Chapter 3

Analysis of Potential Impacts of Using Agricultural Commodities as Industrial Raw Materials

Despite claims that new industrial crop and use development will result in many benefits for society, few studies have attempted to examine whether this is, in fact, the case, and if so, what are the magnitudes of the impacts. Because of the lack of needed information, a definitive answer cannot yet be given. However, extrapolations from a few existing studies can be made, and market size and market trends for some products can be roughly estimated. Studies that examined the rural employment impacts of expanding agricultural production in the 1970s provide a framework to examine the potential employment impacts that could result from new industrial crop and use development. Analysis of technology adoption by farmers can yield insights on the potential impacts on different size farms. And, potential environmental impacts can be discussed. An examination of these issues follows.

Rural Development

Proponents of the commercialization of new industrial crops and uses for traditional crops indicate that these new technologies will revitalize rural[1] economies in two major ways: by changing farm income and number; and by creating jobs related to resource use, the processing of the raw commodities, and the production of new products. Increased farm income can have a multiplier effect, allowing farmers to spend more money in the community. Sustained income increases could also increase farmland prices and hence the tax base of many rural communities. Increased levels of production require increased inputs, transportation, and storage, and would foster the associated industries. Development of new industrial crops and uses of traditional crops could also have an impact on job creation via the construction, expansion, or fuller utilization of processing and manufacturing facilities.

Impacts of Changing Farm Income and Numbers

The crisis within the agricultural sector in the 1980s is a reflection of decreased farm income, declining asset values, and high debt load. Total farm-family income in the first half of the 1980s remained relatively stable and did not decline from 1970s levels, despite low commodity prices, because increasing off-farm income helped compensate for decreased farm income (table 3-1).[2] The value of farm assets, however, declined significantly. Lower land values decrease local government revenues. Development of new industrial markets for commodities might help to increase farm land values since these values depend in large part on future market and income growth expectations (37).

Table 3-l—Farm Family Income (dollars)

Year	Net farm income[a]	Off-farm income	Total farm family income
1960	2,729	2,140	4,869
1970	4,869	5,974	10,843
1975	8,785	9,481	18,266
1980	9,233	14,263	23,486
1981	8,378	14,709	23,087
1982	9,997	15,175	25,172
1983	10,074	15,619	25,693
1984	11,345	16,265	27,610
1985	13,881	17,945	31,826

[a]Before inventory adjustment.

SOURCE: Dorm Reimund and Mindy Petrulis, U.S. Department of Agriculture, Economic Research Service, "Performance of the Agricultural Sector," *Rural Change and the Rural Economic Policy Agenda for the 1980's: Prospects for the Future,* September 1988, pp. 77-102.

[1]Rural and nonmetropolitan are used interchangeably throughout the text. Nonmetropolitan counties are defined as those not in Metropolitan Statistical Areas (MSA), which include core counties containing a city of 50,000 or more people and a total area population of at least 100,000. Additional contiguous counties are included in the MSA if they are economically and socially integrated with the core county. Based on the 1980 Census of Housing and Population there are 2,357 nonmetropolitan counties. (Based on the 1970 Census, there were 2,443 nonmetropolitan counties). Source: Thomas F. Hady and Peggy J. Ross, U.S. Department of Agriculture, Economic Research Service, "An Update: The Diverse Social and Economic Structure of Nonmetropolitan America," Staff Report No. AGES 9036, May 1990.

[2]Average farm-family income did not substantially change, but there were differences in subsectors of the farming population. Small, commercial-scale operations with gross sales of $40,000 to $150,000 were most negatively affected.

While farm-family income remained relatively stable, farm[3] numbers continued to decline throughout the 1970s and 1980s (table 3-2). Impacts of declining farm numbers are difficult to ascertain. In general, the land is bought by other farmers and continues to remain in production, so that total agricultural output does not significantly decline. However, declining farm numbers may negatively affect community employment levels. Multiplier effects for agriculture are generally estimated to be between 2.5 and 4, but these effects are for the total economy and do not consider location. Studies that have analyzed local rural area impacts from changes in agriculture estimate multiplier effects of less than 2. These estimates imply that in farming dependent counties,[4] for every one farm producer that leaves the industry, up to one additional job maybe lost in the community (27).

Impacts resulting from changes in farm number, income, and land values will be highest in areas that are most dependent on agriculture as a source of income and employment (table 3-3). Approximately 22 percent of nonmetropolitan counties are farming dependent, and an additional 23 percent are farming important.[5] These counties are concentrated in the Plains Region (North Dakota, South Dakota, Nebraska, Kansas, western Oklahoma, and northern Texas) with some spillover in neighboring States. Between 1979 and 1985, total employment declined by 0.3 percent in these counties (6,15,51).

Development of new uses for traditional commodities would most affect the 17 percent of all nonmetropolitan counties with at least 50 percent of farm sales from corn, soybeans, wheat, cotton, or rice (i.e., agricultural-export-dependent counties). About 7 percent of all nonmetropolitan counties are both agricultural dependent and agricultural-export dependent.[6] These counties are concentrated along the Canadian border in the Northern Plains Region and in the Central Corn Belt and Delta Region (16).

Table 3-2—Farm Numbers

Year	Number
1960	3,963,000
1970	2,949,000
1980	2,433,000
1981	2,434,000
1984	2,328,000
1986	2,214,000
1989[a]	2,172,920

[a]Preliminary estimation obtained from U.S. Department of Agriculture, *Agricultural Statistic 1989*

SOURCE: Dorm Reimund and Mindy Petrulis, U.S. Department of Agriculture, Economic Research Service, "Performance of the Agricultural Sector," *Rural Change and the Rural Economic Policy Agenda for the 1980's: Prospects for the Future,* September 1988, pp. 77-102.

