a stationary engine. The power take-off, transmitting power from the tractor, increased the efficiency and dependability of such harvesting equipment as mowers, grain and corn binders, small combine harvesters, corn pickers, and field ensilage cutters.

From the heavy, cumbersome tractor, limited to heavy-draft field work and certain types of belt work, the trend in tractor development has been to lighter tractors of higher speeds, adapted to a greater variety of uses. Further modifications in tractor design may be expected, and the production of a small tractor at low cost is a possibility. Developments in agriculture in the immediate future, however, are most likely to result from (1) increased use of general-purpose tractors, (2) increased use of small tractors on the smaller farms, and (3) equipping tractors with rubber tires.

According to recent estimates there are something like 1,600,000 tractors in use in the United States. This is almost double the number reported by the census in 1930 and indicates an increase of 746,000 tractors during a 9-year period.

Three-fourths of all tractors sold in the United States in 1937 were general-purpose tractors, and as the all-purpose type has dominated sales since 1935, it is probable that 50 percent of the tractors now on farms are of this type. The proportion of tractors equipped with rubber-tired wheels is increasing (fig. 1).

Tractors are used in all areas, but the highest degree of mechanization has been reached in the small-grain-producing areas, in the Corn Belt, and in specialized areas such as the dairy, truck, and orchard areas of the Eastern and Western States. In the Southern and Eastern States small farms and low incomes have not favored the use of tractors; mechanical power is used, however, in certain areas on large farms and for specialized production. The small all-purpose tractor will probably increase the rate of mechanization in the areas where farms are small, and large numbers of workers and work stock may be displaced.

The small tractor is also adapted to the small farms of the North Central States. Here it may offset the tendency to combine and enlarge family-operated farms. Continued mechanization would displace more work stock and encourage larger farms in some areas where the units are now small. In the small-grain areas, which are more fully mechanized than others, the small tractor may displace horses for work on small farms. Adjustments of size of farm to power equipment, which have been under way for some time, will probably continue.

Figure 1.—Tractors equipped with rubber tires have a wider range of usefulness and a longer working life, yet cost less to operate and repair than those not so equipped. Their increased use in the past few years has been revolutionary in the farm machinery field.

Probably the most rapid single development in the field of farm power and machinery in recent years is the adaptation to and use of rubber tires on agricultural tractors and field machinery. This development has not only expanded the sphere of usefulness of tractors but also reduced tractor operating costs. With fuel consumption per acre reduced about 10 percent on rubber-tired tractors as compared with those with steel wheels, repair bills reduced as much, and the life of the machine extended, the cost of doing farm work with tractors should be less now than it was with the best type of equipment available a few years ago.

Eventually the total investment for farm power may also be reduced. With a small outlay for trailers to use with the higher-speed rubber-tired tractors it may be possible, in some areas, to dispense with motortrucks. Field-to-field movement of the tractor and tractor equipment will also be facilitated by the use of rubber tires.

**Tillage and Seeding Equipment**

The trend in the development of tillage implements during the last 5 years has been toward lighter, more flexible machines that can be used successfully in connection with light and easily maneuverable tractors. Trends in development have also been influenced in the last few years by recognition of the erosion problem and modification of tillage practices to control rather than to increase erosion. Tractors...
equipped with power-lift mechanisms and mounted implements such as plows, cultivators, drills, and planters will facilitate the adoption of conservation practices on the rougher land areas of the eastern part of the United States. The development of implements for the steeper slopes will make operations on rolling and hilly land less disadvantageous as compared with operations on level land.

Recent developments in planting machinery are largely concerned with tractor-operated planters, features to permit the use of new planting methods, and the combining of tillage, fertilizer-distributing, and planting equipment in single units. Advantages of reducing man labor and insuring timely operations during critical periods are gained by combining in one operation some phases of the preparation of the seedbed, the distribution of fertilizer, and the planting of the seed. Such combinations have been accomplished with various classes of horse-drawn machines, but with tractors sufficient power is available for the use of heavy tools and for satisfactory simultaneous operation of several kinds of equipment.

Changes in fertilizer-placement devices by means of which the fertilizer is placed more advantageously for the growth of the seed or plant may have considerable economic importance.

**Harvesting Equipment**

Developments have been more rapid in harvesting equipment than in other types of machinery. The new machinery has reduced the need for seasonal harvest labor, and many farmers use such equipment to avoid the problems associated with hiring seasonal labor as well as to take advantage of lower harvesting costs.

Of recent developments in harvesting equipment, the grain combine is probably the most important, and the manufacture of new types of combines adapted to harvesting grass, seeds, and soybeans, as well as small grains, has increased their use. In 1939 about 110,000 combines were in use. In 1920 less than 5 percent of the wheat crop was harvested with combines; in 1938 approximately 50 percent of the crop was “combined.”

