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Assessing U.S. Corn* Production Technology

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Introduction

No two farmers produce corn under identical circumstances. Yields and production practices vary both between farms and between production regions. Yet there are important similarities in the technologies used by most farmers. This article briefly examines: (1) historical changes in commercial corn production and utilization, (2) the important production technologies involved, (3) yield projections to the year 2000, and (4) potential vulnerabilities of the current corn production system.

Historical Perspective

The acreage of corn harvested for grain peaked at more than 97 million acres in 1932, then dipped to below 60 million acres in the 1960s, and has remained at more than 70 million acres since 1976 (Figure 1). Currently corn acreage makes up about 22 percent of the acreage of principal crops. In 1978-80 more than 70 percent of U.S. corn was produced in the North Central Region.

Figure 2 shows the dramatic increase which has occurred in average U.S. corn yields since 1930. From 1930 to 1980 yields increased by an annual average of 1.7 bushels per acre. Despite some leveling off in the 1970s, the annual increase from 1945 to 1980 was 2.1 bushels. Figure 2 also illustrates the significant variation in year-to-year yields caused mainly by fluctuations in weather but also by pests and economic factors.

Figure 3 shows the changes in corn use since 1945. Domestic feed has remained the largest single use, but exports have increased dramatically since the early 1970s. Industrial use, although still small relative to feed use, has also increased steadily in recent years. Not only is more corn being used, but the way corn is used has also undergone major change. In 1945 almost 80 percent of corn was used on the farm where it was produced. This percentage had fallen to less than 38 by 1979. This major shift in use, together with economic pressures on farmers to increase farm size and production volume, has spurred the development of new technologies for rapid harvest, field shelling, and artificial drying. The old system of harveting ear corn and air drying it in the crib is no longer feasible for most producers.

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*"Corn" in this article refers to corn harvested as grain.

Figure 1. U.S. Corn Acreage Harvested for Grain, 1930-80.

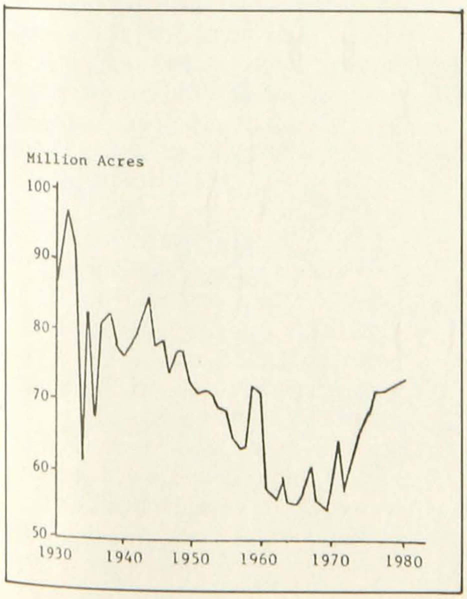


Figure 2. U.S. Corn Yields, 1930-80.

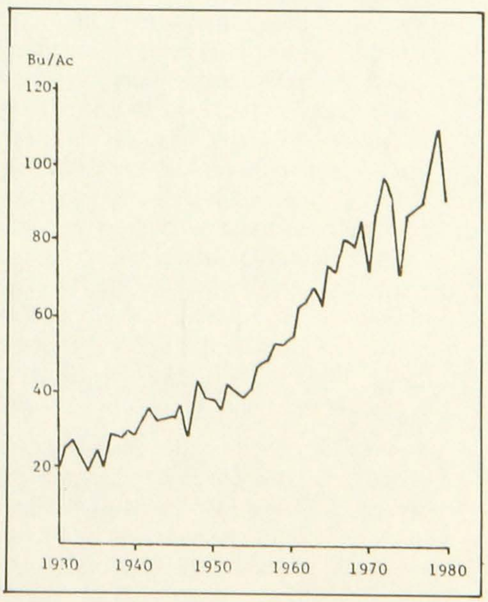
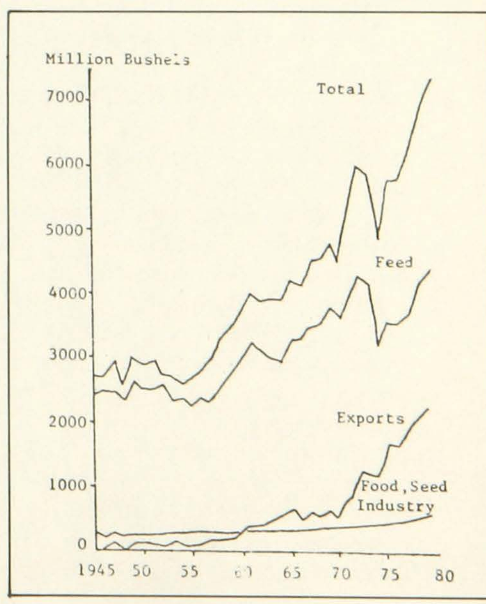