Development of new uses could result in potentially positive or negative impacts in these regions, depending on how the new use development affects the price of the traditional crop grown in the region.

Rural Employment Potential in Agriculturally Related Industries

Studies that explicitly evaluate the rural employment potential of new industrial crops and uses of traditional crops are not available. However, many of the impacts of commercialization of new crops and uses will result from increased demand for agricultural commodities. During the 1970s, U.S. agricultural production increased rapidly in response to increased world demand for food and favorable economic conditions. The effects of increased production on rural employment in agriculturally related industries provides insight into the potential employment impacts in these industries of increased industrial demand for agricultural commodities.

Between 1974 and 1981, U.S. agricultural production expanded by 45 million acres of crops harvested (table 3-4). Employment in rural agriculturally related industries also increased during this

[3]A farm is an establishment that sold or would normally have sold $1,000 or more of agricultural products during the year.

[4]Farming dependent counties are defined as those counties for which farming contributed a weighted annual average of 20 percent or more of total labor and proprietor income over a 5-year time period. Based on the years 1975 to 1979 and on the 1974 nonmetropolitan county definition (2,443 counties), there were 716 farming dependent counties. Using income from the years 1981, 1982, 1984, 1985, 1986, and the 1983 definition of nonmetropolitan counties (2,357 counties) there were 512 farming dependent counties. Source: Thomas F. Hady and Peggy J. Ross, U.S. Department of Agriculture, Economic Research Service, "An Update: The Diverse Social and Economic Structure of Nonmetropolitan America," Staff Report No. AGES 9036, May 1990.

[5]Farming important counties are defined as those counties for which farming contributed a weighted annual average of 10 to 19 percent of total labor and proprietor income for a 5-year time period. Using income from 1981, 1982, 1984, 1985, 1986, there were 540 farming important counties. Source: U.S. Congress, General Accounting Office, *Farming and Farm Programs: Impact on the Rural Economy and on Farmers,* GAO/RCED-90-108BR (Gaithersburg, MD: U.S. General Accounting Office, April 1990).

[6]These calculations were based on the definition of farm dependency using income data from 1975 to 1979 and on 1982 farm export levels.

Table 3-3-Share of Total Employment in Agriculturally Related Industries, 1984
(in percent)

	Us.	All nonrnetro counties	Export dependent counties	Export/farm dependent counties	Nonmetro employment (million)[a]
Total	19.5	31.3	32.4	46.0	6.22
Farm sector	4.1	13.6	15.8	29.9	2.68
Farm inputs	0.4	1.1	1.5	2.7	0.21
Processing/marketing	3.2	5.8	4.7	5.2	1.15
Wholesale/retail	9.5	8.7	8.1	6.7	1.73
Indirect	2.2	2.2	2.3	1.6	0.45

[a]Obtained from Dorm Reimund and Mindy Petrulis, U.S. Department of Agriculture, Economic Research Service, "Performance of the Agricultural Sector," *Rural Change and the Rural Economic Policy Agenda for the 1980's: Prospects for the Future,* September 1988, pp. 77-102.

SOURCE: U.S. Department of Agriculture, *Agricultural OulYook,* September 1988.

Table 3-4--U.S. Agricultural Acreage[a] and Production[b], Selected Years

	1973	1981	1984
Corn:			
Acreage	62.1	74.5	71.9
Production	5.67	8.12	7.67
Wheat:			
Acreage	54.1	80.6	66.9
Production	1.71	2.79	2.59
Soybeans:			
Acreage	55.7	66.2	66.1
Production	1.55	1.99	1.86
Major crops:[c]			
Acreage	310	354	335

[a]Harvested acreage in million acres.
[b]Production is in billion bushels.
[c]*Major crops include* corn, sorghum, oats, barley, wheat, rice, rye, soybeans, flaxseed, peanuts, sunflowers (from 1975), cotton, hay, dry edible beans, potatoes, sweet potatoes, tobacco, sugarcane, sugarbeets, popcorn.

SOURCE: U.S. Department of Agriculture, *Agricultural Statistics, 1988* (Washington, DC: U.S. Government Printing Office, 1988).

Table 3-5—Employment Changes in 1975-81 and 1981-84 (percent change per annum)

	1975-81 [a]	1981 -84[b]
Total U.S. employment	+2.9	+1.1
Total nonmetro employment	+2.9 (1,992)	+1.9 (759)
Nonmetro agriculturally related industries (total)	+1.2 (414)	-0.2 (48)
Farm sector[c]	-0.9 (158)	–1.3 (107)
Input industry	+1.6 (22)	-5.8 (45)
Processing/marketing [d]	+1.2 (84)	-1.5 (53)
Retail/wholesale[e]	+5.7 (400)	+3.3 (157)

[a,b]Numbers in parentheses are the change in total jobs for entire time period (in 1,000's).
[c]Farm sector includes agricultural services, farm proprietors, and agriculture wage and salary workers.
[d]processing and marketing includes those related to food processing and the textile industry.
[e]Retail and wholesale includes restaurants, groceries, dothing stores, etc.

SOURCE: Dorm Reimund and Mindy Petrulis, U.S. Department of Agriculture, Economic Research Service, "Performance of the Agricultural Sector," *Rural Change and the Rural Economic Policy Agenda for the 1980's: Prospects for the Future,* September 1988, pp. 77-102.

time (table 3-5), but relatively slowly. Between 1975 and 1981, rural employment in the agricultural input, and marketing and processing industries (food and textiles), increased by 106,000. Employment in the farm sector (farm proprietors, agricultural services, and farm wage and salary workers) actually declined by 158,000 jobs. The one truly bright spot was the increase in the retail/wholesale industry (groceries, restaurants, clothing stores). Employment in this sector increased by 400,000 jobs. During the early 1980s, demand for U.S. agricultural products and employment in most agriculturally related industries declined; the wholesale/retail industry continued to grow although at a slower rate (37).