Of the approximately 92 million acres of corn harvested in the United States in 1938, about 90 percent was harvested for grain. About 13 percent of this acreage was harvested with mechanical pickers (fig. 2). Since about 100 acres of corn is the minimum for which a farmer can operate a picker economically, expansion of the mechanical pickers is limited. If the design of the corn picker could be simplified so that its cost could be reduced, its use would be greatly expanded. In view of the rapid development during the last few years of machines for so-called family-size farms, a simplified, low-cost picker is a possibility, and this would remove one incentive to concentrate corn acreage on large farms.

The windrow pick-up baler is an example of a group of machines that bring about marked changes in methods for a particular type of farm work, but which, because of their limited adaptation, have a minor influence on production as a whole. Where they are used, pick-up balers effect a considerable reduction in labor requirements for haying, but at present their influence on the general farm-labor

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1 For reference see footnote 4, p. 513.
situation is slight. Their use will probably not be sufficiently extended to cause much change, at least in the near future. Other machines of this class are the field ensilage harvester and the hay drier.

Although over 800 patents have been taken out on cotton harvesters and much attention has been given to their development, the stripper type of cotton harvester is the only one that is considered beyond the experimental stage. The stripper, which removes the entire boll from the plant, has been used to a limited extent in the Southwest, where climatic conditions and the type of plant growth favor this method of
harvesting. The mechanical cotton picker, several of which are now being developed although none is yet in regular production, is intended for use on the higher grades of cotton produced in the South Central States.

In general the quality of mechanically picked cotton is lower than that of cotton hand-picked under similar conditions. This is due in part to leaves and bits of trash that become entangled in the lint and to stains caused by the green leaves. Spinning tests show that machine-picked cotton is more "wasty" than similar hand-picked lots, especially in the case of cotton picked early, when the leaves are greener and more likely to stain the lint.

The beet harvester, like the cotton picker, has not yet reached a stage of development where it can compete with labor at current wage rates. It may, however, have an important influence on sugar-beet production in the future. The labor peaks in growing sugar beets occur when the plants are blocked and thinned and when the beets are harvested.

Equipment and methods for blocking and thinning beets are being developed. A harvester that lifts and tops the beets and separates the tops and roots into piles has been developed and has performed fairly well under some conditions; but under other conditions, particularly where there is a considerable variation in the size of the beets and in the height of the crowns from the ground, the performance of the machine has been unsatisfactory. The development of an improved lifting and topping machine within the next few years, however, is a possibility.

Improvements in pumps and power for irrigation have made feasible an extension of pumping in some pump-irrigation areas. Although the development or expansion of irrigation has important consequences in a particular locality, total production in the United States is not likely to be affected. Changes in pump equipment in wells already in use affect farm operations only to a minor degree. Deep-well pumps with semiopen impellers, for instance, appear to be replacing other deep-well types, particularly where wells yield water containing much sand. The advantage is primarily that of making operation more dependable and reducing the necessity for frequent repairs. More significant are the portable sprinkling irrigation systems used to supplement rainfall, to supplement surface irrigation where the distribution of water is uneven, and to water land where gravity systems are not practicable. The use of these systems is increasing, although no estimate of the rate of increase is available. The most important use is to supply water to crops of high value in areas where irrigation is not regularly practiced. In this way the production of crops sensitive to variations in moisture conditions can be stabilized, and the quality, particularly of small fruits and vegetables, can be improved.

**CROP PRODUCTION**

The combined influence of the multitude of recent developments in the field of crop production and farm practices may be as significant as developments in equipment and power, or even more significant.
Plant breeders develop superior varieties of crops adapted to local conditions and resistant to disease and insect pests (fig. 3). Advances in this field may more than offset the gradual decline of fertility in continuously cropped soils.

An outstanding example of crop improvement is hybrid corn, which in the course of 7 years has replaced open-pollinated varieties on a major portion of the corn acreage in the Corn Belt and on about 25 percent of the national acreage. The greater vigor of the hybrids and their resistance to lodging, plant diseases, and insects increase acre yields by 10 to 20 percent in the Corn Belt, where they are adapted to prevailing conditions. It is estimated that, because of the use of hybrid seed, corn production in 1938 was nearly 100,000,000 bushels greater than it would have been had open-pollinated seed been used on all the corn acreage; further increases when known hybrids are put into use may be twice as great. The possibilities of hybrid vigor are not fully measured by this estimate, for the development of hybrids adapted to the Southern and Eastern States may bring increases in production in these areas also. As the areas capable of the highest production receive the greatest benefits from hybrid corn and as costs do not increase in proportion to the increase in yields, a tendency to concentrate production in the better areas may be expected. Moreover, because of their resistance to lodging, the hybrids are particularly well adapted to the use of a mechanical picker, and this combination of advantages from two technical developments increases the advantage of both to growers in areas where they can be used.
If there is no control over corn acreage, the combined inducement of higher yields and lower production costs for hybrid corn is likely to increase production in commercial areas, with the probable result that supplies of corn will be so great that they can be absorbed only at lower prices. As most of our corn is marketed through livestock, the consequence of such a development would be lower prices not only to those benefiting from the improved techniques but also to producers in areas where hybrids are not adapted.