Figure 3. Corn Use in U.S., 1945-80.



Important Corn Production Technologies

In the following section we highlight some of the many different technologies used by corn producers.

Conventional Plant Breeding: The first lines of hybrid corn became available in the 1920s. Adoption by farmers was rapid, with the transition from open-pollinated varieties being virtually complete in major commercial corn production areas within 10 years. Since then, the breeding of newer and better hybrids, together with increased plant population rates, has added an estimated 1 bushel per acre per year to corn yields. In addition to yield increases, new hybrids are a low-cost source of much disease and insect resistance. Also, early-maturing hybrids have made corn production profitable in some areas where short growing seasons had severely limited production in the past.

Almost all corn hybrids used in commercial production are now private. The corn seed industry spends an estimated $26 million annually for research and development and realizes about $1 billion in sales of hybrid seed. The public sector also contributes importantly via basic research, technical training and development of inbred lines.

Fertilizer Technology: The contribution of chemical fertilizers, particularly nitrogen, to corn yield increases is broadly documented. Between 1954 and 1980 average U.S. corn yields increased by an estimated 36 bushels per acre from nitrogen fertilizer (N) together with supporting applications of phosphorus (P_2O_5) and potash (K_2O). By 1980, 96 percent of corn acres received applications of N, 87 percent received P_2O_5, and 81 percent received K_2O (at average per acre application rates of 130 pounds of N, 66 pounds of P_2O_5, and 87 pounds of K_2O). Rapid adoption of fertilizer was abetted both by resulting high yields and by a decline in the real price of plant nutrients during the 1950s, '60s, and early '70s. Yield increases for irrigated corn were even greater, which played a major role in the increase of irrigated acres.

Our assessment indicates that the annual yield increases attributable to N dropped substantially in the 1970s compared to the 1950s and 1960s. This occurred because by the 1970s most corn acres were already receiving fertilizer applications and average application rates had reached high levels. At application rates in the 1950s, an additional pound of N was estimated to contribute more than five times as much to corn yields per acre (.8 bu.) as did an additional pound at application levels in the 1970s (.15 bu.). Thus, at current high application rates, the major yield increases from fertilizer appear to have peaked, and future increases will be much smaller.

Soil Moisture Modification: Both irrigation and drainage have been of major importance in increasing corn production.

An estimated 11.3 million acres of corn were irrigated in 1980 and probably increased annual corn production capacity by more than 700 million bushels. In addition, year-to-year variability in production has probably been reduced by 300 to 400 million bushels. Development of light-weight aluminum tubing in the 1940s and the labor-efficient center-pivot technology in the 1950s provided incentives for major increases in corn irrigation. In general, irrigation has been very profitable on the coarser soils on the western and northern fringes of the Corn Belt where yield increases of 60 to 120 bushels per acre are common. Irrigation is a more marginal economic option, however, on the fine- to medium-textured soils of the Corn Belt proper.

The primary issues in irrigation economics are high energy costs, and, in some areas, declining or inadequate water supplies. As a result, researchers both in industry and in the public sector are focusing on increased efficiency in water and energy use.

In drainage technology, the development of small diameter plastic tubing and its installation with trenchless laser-leveling equipment has reduced real costs of subsurface drainage systems in recent years. Labor costs, particularly, are much lower than with clay or concrete tiles installed in trenches, although the latter technology is still effective and in extensive use. Overall, drainage on an estimated 30 million acres of land used for corn probably adds about 1.2 billion bushels to annual productive capacity.