These trends suggest that expanding agricultural production will increase rural employment modestly in the input supply industry. Favorable agricultural income conditions did not alter the long-term decline in farm-sector employment (over 40 percent of total rural agricultural employment), which is largely due to technological change and increased productivity. Farm numbers will likely continue to decline if agricultural productivity continues to increase. Rural employment in the retail/wholesale industry appears to be more closely tied to the condition of the overall economy than to agriculture specifically.

Rural processing-sector employment increased slowly from 1975 to 1981, in part because increased supplies were primarily exported as raw, rather than processed commodities. Employment expansion potential related to new crops and use development will depend on how much new or additional processing capacity will be needed to accommodate these new crops and uses. Processing capacity has

increased in the 1980s, but the number of mills (wheat and oilseed) has declined. Oil refining capacity increased about 17 percent between 1975 and 1983. Refiners typically operate at about 75 percent of capacity (41).

Recent trends of automation and productivity increases within the processing sector will limit future employment growth potential (37). Economies of scale favor large plants; capacity can be increased with a less than proportional increase in energy and equipment costs. The number of laborers needed in larger and smaller plants is comparable because milling and processing is more capital-than labor-intensive (7,17,41). Approximately 40 percent of the wet corn, cotton, soybean oil, and flour mills in the United States have fewer than 20 employees per mill. The total employment (number of production workers plus management, maintenance workers, etc.) in soybean processing facilities is approximately 9,000 to 10,000 (2,41).

A majority of the jobs in several agriculturally related industries are in fact located in metropolitan, rather than rural, areas (table 3-6); expanding employment in these industries may benefit metropolitan regions more than rural areas. Commodity-processing plants are not always located near the site of commodity production. Transportation costs of the raw commodity relative to the processed product is a major factor in determining plant location. Access to road and rail transportation, and frequently to barge transportation, is an important consideration. For example, of the wheat grown in Kansas and milled into flour, half is milled in Kansas (primarily in mills located in urban areas) and the rest is shipped throughout the country for milling. Oilseed refining capacity is located primarily (60 percent) in urban areas, although there has been a recent trend for companies with large processing mills to build new refineries near the processing plant (17,26).

The new crops guayule and kenaf might be good candidates for new processing plant construction in rural areas and near the site of production. The rubber in guayule is contained in thin-walled cells located on the stems and branches of the shrub. Excessive handling and storage decreases rubber quality (28). Kenaf is a bulky product to transport.[7]

Table 3-6-Distribution of Jobs in Agriculturally Related Industries

	Metro	Nonmetro
	(percent)	
Farm sector	36	64
Input supply	51	49
Processing/marketing	65	35
Food	71	29
Textiles	60	40
Retail/wholesale	82	18

SOURCE: Dorm Reimund and Mindy Petrulis, U.S. Department of Agriculture, Economic Research Service, "Performance of the Agricultural Sector," *Rural Change and the Rural Economic Policy Agenda for the 1980's: Prospects for the Future,* September 1988, pp. 77-102.

Oilseeds, on the other hand, are generally readily transportable and storable; some modification of existing oilseed mills might suffice to accommodate many of these new crops. A case by case evaluation of processing needs and constraints is needed to assess the potential of new crops and uses to contribute to rural processing-sector employment.

Rural Employment Potential in Manufacturing

The impacts of increased industrial use of agricultural commodities on rural manufacturing employment will depend on the need to expand and modify capacity, and on the location of the expansion. In many cases, major users of chemicals derived from new and traditional crops will be firms that already exist. In some cases, substitution of agriculturally derived chemicals for petroleum-derived chemicals in production will be relatively easy, and only modification of existing plants may be needed. In other cases, either major production modifications or increased capacity will be needed; expansion will be more likely in these circumstances.

The location of new manufacturing facilities will depend on resource availability, transportation costs, availability of skilled workers, and easy access to information. Industries that are dealing with volatile or unestablished markets, rapid technical change, or other conditions that require innovative responses will generally favor metropolitan locations where they have access to information, specialized skills, and professional expertise (25). Rural areas generally have a comparative advantage over metropolitan areas in terms of availability of

[7]A kenaf-based newsprint mill is scheduled to begin operation in 1991, and to provide 160 jobs once full operation begins. The new mill is located in Willacy County, Texas.

natural resources, and in lower tax rates, land and labor costs.

The importance of resource availability and low-cost labor relative to the need for highly skilled labor will largely determine the type of personnel employed, and whether a firm locates in a metropolitan or rural area (5). Urban companies have a higher proportion of managerial and professional-technical jobs than do rural firms (table 3-7). Rural production jobs are generally lower paying, less technically skilled, and the first to be eliminated by unfavorable economic conditions (5,25).

Industries characterized by top-of-the-cycle[8] products are more concentrated in metropolitan areas, because they require technically skilled labor (table 3-8). High tech companies are an example. These firms employ relatively more scientific and technical personnel, have higher levels of research and development expenditures, manufacture more highly sophisticated products, and generally have proven to be more competitive in the world economy than companies characterized as bottom-of-the-cycle. The latter tend to use highly standardized production methods and employ relatively less-skilled labor (5).

Although rural manufacturing is characterized by a higher percentage of bottom-of-the-cycle and natural resource based industries, some top-of-the-cycle firms do locate in rural areas. In recent years, rural employment in these firms has increased, primarily in the South and West. Rural employment in top-of-the-cycle industries in the Midwest and Northeast has been declining. The greatest growth, particularly in the West, has been in rural counties adjacent to urban centers (5).