Progress in breeding other plants that are as important to other areas as corn is to the Corn Belt is helping to increase or stabilize the Nation's food supplies.

Thatcher wheat, introduced as late as 1934, is resistant to the stem rust that cut spring wheat yields in 1916, 1935, and 1937, and it gives promise of greatly reducing crop injury from this disease. Probably more important for the future, however, are the tests now under way to produce varieties of wheat resistant to other types of rust and to other diseases. The gradual improvement of wheat varieties has enabled farmers to maintain yields in spite of declining soil fertility and increasing damage from weeds, insects, and plant diseases; and it has permitted an extension of production into areas of high risks and low average yields.

Early-maturing varieties of grain sorghum adapted to the western parts of Nebraska and South Dakota may so stabilize feed production there that some farming risks from drought will be removed.

The introduction of Punjab flax in California and the development of cold-resistant varieties for the Southern States may increase flax acreage, make it possible to replace part of the cotton acreage with flax, and reduce the need for imported flaxseed.

Strains of sugar beets resistant to curly top have removed one danger for western beet producers. Recently developed varieties of beets superior to the European varieties promise to eliminate the risks connected with beet production in the humid areas, but no immediate increase of sugar production per acre is anticipated. One factor limiting sugar production is the assignment of quotas. A removal of quotas with no change in prices would probably result in an increased domestic production.

Soybean production, which has increased rapidly and reached a new high acreage level in 1939, will probably expand somewhat further. The increase will probably be largely in the Corn Belt States pending the development of seed varieties suitable for other sections. Although the 1939 acreage would produce sufficient soybeans to meet the current demand, a prospective decline in the need for oats and the displacement of low-yielding hays by alfalfa would permit some further expansion in acreage.

Improvement of cotton varieties by increasing the length of staple may strengthen the export position of United States cotton. In 1938, 13 percent of the United States production was grown in single-variety cotton communities. In combination with selection of superior varieties, better production methods, and more careful grading, the one-variety communities should decrease the proportion of cotton of less than 1 inch in staple length. The primary result might be to narrow the price differentials for different staple lengths. All factors
combined might result in an increase of cotton yields, however, for
production is related closely to use of fertilizers, but it seems unlikely
that either production or prices will be immediately affected.

FERTILIZERS AND SOIL AMENDMENTS

Recent developments in fertilizers and fertilizer use are concerned
with concentrated fertilizers and the correction of soil deficiencies in
the so-called minor elements. The increased use of inorganic mate-
rials as sources of nitrogen and the use of double or triple phosphates
and higher-grade potash salts increased the plant-food content of com-
mercial fertilizers from 13.4 percent in 1880 to about 16 percent in 1925
and to 18.1 percent in 1934. The use of concentrated fertilizers is
slowly increasing. In some areas lower handling and transportation
charges per unit of plant food are important to an increased use of
fertilizers.

The use of magnesium in correcting sand drown of tobacco, of
manganese sulfate in curing chlorosis of tomatoes, and of zinc sulfate
in combating pecan rosette, little leaf of peaches, and similar diseases
illustrates what is occurring with an increasing number of elements
that are now used to control nutritional deficiency diseases of plants.
As experience more accurately defines the soil regions deficient in
particular elements and the crops affected, the use of these "minor"
elements will continue to increase. The effect on production may be
more important locally than nationally, and no measure of the po-
tential influence of this development can be made.

The consumption of fertilizers in the next few years is likely to be
influenced more by farm prices and farm incomes than by develop-
ments in fertilizer manufacturing.

CONSERVATION PRACTICES

The immediate effects of conservation practices are of less importance
than are their long-time consequences. The broad program of meas-
ures designed to retard soil erosion and to slow down the rate of deple-
tion of fertility could hardly be expected to have an appreciable
influence on total crop production within the next decade. Soil
deposition and its correction are tied closely to farm practices, local
customs, prices of farm products, and conditions of land tenure. A
conservation program must make use of a wide variety of corrective
measures and adapt them to local conditions. Consequently, informa-
tion on the rate of introduction of even well-recognized practices
and on the benefits from recently introduced practices is difficult
to obtain.

Although the immediate effects of conservation practices on crop
yields are less important than the lasting benefits to crop production,
certain practices, especially the selection of better land for crop pro-
duction and the use of cover and soil-improvement crops, may increase
acre yields.

Shifting low-producing land from crop production and concentra-
ating grain crops on the more fertile land of a farm increases average
acre yields without an increase of total production. This aspect of the
conservation program permits farmers to eliminate from crop production, or to shift to soil-improvement crops, areas on which yields and profits are low.

Such practices as terracing, strip cropping, contour farming, and, to a large extent, crop rotation enable a farmer to slow down the rate of soil depletion on his farm. They would, in time, increase crop production.

Cover and soil-improvement crops, on the other hand, have caused considerable increases in yields of the crops following them. Their use has been made an important part of the agricultural conservation program in the Southern States. In 1937 nearly 10,000,000 acres were in crops planted for cover and soil improvement. The acreage of these crops was more than double that of 1928–32. Without doubt the increased use of soil-improving crops has contributed to the higher yields in recent years in the Southern States. Moreover, the cumulative effect of green-manure and cover crops may be still more important. Increases in yields per acre of 70 percent for corn and 25 percent for cotton have resulted when green-manure crops were plowed under.