Pest Control: With present control practices, losses due to disease are perhaps 10 to 14 percent of the total crop, with 12 percent loss due to insects. Current control practices contain losses from weeds to within generally acceptable levels.

Almost all corn acreage now receives herbicide applications, and an estimated 52 percent receives insecticide. Three insects (rootworms, European corn borers, and the black cutworm) are major pests. Increased use of crop rotation and scouting could reduce insecticide use substantially from its current level of 36 million pounds of active ingredient. Decreasing herbicide use from its current level of 209 million pounds would, however, require additional mechanical tillage for weed control. This, in turn, would increase soil loss due to erosion.

Modern corn herbicides are, in general, strongly adsorbed on soil, and they are non-persistent. They are highly toxic to humans. New insecticides (mainly organophosphates and carbamates) are toxic to humans and other non-target organisms, but they are less persistent than their predecessor insecticides (organochlorines). No known environmental hazards of these pesticides have been determined to exist over wide areas.

Among the needs for improved management of pest control technology are those of: (1) improving biological control mechanisms, (2) inventorying effective chemicals, (3) adopting legal and administrative procedures to move quickly against unforeseen pest outbreaks, and (4) inventorying appropriate plant genetic materials.

Tillage Practices: In 1980 approximately one-third of total U.S. corn acreage was reduced-tilled, and no-till was practiced on about 4 percent. Compared to conventional tillage, reduced tillage saves on farm operating costs (by an estimated $5.50 per acre, on average), while also reducing soil losses due to erosion. No-till technology, although requiring high-level management skills to avoid yield reductions, can reduce operating costs and soil erosion even more.

In 1977, 33 percent of the U.S. corn land was estimated to have annual erosion rates in excess of five tons per acre. Thus, modifying current corn production technology to reduce soil loss is critically important. But the relationships between soil loss and productivity are, at best, poorly documented. Indications are strong that increased use of conservation tillage and no-till, together with contouring and terracing on some steeper soils, would control excessive soil loss on almost all corn acres.

Crop Rotation: During the 1930s, corn was usually grown in rotation with hay and small grains. This was necessary to ensure adequate nitrogen for the corn, and because on most farms roughage feeds had to be grown for livestock. Soybeans were not grown extensively in this earlier period.

Two subsequent developments altered the rotational pattern: (1) the availability of cheap fertilizer nitrogen, which substituted, to some extent, for legume crops; and (2) widespread adoption of soybean growing in traditional corn-growing areas. Note that these soybeans did not displace corn, in that corn acreage remained fairly constant, but they did replace hay and small grain on many acres.

Thus, in the Corn Belt, the crop now most commonly grown in year-to-year rotation with corn is soybeans. Forty-eight percent of corn acreage is grown in this rotation. Twelve percent of corn follows a previous corn crop, but is not "continuous" corn, while another nine percent of corn is continuous. At moderate fertility levels, it appears that corn yields following soybeans are about 15 percent higher than corn yields following corn. A shift from corn-corn to corn-soybeans is usually very profitable.

Many cash-crop farmers have now made large investments in specialized planting and harvesting machinery for row crops and in storage-handling-drying facilities for grain. These "structural" changes mean that only a dramatic fall in the relative prices of corn and soybeans would entice these farmers back to growing hay. A consequence of the high incidence of row crops, however, has been the realization of increased soil erosion hazards.

Mechanical Technology: One of the most pervasive changes in corn production over time has been the machanization of seed-bed preparation, planting, weed control, and harvesting. The overriding incentive for farmers to mechanize has been to reduce labor requirements and expand acreage in order to increase income. Primarily because of mechanization, labor requirements in corn production have been reduced seven-fold since World War II to the 1975-79 average of only 3.6 hours per acre. The mechanization process has also carried high capital costs, however, and it appears likely that further mechanization, aimed solely at saving more labor, merits rather low social and economic priority.

Among the benefits of mechanization have been earlier planting dates, more timely field operations, and earlier harvest at higher grain-moisture levels. Earlier harvest alone has probably reduced total field losses by more than half. Moreover, mechanization has enabled farmers to increase plant density, reduce tillage, distribute fertilizers and herbicides efficiently, and shell corn in the field.