Many industries that are expected to use chemicals derived from agricultural commodities are considered to be top-of-the-cycle industries, although there are two major exceptions. The rubber and allied products industry is characterized by more routine procedures and is generally classified as a bottom-of-the-cycle (mature) industry. The paper and allied products industry is heavily reliant on natural resources. The detergent industry, a high-tech industry that uses agriculturally derived chemicals, is expanding its capacity to use vegetable oils. New plant construction, however, is in urban rather than rural areas (14).

Table 3-7—Nonmetro Share of Manufacturing Jobs by Job Type

	Metro	Nonmetro
Managerial	90	10
Professional/technical	90	10
Sales/administrative support	75	25
Precision production jobs	77	23
Machine operators	70	30
Laborers	65	35

SOURCE: David A. McGranahan, "Rural Workers in the National Economy," *Rural Change and the Rural Economic Policy Agenda for the 1980's: Prospects for the Future,* September 1988, pp. 29-47.

Table 3-8-Distribution of Manufacturing Jobs, 1984

Type of industry	Metro	Nonmetro (million jobs)	Proportion of nonmetro employment
Total manufacturing	15.2	4.2	21.7
Top of the cycle	7.4	1.2	13.7
Bottom of the cycle	5.6	2.0	25.9
Resource	2.2	1.1	33.3

SOURCE: Leonard E. Bloomquist, U.S. Department of Agriculture, Economic Research Service, "Performance of the Rural Manufacturing Sector," *Rural Change and the Rural Economic Policy Agenda for the 1980's: Prospects for the Future,* September 1988, pp. 49-75.

Many of the industries that are likely to use agricultural commodities as a raw material source are undergoing worldwide consolidation, and capacity is increasing. Employment trends have been mixed (table 3-9) (9).

It is difficult to determine the multiplier effects of manufacturing plants in rural locations. Total 1984 U.S. manufacturing employment was 19.4 million. It is estimated that an additional 6.5 million jobs were created supplying input services to these manufacturers; an additional 1.8 million jobs in the agricultural, mining and construction industries are also linked to manufacturing. No estimations were made of the rural-urban distribution of these jobs (54). Some studies have suggested that in rural areas, one additional community job is created for every three manufacturing jobs (47). Growth in manufacturing employment in nonmetropolitan areas aver-

[8]Product development goes through many phases, from conception to routine manufacturing. Products at the top of the cycle are in the earlier phases of development. These phases include conception and prototype development, and the establishment of the manufacturing procedures, Products at the top of the cycle use a high proportion of highly skilled technical labor. Top of the cycle industries are those characterized by having top of the cycle products. These fiis are generally the innovative (high-tech) firms. Bottom of the cycle products are those that are more highly developed and for which the manufacturing process is highly standardized and routine. Bottom of the cycle industries use a higher proportion of labor with lesser technical skills.

Table 3-9-Manufacturing Employment Trends of Industries Potentially Using Industrial Agricultural Commodities

	1989 employment level	Trend (1979-89) percent per annum change
Plastics and synthetic materials. .	187,000	–1
Paints and allied products.	63,000	-1
Soaps, cleaners, toilet goods	161,000	+1
Rubber and miscellaneous products	840,000	+1
Petroleum and coal products	163.000	–3

SOURCE: *Chemical and Engineering News,* "Employment in the U.S. Chemical Industry," June 18, 1890, p. 60.

aged 1.4 percent per annum between 1982 and 1986, and jumped to 2.6 percent in 1987.

Potential Rural Employment Implications

Agriculturally related industries are a significant, but declining, source of employment in rural communities. Employment trends in the 1970s and 1980s suggests that large increases in demand and production of agricultural commodities will be needed to increase employment significantly in rural agriculturally related industries. Agriculturally dependent communities are likely to benefit the most. Significantly, much of the employment growth in agriculturally related industries is likely to occur in metropolitan, rather than rural, communities. Rural areas are likely to have a comparative advantage with firms for which natural resources or low-cost labor are important considerations. As noted, firms requiring highly skilled labor, are likely to concentrate in metropolitan regions. These include several of the industries that are expected to commercialize products derived from agricultural commodities. These studies and industry trends suggest that commercialization of industrial uses for agricultural commodities may have modest impacts on rural employment, and that much of the employment growth may be in metropolitan communities. From society's point of view, new job creation may be desirable regardless of location, but firm location in metropolitan areas does not revitalize rural economies.

Proponents of industrial crops and use commercialization argue that even modest rural employment increases are worth pursuing. This is true only if equivalent benefits cannot be obtained by other methods at lower cost. The cost-effectiveness of this strategy has not been evaluated and conclusions cannot be made. Historically, however, social returns to agricultural research investments have been high, ranging from an estimated 45 to 135 percent (30).

Regional Specialization

Many new crops under development potentially can be grown in several regions of the United States (table 3-10). However, like traditional crops, some regions may have a production advantage over others, and regional specialization of production may result. Thus, the introduction of new crops or uses of traditional crops may benefit some regions, while having little effect on others.

Two examples illustrate the point. Kenaf can be grown throughout the South, but appears to be particularly attractive compared to the net returns of other options in parts of Texas. This area is likely to be one of the earliest producers of kenaf. *Crambe* and rapeseed can be grown extensively in the United States, but *Crambe* is more tolerant of dry conditions than rapeseed. *Crambe* may have an advantage over rapeseed in the Plains region, whereas rapeseed, particularly the winter varieties, may have advantages in the Southeast (20).