**ANIMAL BREEDING AND FEEDING**

Important current developments in the field of livestock production are progeny testing, artificial insemination, correction of nutritional deficiencies, and disease control.

Progeny testing enables breeders to locate sires capable of transmitting high producing ability to their offspring (fig. 4). Production and breeding records on 2 1/2 percent of the dairy cows in the United

Figure 4.—Milk-producing ability of cows has been greatly increased by selection of sires capable of transmitting this capacity to their offspring. These 16 daughters of a proved sire produce more milk than their mothers.
States furnish a basis for selecting a limited number of proved dairy sires. The ultimate effect should be a gradual increase in the productive capacity of dairy animals, but because selection itself is a slow process and the transmission of superiority requires time, the improvement will not lead to maladjustment in production. Progeny testing has been limited so far to dairy animals and poultry, although it has been shown that beef cattle, hogs, and sheep can be improved by the same process. Production of meat and other animal products is not likely to be affected by it in the near future.

Cross-breeding of beef cattle, hogs, and sheep has been practiced for a number of years. Probably 20 percent of the cattle in the Gulf coast region have some Brahman breeding, and the percentage is increasing. Cross-breeding of swine is still largely experimental, although 60 percent of the hogs marketed in Chicago in 1938 and 65 percent of those marketed from Iowa were of mixed breeding. A cross-breeding program would have greater advantages for large than for small herds, since with the latter the cost of maintaining breeding stock would offset the advantages of crossing. Under experimental conditions crossbred hogs required 5 percent less time to reach maturity and 5 percent less feed to produce better carcasses than did standard-bred hogs.

Cross-breeding of sheep to produce good-quality mutton lambs from high-producing ewes of wool types is practiced on about 10 percent of range sheep. Relative values of mutton and wool have increased the practice in recent years, but it is not likely to affect production in the range area.

Cross-breeding of poultry has been more effective in broiler production than in other aspects of the industry. Although crossbred stock will probably replace standard stock for specialized broiler production, it is not likely to have a marked effect on the total output of poultry and eggs.

Artificial insemination of dairy cows should give wide distribution to the advantages of progeny testing. Seventeen breeding associations controlling 15,000 cows now practice artificial insemination. The results should be a reduction in the number of males, elimination of the sire as a factor in spreading disease, and improvement in the genetic make-up of herds. Improvements would take place gradually, however, and adjustments could be made as needed. Artificial insemination is feasible for all classes of livestock, but a practical application has been made only in dairy cattle breeding.

Recent developments in feeding have been concerned largely with vitamins and minerals. The correction of deficiencies of minerals such as iodine, calcium, phosphorus, iron, copper, and cobalt has been influential in eliminating some difficulties in livestock production in certain areas. A notable instance is the use of manganese to eliminate perosis in broilers produced in batteries. Determination of mineral and vitamin deficiencies in rations requires study of local feeding conditions. One result of the recognition of these deficiencies, in poultry production particularly, will be an increased use of standardized commercial feeds that contain the necessary elements.

Changes in beef and dairy cattle rations are to be expected with variations in supplies and prices of roughages and concentrates.
In some areas a minor shift to feeding less concentrates has probably increased the use of forage.

**Forage Production**

The acreage of pasture in the United States seems to have increased somewhat since 1930. The total acreage of tame hay has changed very little, an increase in the Southern States being offset by a decrease in the Western States. Alfalfa acreage increased in the North Central States, and that of lespedeza increased particularly in the southern portions of the North Central States. The most important shift has been from clover and timothy to higher-yielding legume hays. This shift to high-producing hay crops, together with the application of lime and phosphate, has increased yields per acre. A shift to higher-yielding hay seems to have been made in the Northeast and the North Central and East Central States. The shift in the Southern and Western States seems to have been to lower-yielding hays. For the country as a whole the influence of the shifts would probably be to increase hay production.

The influence on production of the change in total acreage and in kinds of hay varies among regions. In the North Central States the decrease in hay acreage between 1928–32 and 1938 just about offset the increase in the proportion of high-yielding types of hay, so that total production there as well as in the Northeast has not changed. Increases in hay production amounting to 46 percent in the South and 18 percent in the East Central States may be expected from an increased acreage and changes in kinds of hay which took place between 1928–32 and 1938. Decreases in the acreage of alfalfa in the Western States were sufficient to reduce hay production about 12 percent. If these shifts in acreage of hay represent permanent changes, an increase in livestock numbers will probably take place in the Southern States. In the East Central States the trend toward less use of concentrates and greater use of forage will probably continue. Insofar as the decrease in hay production in the Western States represents a loss of alfalfa because of drought, a recovery of acreage may be expected, and there should be little influence on livestock production.