On-Farm Drying: Before the introduction of on-farm drying technology, excessively wet corn for on-farm use often had to be fed promptly to livestock to avoid spoilage. Moreover, much of the stored ear corn had to be fed before the advent of humid and hot summer weather.

As recently as 1962, almost 80 percent of the corn in the Corn Belt was harvested as ear corn by use of mechanical pickers. This resulted in field losses ranging from 3 to 11 percent, depending on length of the harvest period and grain moisture content at harvest. Losses were particularly high for those farmers with a large acreage who had to extend their harvest period beyond that suitable for harvesting under near-optimal conditions. The development and use of large-capacity, rapid harvesting equipment which both picked and shelled corn in the field, coupled with the need to meet stringent moisture requirements in order to sell corn or store it in the shelled form for extended periods, pressured many farmers to adopt on-farm corn drying technology.

Other benefits of drying include more time for fall plowing (permitted by early harvest) and the fact that longer-growing, later-maturing hybrids can be more widely used. Longer-growing hybrids have rather consistently outyielded earlier-maturing varieties (which, because of their earlier maturity, can dry naturally in the field). Farmers have preferred to plant the higher-yielding, later-maturing varieties despite their greater requirements for artificial drying.

By the early 1970s the shift to use of field picker-shellers and corn head-on-combines for harvesting had been largely completed in the Corn Belt. For example, in 1973, about 80 percent of the corn acreage in Illinois and Indiana and about 70 percent in Iowa was harvested with this equipment. Simultaneously, farmers were widely adopting artificial corn-drying technology, and by 1978 more than two-thirds of the farms harvesting corn in the Corn Belt used artificial drying.

The major issue surrounding artificial drying is the high cost of the fuel required by this technology, but artificial drying will remain profitable even at higher energy prices. Moreover, prototype equipment is now available which uses waste materials, principally corn cobs, as an energy source for drying. Thus, it appears likely that alternative drying technologies, together with energy conservation, can reduce the heavy reliance on liquid fuels.

The Emerging Biotechnologies: A good deal has been written about the substantial impact which genetic engineering may have on crop yields. To assess this and other emerging biotechnologies, we surveyed leading scientists working on corn-related applications of photosynthetic enhancement, plant growth regulators, cell and tissue culture, gene transfer at the cellular level, and biological nitrogen fixation.

Response from this survey indicated that, although one can expect significantly higher yields from the emerging biotechnologies (perhaps approaching two bushels per acre per year by the year 2000), it will probably be well into the 1990s before their impact on commercial corn yields is significant. Nevertheless, investments must be made in these emerging biotechnologies if they are to contribute substantially to increase yields and reduced costs in the future.

Contrary to the contention of some, the emerging biotechnologies *are not* a substitute for conventional plant breeding, but are expected to generate improved plant capabilities which will then be incorporated into conventional breeding programs.

Management of Technologies: The complexities of current corn technologies have resulted in the development of a broad range of computerized decision aids, agricultural consultant services, and both human and electronic monitoring systems for technology management. They include, for example, variety, plant population, and row-spacing recommendations; soil sampling and testing; fertility recommendations; stand evaluations; insect, disease, and weed evaluations; pest control recommendations; irrigation scheduling; and recommendations for harvest schedules and drying systems. These and other aids for technology management can be expected to grow in importance and to reduce the gap between experimental yields and those realized by farmers. In addition, improved timing of pesticide and water use should reduce application rates and thus be ecologically positive. Rapid adoption of these and other technology management procedures is expected within the next 3 to 5 years.

Yield Projections to 2000

Yield increases resulting from technology applications in corn production are expected to total almost 40 bushels per acre (two bushels per year) between 1980 and the year 2000. The annual yield increase rate projected for the 1980s (1.5 bushels per acre) is about one-third below the realized increase rate for 1954-1980. This decline is mainly the result of the continued declining impact from additional nitrogen fertilizer. Technology trend (mainly associated with improved hybrids) is expected to add about 1 bushel per acre annually and improved technology management about .2 to .3 bushels. By about 1995, the contribution to annual yield increases from the emerging biotechnologies is expected to exceed 1 bushel per acre. These projections assume about the current levels of acreage and research funding for corn.