Transportation costs could also play a role in determining production location. Prices received by farmers reflect transportation costs. Farmers at great distances from processing plants receive lower prices. For example, soybean producers in the Plains region receive lower prices than producers in the Midwest, in part due to lower quality (less oil), but largely due to transportation costs (41). Lower prices decrease the attractiveness of a crop to farmers. A new crop's competitiveness may be enhanced if it is grown in an area where it is relatively easy to convert existing processing facilities to accommodate it.

Agricultural Sector Stability

Market failure and macroeconomic policy are the primary factors affecting the stability (extent of farm price and net return variability over time) of agriculture (48). Market failure arises from uncertainty (e.g., such as weather and assymetric information between buyers and sellers). Development of new marketing institutions, or use of existing institutions that reduce marketing uncertainties (e.g., forward contacting, futures and insurance markets) potentially could reduce inefficiencies in the marketing of industrial crops and uses of traditional

Table 3-10—Likely Production Locations of New Crops

Crop	Location
Oilseeds:	
Buffalo gourd	Southwest
Chinese tallow	Southeast
Crambe	Midwest/Southeast/Plains States
Cuphea	Northwest/Midwest
Honesty	Northern States/Alaska
Jojoba	Southwest
Lesquerella	Southwest
Meadowfoam	Pacific Northwest
Rapeseed	Northwest./Plains States/ Midwest/Southeast
Stokes aster	Midwest/Southeast
Vernonia	Southeast
Gums and resins:	
Baccharis	Southwest
Grindelia	Southwest
Guar	Southwest
Guayule	Southwest
Milkweed	Plains/Southwest/West
Fibers:	
Kenaf	South

SOURCE: Office of Technology Assessment, 1991.

crops. Diversifying agricultural production potentially could reduce adverse weather impacts.

Macroeconomic policy influences the price of commodities and land values in the United States, as well as exchange rates, interest rates, inflation, and rates of economic growth here and abroad. During the 1970s, attempts to recycle petrodollars sparked rapid economic growth in developing countries. Coupled with the switch from freed to flexible exchange rates, this growth led to an export boom for U.S. agricultural commodities. At the same time however, inflation in the United States was rising and the Federal deficit was being paid for by monetary policy. In late 1979, the Federal Reserve began to disinflate the U.S. economy. This severe monetary action led to high interest rates and values of the U.S. dollar as Federal Government deficits were now being financed by foreign savings. High debt loads at high interest rates, coupled with high U.S. dollar values, meant that developing nations could no longer afford to pay for U.S. agricultural commodities and exports plummeted. Because nearly 1 in every 3 acres planted in the United States is destined for the export market, decreasing exports lead to declining U.S. farm income and land prices (42).

The roller-coaster ride that U.S. agriculture has undergone since 1975 points out the vulnerability of that segment of the economy to macroeconomic policy (3,42). Several industries that would use chemicals derived from agriculture are also susceptible to macroeconomic policies, and display highly variable demand for raw commodities. The rubber industry serves as an example. Nearly 60 percent of all rubber used in the United States is used to make tires. Tire production is intimately linked to the automobile industry, which is highly vulnerable to interest rates. Between 1977 and 1989, U.S. rubber consumption has fluctuated between 5.3 and 7.4 billion pounds (45).

Thus the impact of new crops and uses of traditional crops on agricultural stability may be small. While new crops can offer production opportunities that help limit the risk from adverse weather, disease, or insect problems, development of new uses for traditional crops potentially could have the opposite effect by increasing monoculture. Development of new risk-reducing marketing arrangements, or increased use of those that exist could lead to some increased stability, as could diversification of markets for agricultural commodities. As noted, however, many industries that are expected to use agricultural commodities fluctuate in their use of raw materials. Whether these markets will lead to increased stability has not been adequately analyzed. Macroeconomic policy will continue to be a key factor in agricultural stability.

International Implications

Some new mops being developed potentially could replace a significant proportion of major exports of some developing countries, which could result in economic stress for these countries. *Cuphea*, for example, could substitute for coconut and palm kernel oil. Tropical oils represent 11.5,2.5, and 7.5 percent of the total 1985 exports of Malaysia, Indonesia, and the Philippines respectively (59). Additionally, *Hevea* rubber, which potentially could be at least partially replaced by guayule, is a major export of Malaysia and Indonesia. Some of these countries, the Philippines in particular, are considered to be strategically important to the United States.

In addition to the strategic implications, there are potential long-term impacts on U.S. export markets to consider. Studies indicate that the future growth of U.S. exports depends largely on expanding markets in developing countries rather than industri-

alized nations (39). Replacing the exports of these countries narrows their opportunities for economic development and for attainment of scarce foreign reserves to purchase U.S. products.

An additional consideration is trade relationships with industrialized nations. For example, the export of corn gluten meal (a byproduct of ethanol production) to Europe is a contentious issue between the United States and the European Community. The economic competitiveness of ethanol production depends in part on having markets for corn gluten meal; being able to export the meal decreases the downward price pressure that ethanol production has on soybeans. Understanding of potential international impacts is needed to help anticipate possible trade disputes.

Competition With Current Crops and Interregional Impacts

A major goal in the development of new industrial crops and uses is to provide new markets that do not compete with markets currently supplied by traditional crops. Many primary uses being developed will not, but there will be some exceptions. There may, however, be considerable competition with traditional crops through competition in the byproduct markets. It cannot be unambiguously stated that new industrial crops and uses of traditional crops will not compete for markets currently supplied by traditional crops.

If new crops compete directly for markets with crops that are currently being grown, the latter could fall in price, resulting in decreased income to producers of that crop. For example, some new oilseed crops could potentially compete with soybeans. Examples are *Vernonia* and *Stokesia* which produce oils containing epoxy fatty acids, that potentially could replace the approximately 100 to 180 million pounds of soybean, linseed, and sunflower seed oil that are converted to epoxy fatty acids for industrial use each year (the equivalent of 8 to 15 million bushels of soybeans) (36). Additionally, potential byproducts of glycerol and high-protein meals could compete with soybean oil for industrial markets and for use as livestock feeds (2).