**Disease Control and Sanitation**

A more widespread knowledge and application of measures to control animal diseases and insects injurious to animals should reduce death losses and, by increasing the proportion of thrifty animals, increase the efficiency with which livestock and livestock products are produced. Although no campaigns on the scale of those carried out in the past against hog cholera, bovine tuberculosis, or tick fever are in prospect, general improvement in control measures may be expected. The bovine-tuberculosis-eradication program has been extended to nearly all counties in the United States. As a result the disease has been practically eliminated. While the program was under way, demands for replacement stock in areas being tested amounted to about 300,000 head annually. This demand for animals has ceased. Moreover, only a negligible number of slaughtered animals are now condemned because of tubercular infection. The decrease has been
gradual since 1917 and therefore will have no appreciable influence on the output of meat.

Testing for Bang's disease and condemnation of infected cows are now largely responsible for the demand for replacement animals. The continuation of this demand, which was for about 175,000 animals in 1938, depends on the continuation of the Bang's disease program. Infectious equine encephalomyelitis has caused severe losses of horses and mules in recent years. Approximately 200,000 cases and 40,000 deaths were reported in 1938. Improved preventive and control measures should reduce losses in the future.

Improved methods of treatment for internal parasites (fig. 5) and such diseases as hog cholera, mastitis in dairy cows, pullorum disease and range paralysis in chickens, and blackhead in turkeys will tend to reduce occasional losses from outbreaks of these diseases and should increase the output of products not only per animal but also per unit of feed and of labor. Cyanide poisoning of livestock in areas where sorghums, Sudan grass, and Johnson grass are used for feed should be reduced either by treatment of affected animals or through breeding sorghums with low hydrocyanic acid content.

The combined influences of these and other developments in the control of diseases and injurious insects cannot be measured, but as more effective measures are devised and as methods of sanitation,

Figure 5.—It takes a big dose of phenothiazine—1 full ounce—to remove worms from sheep. Department zoologists, who discovered the value of this new drug as a livestock medicine, use a balling gun to administer a capsule of it to an infested sheep.
prevention, and treatment become more widely known and practiced, the output of livestock products should be increased. Education regarding control measures is particularly important in regions where parasites have seriously affected livestock enterprises, as in the South and Southeast.

Changes in the volume of production of livestock are more likely to result from changes in supplies of feed available than from changes in production methods. Developments in methods may, however, be essential to successful livestock production in areas like the Southwest, where larger quantities of feed are becoming available.

**EFFECTS ON PRODUCTION**

The preceding discussion of developments most likely to affect agricultural production leads to the conclusion that technical improvements will tend to increase the volume of farm products for sale. Any attempt to estimate probable increases would have to be in simple terms and cover only the major commodities most likely to be affected. Not only will adjustments in actual production on farms be made in the light of the advantages of technical improvements, but they will also be conditioned by changes in agricultural programs and in the relative prices of different commodities. Moreover, the economic situation at any given time may either advance or retard the use of new methods so that estimates of increased production cannot be given definite time limits.

The influence of mechanization on the output of the farm is made primarily by replacing work stock with machinery and thus adding salable crops or livestock products as a result of using for commercial production land that was needed for the production of horse feed. Assuming that there are no changes in present crop acreages, an additional 500,000 tractors on farms could easily release for other uses land now producing 70,000,000 bushels of grain and 2,500,000 tons of hay. One possible adjustment would be a diversion to other crops of the acreage in corn, oats, or hay for horse feed. With favorable prices the acreage of cotton in the South could be increased; otherwise a shift might be made to other possible cash crops. Such crops as sweetpotatoes for starch and other vegetable crops may be suggested; however, the only major shift in sight is in the Corn Belt, where land in corn or oats may and probably will be shifted to soybeans. In the Eastern States some acreage might be shifted to hay, but as the area is deficient in grain production such a shift would probably not be extensive.

Increases in production due to conservation practices are those immediate returns in crop yields which result from the use of cover and green-manure crops. If in the Southern States the soil-improving crops now being grown were to be turned under and followed by corn or cotton, the production of corn and cotton would be increased. Whether such a program as this is carried out will depend on the availability of power and equipment for turning under the soil-improving crop.

Estimates of increased crop yields due to improved varieties may be limited to the supposition that hybrid corn will occupy the major
portion of corn acreage in the Corn Belt and that the increased production on farms will correspond to that under experimental conditions. On that basis, corn production in the Corn Belt could be increased 100,000,000 bushels a year. The subject of improved varieties of small grains is too large a one to consider here in detail, but progress in developing varieties suited to particular conditions and resistant to plant disease promises to eliminate hazards in production and may, as in the case of flax in the Southern States, open new areas for production. Thatcher wheat, for instance, is expected to increase the production of hard spring wheat by reducing damage from stem-rust epidemics.

As already noted, expansion of soybean acreage in the Corn Belt will probably continue. The ultimate acreage will depend on the relative returns from soybeans as compared with those from corn and hogs. A reduction of the acreage in oats and a shift from other hay crops to alfalfa will make room for some expansion of soybean acreage.