Potential Vulnerability of Future U.S. Corn Supplies

Corn production plays an important role both in generating farm income (about $20 billion in both 1979 and 1981) and in supplying the needs of domestic and foreign users. As a result, considerable concern is expressed about the vulnerability of this production system to major shocks such as disease, weather, resource shortages, price changes, and environmental impacts. In the section which follows we provide a brief assessment of this vulnerability.

Weather: Irrigation, drainage, and other technologies have reduced the vulnerability of corn yields to weather. Yet, after adjustment for other factors, weather still causes an average annual variability in corn yields of about 5 bushels per acre (350 to 400 thousand bushels on a crop of 70 to 80 million acres) and as recently as 1974 the yield was about 16 bushels per acre (or 1.2 billion bushels total) below trend. Thus, adverse weather can still generate major shocks to the corn production system.

Genetic Resources: Although some increase in genetic diversity of corn has probably occurred since 1970, a disease or insect attack of the magnitude of the 1970 corn blight could still occur. Genetic resources in breeding pools and gene banks appear adequate to hold such setbacks to a year or two in duration, but the total world supply of genetic resources is diminishing. This poses a potential threat to corn supplies in the long run, and corrective action is badly needed to inventory and preserve existing germ plasm.

Environmental Impacts: In the short term, environmental considerations do not pose major threats to the supply of corn. In the long term, continued soil erosion from water runoff could pose a serious threat, if unchecked. However, changes in tillage practices together with contouring and terracing can, even now, control most excessive soil loss. There is a need to find effective ways to induce farmers to adopt these practices.

Nutrient and toxic pollution are other undesirable effects of current technologies. Nitrate pollution of drinking water supplies is a local problem needing correction in some areas of coarse soils and heavy irrigation. Among the chemical technologies, only the potential inability to use effective herbicides would pose a substantial threat to aggregate corn supplies, and this seems unlikely.

Resource Supplies and Prices: Of the important resources used in corn production, only water and energy (including agricultural chemicals, with their high-energy embodiments) appear vulnerable to short supplies in the near-term.

The energy-intensiveness of corn production has increased on a *per acre* basis but not on a *per bushel* basis since 1945. Fertilizer, irrigation, and drying are the energy-intensive technologies now used in corn production. Of these, only deep-well irrigation appears seriously threatened by "high-priced" energy. Even in this case, a combination of energy conservation in current uses, adoption of more energy efficient technology, and a shift to new shallower-well water supplies will likely postpone the vulnerability of aggregate corn supplies to energy prices until the year 2000.

In the near future, water resources will likely limit corn production below current levels only in the southern plains. This decline will be more than offset by expanded water use for irrigating corn in other areas, particularily in Nebraska. Though competition from non-agricultural water uses is rising rapidly, because of the location of irrigated corn acreage, it does not appear that this competition will be intense before the year 2000. This situation could change, however, with an extended drouth in the central U.S.

Farm Structure: Concern has been expressed that large farms (particularly corporate farms) may make supplies of farm products vulnerable. Although this may well be a legitimate concern in the long term, aggregate corn production does not appear to be vulnerable in the short term. Only a small portion (about 5 percent) of U.S. corn production is now from farms with annual sales of $500,000 or more, and there is little evidence that this will change much in the near future.

Production Costs and Profits: Some corn producers have borrowed heavily to invest in durable capital (land, machinery, irrigation equipment, and drying and storage facilities) for corn production at high prices. High interest rates and low real product prices have created problems for them. Their current and future financial solvency is vulnerable. This financial vulnerability for individual producers might translate into lower land prices, but it is not a near-term threat for aggregate corn production. As long as someone can produce profitably, corn land will likely continue in production under a high level of technology, even though individual producers experience financial problems severe enough to create business insolvency. Remaining producers have a strong incentive to absorb any cropland which becomes available to them.

Over time, the real net return for corn producers has declined dramatically (several-fold since World War II) on both a per-bushel and a per-acre basis. As a result, if U.S. corn production is to remain economically competitive in the long run, ways must be found to either decrease real costs or increase real corn prices, or both.

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