New uses for traditional crops may also affect demand for current crops. For example, many new uses being developed for corn only use the starch component of corn. Oil, distillers dried grains, and corn gluten meal are produced as byproducts. The oil competes with oils derived from oilseeds, particularly soybeans. The distilled dried grains and gluten meal compete directly with soybean meal as high-protein livestock feeds. Increased supplies of these corn byproducts will decrease the price of soybeans, possibly by up to 4 cents a bushel per 100 million additional bushels of corn used (60,61).

Competition with traditional crops would have different regional impacts. For example, soybean production is located primarily in the Corn Belt, Southeast, and Delta regions of the United States. Soybean producers in the Corn Belt can switch to corn production; producers in the Southeast and Delta regions will have problems. Production costs of soybeans are also higher in the Southeast and Delta regions. The result could be a decrease in farm income in those regions (41). Finding new uses for soybean oil or meal may help to alleviate some of the potential impacts on soybean prices.

Small Farm Impacts

Most new crops can be grown on large and small farms (defined in this report as those with less than $100,000 in sales), but some advantages may exist to their production on large farms. Since many of the crops are bulk commodities, they may have relatively low unit values. Minimizing production costs will be important. Economies of scale, particularly for machinery, might help lower production costs for large farms. Additionally, farms that have a larger financial base may be able to absorb the economic risk associated with new crops better than smaller farms. Some new crops, such as jojoba and guayule are perennials that require several years to reach maturation. Crops such as this require large upfront costs and have long payback times on the investment. This could create serious cash-flow problems, particularly for small farm operators or those with little access to financing.

A correlation exists between farm size and speed of adoption, with larger farms adopting technology first (55). Small farm operators may be unwilling or unable to adopt new technologies. For example, a study of Oklahoma farmers showed that although production of specialty vegetables could raise farm income for part- and full-time farmers who operated small enterprises (defined in the Oklahoma study as those having sales of less than $40,000), fewer than 6 percent of the farmers in these categories ex-

pressed a willingness to grow specialty vegetables (40). Thus, even if a new crop can be grown on small-sized farms, operators of large farms may be the earliest adopters and, thus, may capture most benefits.

The income impacts of new uses for traditional crops will be affected by farm commodity programs. For crops covered, commodity programs buffer the effects of changing market prices on farm income. High market prices are offset by lower deficiency payments, and low program participation. When market prices are low, program participation by farmers is high, and modest changes in market prices have little impact on total farm income. Impacts of higher market prices would be greatest for farmers who do not participate in commodity programs or for producers of commodities not covered by commodity programs. Participation rates are lowest among the smallest and largest farms. Producers who specialize in the production of cash grains[9] have the highest rates of participation (table 3-11). In 1987, 83 percent of all cash grain farmers participated in farm programs, more than 83 percent of the feedgrain, cotton, wheat, and soybean acreage was grown on farms operated by program participants (table 3-12) (32).

Significant changes in aggregate income would occur only if market prices exceed target prices, or if demand is high enough to reduce set-aside acreage requirements significantly. It is estimated that ethanol production from corn would need to increase current production levels by a factor of 3 to 4 to approach that situation[10] (60).

Many small farm operators do not rely on farm income for the majority of family income (table 3-13) (57). These statistics suggest that modest changes in market prices for many of the traditional crops that are in surplus may not result in large increases in income for small-sized farms, and small-farm operators may be unable to adopt new crops. Policies that help small-farm operators accept the added risks of new crops, and programs that teach new management skills would increase the likelihood of new crops and uses benefiting small-farm operators.

Table 3-n-Participation in Federal Farm Programs by Farm Size, 1987a

	Percent participating
Harvested acres	
1 to 99	*20.6*
100 to 199	*59.9*
200 to 499	*78.0*
500 to 999	*87.0*
1,000 to 1,999	*87.3*
Greater than 2,000	*81.6*
Farm sales class	
Less than $1,000	*6.7*
$1,000 to $4,999	*12.0*
$5,000 to $9,999	*23.3*
$10,000 to $24,999	*38.8*
$25,000 to $49,999	*54.3*
$50,000 to $99,999	*62.2*
$100,000 to $249,999	*65.7*
$250,000 to $499,999	*60.0*
$500,000 to $999,999	*49.7*
Greater than $1,000,000	*34.8*

[a]Note that 1987 was a year characterized by low commodity prices, and participation rates in agricultural programs were high.

[b]Participants are defined as farm operations that receive any cash payments or payments in kind from Federal farm programs. These include benefits such as deficiency payments, whole herd dairy buyout, support price payments, indemnity programs, disaster payments, paid land diversion, inventory reduction payments, or payments for approved soil and water conservation projects. Participants also include farmers who place any portion of their production in the Commodity Credit Corporation for nonrecourse loans or have any acreage under the annual commodity acreage adjustment programs or the conservation reserve program.

SOURCE: Merritt Padgitt, U.S. Department of Agriculture, Economic Research Service, "Production, Resource Use, and Operating Characteristics of Pariticpants and Nonparticipants in Farm *Prograrns," Agrikultural Resources: Cropland, Water, and Conservation Situation and Outlook Report*, September 1990, pp. 48-54.

The question also arises of who captures the value added[11] of new products. For example, in 1987 consumers spent $377 billion for foods produced on U.S. farms. About 25 percent ($94 billion) went to farmers and the remainder went to the food industry for processing, handling, and retailing. For many food crops, such as grains and oilseeds, the farm value is a small share of the retail price (13). Studies that assess who captures the benefits of the value added from industrial uses of agricultural commodities are needed.