Considered by areas, the increases in crop production for which new outlets must be found seem likely to be largest in the corn and livestock areas of the North Central States; yet significant changes may be expected in the Southern States. Mechanization and a shift from horses to tractors provide the basis for crop increases in all areas. Hybrid corn in the Corn Belt and conservation practices in the Southern States should increase production. Unless the cropping systems are altered because of a decreased demand for certain crops and unless there is a shift to cotton in the Southern States or to cash grains in the North Central States, the primary influence of increased crop production would be to increase livestock production rather than to make more crops available for market.

A further reduction of 1,500,000 in the number of horses would make available for cattle and sheep nearly 4 percent of the average annual hay production for the period 1927–36, which would amount to an increase of approximately 5.5 percent of the hay used by cattle and sheep. One influence of the conservation program is to increase acreages of hay and pasture crops. This increase, plus the effects of pasture-improvement programs, should encourage the production of roughage-consuming animals. If, as seems likely in most areas, the production of roughage can be adjusted to the need for it, the influence of crops on livestock production would be in proportion to the probable increases in grains.

Technical developments in animal production and marketing should remove some of the difficulties of raising livestock in the Southern States. There seems to be no reason, however, to expect developments that would change present regional advantages in livestock production. Differences in methods of handling livestock result in some differences in feed requirements for production. If the excess of feed crops were to be used by different kinds of livestock in the same proportion as feed was used in the different regions in 1928–32, livestock production would be increased in all areas.

A large increase in livestock production would be made possible in the South Atlantic and South Central States by the combined influence of mechanization and conservation practices. Prospective increases of available feed would permit an increase of nearly 25 percent in
livestock production. An expansion of the hog enterprise to a point at which byproducts became an inadequate source of feed might result in increased grain requirements per 100 pounds of pork. Some changes might be made in feed requirements for other livestock. However, it has been estimated that an increase in livestock numbers amounting to 31 percent for milk cows, 136 percent for other cattle, 31 percent for hogs, and 54 percent for chickens over the numbers on farms in 1937 would be needed to provide sufficient livestock products to meet even minimum diet requirements for the farm population in these regions.

If livestock could be distributed according to population it would seem unlikely, therefore, that production in the Southern States will increase to such an extent that large quantities of livestock products will be placed on the market. A need for cash income and a concentration of livestock on a small proportion of the farms would lead to some increased sales of livestock and livestock products. A need for cash income might bring about a shift from feed crops to cotton or some other cash crop unless such a shift were prevented by restrictions on the acreages in these crops.

An increase of livestock production in other areas would probably result in a greater quantity of products for market and significant increases in the production of dairy products, meat, and eggs might be anticipated. This increase in areas outside the Southern States would add to the quantities of livestock products placed on the market, which in time might amount to an annual output approximately 5 percent greater than the 1938 production.

**EFFECTS ON MANPOWER NEEDED IN AGRICULTURE**

The saving in the time required for farm work resulting from the use of tractors, tractor equipment, motortrucks, and electrical equipment has reduced the need for workers, particularly in some sections. The trend toward reduction in the number of workers in agriculture seems likely to continue for the next decade at approximately the rate of decline in the last 10 years. If it does continue at this rate, displacement of 350,000 to 400,000 workers will probably take place unless (1) wage rates are lowered to the point where a shift to the use of equipment is retarded and workers lacking alternative employment outside of agriculture are retained on farms; (2) agricultural production is increased to such an extent that workers can be profitably employed regardless of the extent of mechanization; or (3) individuals displaced in areas of commercial production are established in non-commercial areas or on subsistence units in commercial areas. Unless planned direction is given to developments, some adjustments will probably be made along all three lines, and, as in the past decade, many displaced workers will be thrown on relief rolls or will join the stream of migrants in search of work.

In the North Central and Eastern States an increase in the quantity of feed for livestock, if it resulted in an increase in livestock production, would in a measure offset the saving in labor and might

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even increase labor requirements in some areas now mechanized. It seems likely, however, that there will be a gradual trend toward a clearer differentiation of commercial and subsistence farming and less demand for seasonal hired labor.

A shift in the power used on farms and in the type of farm organization in the Southern States would probably release a large number of agricultural workers, and a shift to livestock and crops requiring less labor than cotton would not increase the need for labor. Consequently, the displacement of labor by machinery may be more serious in the South than in other areas.

**CAPITAL REQUIREMENTS IN AGRICULTURE**

Substitution of mechanical power and equipment for hand labor will tend to increase the capital invested in the farm plant. Changes in equipment are unlikely to affect total investments, however, for in 1930 the value of land and buildings made up 84 percent of the value of farm property. Machinery represented only 5.8 percent of the total valuation. Moreover, since motortrucks, tractors, and automobiles reduce the number of horses and displace horse equipment, they do not increase farm investment in proportion to their cost. The investment in tractors and equipment on a 950-acre mechanized cotton plantation would be approximately the same as the investment in animals and equipment for operating with mules. On small farms mechanization would probably increase the investment to some extent, depending on the number of work animals displaced.