[9]For farms to be classified as a particular specialty, it must derive 50 percent or more of its sales from a special class of products. Cash grain farms include those specializing in the production of wheat, feed grains (corn for grain and silage, sorghum, barley, and oats), soybeans, sunflowers, dry beans, peas, or other grain crops.

[10]This estimation was made using target prices established in the 1985 Food Security Act. The 1990 Farm Bill froze target prices at 1990 levels, so the general principal still holds.

[11]Value added is the sum of wages, interest, rent, profit, depreciation, and indirect business taxes in the sector or industry considered.

Table 3-12—Participation in Federal Farm Programs by Crop Acres, 1987a

Crop	Percent participating[b]
Feed grains[c]	83.0
Soybeans	85.8
Wheat	88.6
Cotton	89.5
Rice	91.1
Peanuts	75.7
Tobacco	47.9

[a]Note that l987 was a year characterized by low commodity prices and participation rates in farm programs were high.
[b]Participants are defined as farm operations that receive any cash payments or payments in kind from Federal farm programs. These include benefits such as deficiency payments, whole herd dairy buyout, support price payments, indemnity programs, disaster payments, paid land diversion, inventory reduction payments, or payments for approved soil and water conservation projects. Participants also include farmers who place any portion of their production in the Commodity Credit Corporation for nonrecourse loans or have any acreage under the annual commodity acreage adjustment programs or the conservation reserve program.
[c]Includes acres of corn for grain and silage, and sorghum, barley, and oats for grain.

SOURCE: Merritt Padgitt, U.S. Department of Agriculture, Economic Research Service, "Production, Resource Use, and Operating Characteristics of Paritic pants and Nonparticipants in Farm *Programs," Agricultural Resources: Cropland, Water, and Conservation Situation and Outlook Report*, September 1990, pp. 48-54.

Table 3-13-Income Sources by Sales Category, 1988

Sales category	Percent total income from off-farm sources[a]	Percent gross cash farm income from government	Percent of total farms
Less than $10,000	89	4	45
$10,000 to $19,999	74	7	12
$20,000 to $39,999	49	10	11
$40,000 to $99,999	24	11	14
$100,000 to $249,999	13	11	12
$250,000 to $499,999,	6	9	4
Greater than $500,000.	3	4	2

[a]Total income is the sum of total off-farm income and total gross cash farm income.

SOURCE: Office of Technology Assessment, 1991. Calculated from data contained in U.S. Department of Agriculture, Economic Research Service, "Financial Characteristics of U.S. Farms, January 1, 1989," Agriculture Information Bulletin No. 579, December 1989.

Environmental Impacts

New industrial crops and uses of traditional crops potentially could have positive or negative environmental impacts. Replacing salt with calcium magnesium acetate (a new product) as a road de-icer could reduce the soil and water contamination problems associated with salt. Use of starch, or starch-vegetable oil mixtures as a delivery system for herbicides and pesticides potentially could mitigate rapid leaching of these chemicals. Degradable plastics may in the future help alleviate waste disposal problems, but at the present time, too many questions exist regarding the extent of degradation, the chemicals released, and the impact on plastic recycling to state that degradable plastics will have a positive effect on the environment. Likewise, using ethanol as a gasoline additive decreases carbon monoxide emissions, but may increase volatile hydrocarbon emissions. Increased uses for corn could increase corn production, which is chemically intensive. The implications this might have on groundwater pollution need further investigation.

Many new crops may be better suited to certain environments than crops that are currently being grown there. Many new crops are drought tolerant and their water demands are much lower than many traditional crops. In areas where irrigation is becoming more expensive, these new crops could be attractive. Additionally, several crops provide good ground cover and possibly could reduce soil erosion.

For many potential new crops, information concerning pest, weed, and disease problems is lacking. In the wild, plants maybe relatively free from pests and disease, but intensive cultivation creates a different environment, one that is often favorable for the development of pest and disease problems. This is true with traditional crops and appears to be what is happening with jojoba, a new crop now being cultivated in the Southwest. In the wild, jojoba is relatively free of pests and diseases, but cultivated stands are beginning to experience problems (29).

The availability of new crops will provide more options to farmers who wish to rotate crops. Crop rotation patterns can be used to reduce soil erosion and chemical and fertilizer applications. However, in most cases, crop rotation is limited in U.S. agriculture primarily because of economic disincentives, some of which stem from agricultural commodity programs, rather than, lack of crop options. Development of new crops is unlikely to increase crop rotation significantly without changes in economic incentives. Changes in the 1990 Farm Bill may improve this situation.

Several potential new industrial crops are not native to the United States. Commercialization in the United States will require the introduction of alien species. Historically, new crops have been introduced without problems; most of the major crops produced in the United States today are not native. However, on occasion, the process does go awry with severe repercussions (34). Johnson grass

is an example. Originally and purposely introduced into U.S. agriculture as a superior forage crop, it is today a serious weed requiring widespread use of herbicides. It is also a close relative of sorghum and is able to cross-fertilize with that crop, rendering a useless offspring. Sometimes a newly introduced species, while relatively benign itself, may serve as a host for diseases of other plants. A historical example is common barberry, which served as a host for wheat stem rust, a fungus that debilitates wheat. A national eradication program was needed to destroy this plant (24). Domestication of native wild species raises issues of weediness potential and cross-hybridization with wild relatives. These issues have not been adequately evaluated.

Some new crops and uses will involve biotechnology; crops may be genetically engineered to have new characteristics. Many environmental concerns have been raised concerning the release of these plants. Genetically engineered organisms will need regulatory approval. Well-defined regulations and regulatory agencies operating in a timely and effective manner will be needed to ensure speedy commercialization of biotechnologically derived new crops and uses of traditional crops.