Mechanization in the North Central States apparently increased the investment in equipment and power. On farms of 135–174 crop acres on which horses were used, the investment in animals and equipment in 1937 averaged $1,640; on farms of the same size on which general-purpose tractors were used, the investment averaged $2,192. As these figures are based on current values, part of the difference may be accounted for by the tendency to have newer and more expensive equipment on farms using tractors, and by the likelihood that some horse-drawn equipment was still carried in the inventory.

Although mechanization of farms will require some increase of investment in working capital, the increase is not likely to be more than 25 or 30 percent greater than that required for nonmotorized farms. In any case it would represent a small proportion of the total investment in the agricultural plant.

More important than the actual increase in the investment in equipment for the ordinary farm is the fact that a given set of machines is most economical with a certain acreage. With less acreage, the cost of machinery is relatively higher. At the same time, the small-scale operator must invest in a complete set of machines for a certain operation, since the equipment cannot be divided. This may retard some beginners unless they receive aid to finance purchases.

New varieties of crops and new cropping practices require little or no additional investment, although such items as structures for soil conservation may necessitate an outlay for rented equipment or for

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construction. Such outlays would be in the nature of permanent investments.

If livestock numbers are increased, the farm investment in animals other than work stock would be increased and some additional outlay for buildings and equipment would be needed on some farms.

The evidence at hand points to increased capital needs for agriculture, of not more, however, than 25 percent of the working capital and 5 percent of the total investment. Whatever increase is made in the size of commercial farms would increase the required investment per farm, and this would make it more difficult for a farm laborer to acquire sufficient capital to begin tenant operations. On the other hand, the establishment of subsistence farms with smaller capital requirements would tend to prevent a large increase in the average investment per farm for the country as a whole.

SIZE OF FARM UNITS AND FARM ORGANIZATION

Developments related to farm power and equipment seem most likely to affect the number of crop acres in a farm unit. Farms have changed in size through inheritance, sale of land, and from other causes; but the tractor- and power-operated equipment have made an increase in size possible, and in fact have initiated pressure in that direction for the simple reason that tractors can do more work in a given time than horses. When a farmer buys a tractor for a farm too small to utilize it effectively, he will probably want to increase his crop acreage, and in many cases he will find the means to do it.

Adjustments to mechanization occur slowly. There are still adjustments to be made in response to the mechanization that has occurred in the past, and adjustments to future mechanization can be expected. Statistical analyses of changes in the average size of farms in the United States have been inconclusive. Average figures have been obtained by including all types of farms, and reductions as well as increases in size of farms. Thus opposing tendencies cancel each other. It seems quite probable that separating from the mechanized farms the small nonmechanized farms belonging to the self-sufficing, part-time, and sharecropper groups would show that there has been an increase in the size of mechanized farm units.

The appearance of the small tractor in the last year or so introduces a new factor. The somewhat lower costs of purchase and operation of this small machine as compared with those for the larger tractor will tend to bring further mechanization onto the smaller farms. The small tractor may have a tendency to “freeze” the size of the newly mechanized small farms. On the assumption that the small tractor will fit into the small-farm organization economically, there would be less pressure to increase the size of the farm holding beyond the working capacity of the tractor. Increased holdings would soon require more power, and any increase in size would therefore be made from other motives than the pressure of mechanization alone.

The introduction of the small tractor into the Corn Belt should help the small farmer to survive and would therefore aid in checking consolidation of small farms. The small tractor will probably have very little effect in the small-grain States. In the North Atlantic
States it would probably extend mechanization with little effect on the size of holdings.

In the plantation areas of the South the increasing use of tractors, with the accompanying changes in farm organization, is displacing many sharecroppers. This does not, however, represent any real change in the size of holdings; it merely reflects the extension of operations by the owner or large lessor to a greater portion or to the whole of the plantation. In other than plantation areas it appears probable that mechanization will tend to increase the actual size of farms, although the change will be made very slowly.

It is to be expected that the agricultural adjustment programs, the change in emphasis in the various livestock and crop enterprises, and the increasing use of mechanical power will give rise to further changes in the organization of farms. Some changes in kinds of specialization characteristic of various regions might easily follow. For example, the development of more drought-resistant and earlier maturing grain sorghums adapted to areas of Nebraska and South Dakota may increase the production of livestock, replacing cash-grain production. The further development of the quick-freezing process appears likely to diminish the advantage of specialized production of fresh small fruits and vegetables in areas that rely upon the off-season demands of the northern markets. The Pacific Northwest is looking toward the production for quick freezing of small fruits, peas, lima beans, brussels sprouts, and other products. Any shift in production northward and any reduction in the market for fresh vegetables, particularly during the winter, will intensify the economic problems of the rural South.

**EFFECTS ON FARM COSTS**

In general, technological developments are adopted and utilized because it is hoped that the expected returns will exceed the costs. It is true, however, that some equipment will be adopted because of its greater convenience, and that the farmer may be willing to incur an increase in cost or suffer a decrease in net income to obtain the convenience. The extent to which income can be sacrificed has definite limits, of course, for such a sacrifice carried to an extreme would lead to insolvency.

Although a technological development may lower the cost per unit of product, a change in the nature of the costs incurred may be highly effective during periods of economic adversity in creating pressures upon the cash income of a farm. Those farmers who have mechanized their operations usually have increased the relative importance of their cash operating costs. Mechanization also usually increases the total investment in equipment somewhat over that required for doing work with horses.

The cash expenses required for gasoline, oil, grease, and repairs in the operation of tractors and motor vehicles cannot be deferred during periods when prices and cash income are low or when the weather has reduced cash income. The small farmers and plantation operators who mechanize will find themselves more dependent upon commercial farming, and dependence on the market renders them more susceptible to financial difficulties during adverse periods.
During these periods the farmer who uses horses is in a relatively favorable position because much of the operating cost can be furnished by the farm itself in the form of feed and pasture.

During periods of low income, farmers using or planning to increase their use of fertilizers will adjust their purchases by reducing the amount per acre, by decreasing the acreage fertilized and put into production, or by foregoing any fertilization until more favorable conditions return. The fact that the prices of fertilizers and of tractor supplies are less variable than the prices of agricultural products tends during depression periods to intensify the financial difficulties of farmers using them.

**TENURE AND TECHNOLOGY**

Technological developments in agricultural production are placing some barriers in the path of those seeking farm ownership. Any development that increases the investment required makes it more difficult to acquire ownership. Any development that tends to displace farm operators and laborers adds to the ranks of those who are trying to obtain a foothold at the lower levels.

The investment required for mechanization is small compared to the total farm investment. The appearance of smaller power units and equipment with lower first costs, the growth of a used-tractor market, and provisions for financing have aided the farmer in acquiring mechanical equipment. Nevertheless, the burden of the investment becomes proportionately greater at lower income levels. It is also more difficult for individuals at these levels to obtain credit to buy equipment.

Efforts to enlarge the acreage operated have adverse effects upon individuals in the weaker tenure groups. Larger units mean that a smaller number of operators are actively engaged in production. The displacement of farm operators through the consolidation of farms adds to the number seeking farms. The present surplus of prospective tenants, resulting from both technological displacement and the backing up of farm population, increases competition for farms and leads ultimately to higher rental rates. This competition has already altered the straight third-and-fourth-share rent system in the cotton areas of Texas. Tenants are being charged for pasture formerly provided without cost; cash rents are exacted for dwellings and for land used to grow feed crops. It seems reasonable to expect that this competition for farms will be prevalent in the South as mechanization progresses. Another possible development may be the migration of surplus tenants from southern areas into other areas where they will compete with resident tenants for land.

The change in tenure relationships will probably be most striking in the South. Mechanization enables a plantation operator to dispense with sharecroppers by doing more work with his tractor and tractor equipment and by hiring the necessary labor. Such sharecroppers have the alternatives of competing for other tracts of land or of accepting the income that can be derived from wage work.

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Technological developments in agriculture seem to widen the differences in income between wage laborers or sharecroppers and owner-operators or the more well-to-do tenants.

COMMERCIAL AND NONCOMMERCIAL FARMING

The less productive half of the farms reported by the census in 1930 sold only 11 percent of the farm products entering commercial channels in 1929. Not all of those farms are noncommercial, for many sharecroppers and small farmers who produced less than $1,000 worth of products depended almost entirely upon their cash income for the necessities of life.

Although distinctions between commercial, self-sufficing, and part-time farms must be made arbitrarily on the basis of certain ranges of farm incomes, it is convenient to divide farm operators according to their dependence for a living on the income derived from the sale of farm products. A self-sufficing farmer may obtain most of his living from his own farm products. A part-time farmer attempts to supplement his farm income with nonfarm earnings. A commercial farmer may use more of his own products for the family than a low-income operator produces altogether; yet his total sales of products may be large in comparison with the amounts used on the farm.

If a large number of sharecroppers are released from agriculture in the South they may have no opportunity to engage in commercial farming as tenants. Their opportunities are limited to subsistence farming, part-time farming, wage labor, or relief. Although the list of jobs available to part-time farmers is extremely varied, it is doubtful that part-time employment offers much possibility of relieving the expected displacement. Further, migrants leaving the cities for rural areas for the purposes of residence and small-scale farming would offer competition to displaced sharecroppers.

It would seem, on the whole, that under current conditions of industrial unemployment, insufficient demand for a number of farm products, and a surplus agricultural population, mechanization will tend to increase subsistence farming wherever there is a possibility of establishing such farm units.

An increase in subsistence farming as well as in the mechanization of commercial farming would indicate that one part of the farm population is becoming more dependent upon industry and the national economy as a whole, while the other part, to the extent that it actually becomes self-sufficient, is gradually becoming less dependent on other economic groups. Commercial agriculture is so organized that it must sell to other groups in order to carry on production. Mechanization and other developments that have increased the dependence of farmers on cash income have also increased their vulnerability to changes in the economic system.