The potential environmental impacts of large increases inland use for agricultural production have not been adequately evaluated. Major changes in land use patterns will have implications for erosion, ground and surface water contamination, wildlife, and non-agricultural plants among others.

Commodity Surpluses and Government Expenditures

Development of new uses for traditional crops that are in surplus could potentially reduce those surpluses. Current carryover stocks of some major commodities are low due to particularly adverse weather conditions in recent years, but historically, large surpluses of some commodities have existed (table 3-14). Currently, agricultural commodity programs strongly encourage the planting of some crops that are in surplus. Farmers will need strong economic incentives to decrease production of these commodities and begin producing new crops.

Table 3-14-Commodity Stocks (million bushels)

	Wheat	Corn	Soybeans
1985/86 [a]	1,905	4,040	536
1986/87	1,821	4,882	436
1987/88	1,261	4,259	302
1988/89	702	1,930	182
1989/90 [b]	536	1,344	239
1990/91 [b]	945	1,236	255

[a] Marketing year beginning June 1 for wheat, and September 1 for corn and soybeans.
[b] Based on Nov. 8, 1990 estimates.

SOURCE: U.S. Department of Agriculture, Economic Research Service, *Agricultural Outlook,* July 1990.

The development of new crops can reduce surpluses if farmers shift acreage from the production of surplus crops to the new crops. However, this might not occur, because farmers may produce new crops on acreage shifted from the production of minor, non-surplus crops. New crops may be more economically competitive with the latter than they are with the surplus commodities. If this is the case, then the development of new crops may not result in a significant reduction of surpluses. Not enough information is available to determine the impact of new industrial crops on surpluses.

Similarly, it is not possible to state unambiguously that new industrial crops or uses of traditional crops will reduce Federal expenditures. Currently, for example, ethanol derived from cornstarch is competitive as a fuel additive only because it is heavily subsidized via excise tax exemptions. An Economic Research Service (ERS) study indicates that an expansion of the ethanol industry will reduce agricultural commodity support payments, but this reduction will be offset by increased subsidies resulting from lost excise tax revenues (60).[12] The Federal Government still pays, but the program that provides the funding has changed. New uses that utilize commodity program crops, and are competitive (without subsidies) with available alternatives could possibly lower Federal expenditures.

An additional consideration is the potential impact that new uses of one crop may have on other crops covered by commodity programs. For example, increased ethanol production from cornstarch is

[12] A recent GAO study (U.S. Congress, General Accounting Office, *Alcohol Fuels: Impacts From Increased Use of Ethanol Blended Fuels*, GAO/RCED-90-156 (Gaithersburg, MD: U.S. General Accounting Office, July 1990) examining this issue indicated that there would be a net positive impact on government payments for the time period examined in their study. The GAO and USDA studies used different econometric models of the agricultural sector and slightly different assumptions. The USDA study used a longer time horizon and different expansion levels than the GAO study. The negative cumulative net effects on government payments occurred late in the time frame used by the USDA study.

expected to decrease the price of soybeans. Soybeans are covered by nonrecourse loans. Traditionally, the market price of soybeans has been higher than the loan rate, and support payments have not been needed (41). It is not clear whether the price of soybeans would drop low enough for high farmer participation and defaults on nonrecourse soybean loans, but this is a possibility. Under these conditions, Federal agricultural commodity expenditures for soybeans would increase. Alternatively, rising corn prices may cause some livestock producers to switch to other grains for feed. Increased use of wheat, for example, could raise wheat prices. Wheat is also supported by commodity programs and these expenditures might decrease. The interactions in commodity markets are complex and changing one aspect on the market will result in many secondary impacts. The net effect of these impacts and how they would affect Federal commodity expenditures are not known.

Potential To Supply Strategic Materials and Replace Petroleum

It is possible to develop a domestic capability to produce many strategic and essential industrial materials.[13] This capability could lead to an increased sense of security and reduce vulnerability to external political factors. Many potential new crops that could supply strategic and essential materials are in the early stages of development and numerous technical constraints must be overcome. Many new and strategically important crops are not economically competitive with available alternatives. Development takes many years, however, and today's research lays the groundwork necessary for future competitiveness and helps provide flexibility to respond to changing needs and economic environments.

Guayule (rubber) is an example of a new strategic crop that is technically more developed, but is not yet price-competitive with imported natural *Hevea* rubber. However, because of its strategic importance, the Department of Defense has stated in a Memorandum of Understanding with the Department of Agriculture that it will seek to ensure that a significant portion (20 percent) of its annual tire purchases are tires made from guayule rubber, provided: that the initial price of guayule rubber is not over three times that of *Hevea* rubber; and that within 5 years of initial purchase, the price of guayule rubber becomes competitive with that of *Hevea* rubber (31). This arrangement provides a market pull for the development of guayule in the United States despite the fact that it is not currently economically competitive with *Hevea* rubber.

The potential to replace petroleum is an important issue and an extensive and detailed analysis is beyond the capacity of this study. A few pertinent observations can be noted however. Petroleum is used to produce many products in the United States, including gasoline, diesel fuel, residual oil (used in boilers), jet fuel, chemical feedstocks, and miscellaneous products (including kerosene, lubricants, etc.). Transportation fuels are by far the largest use, and account for nearly 64 percent of the petroleum used (53). Chemical feedstocks represent another 7 to 8 percent of petroleum use (10). Many of the new industrial crops and uses of traditional crops potentially could replace some of these uses.

Development strategies required to significantly replace petroleum uses in fuel and the chemical feedstocks industries are likely to be different. This is because fuels are sold in energy units, while chemical feedstocks are sold in weight units. Conversion of carbohydrates (sugars and starches) to ethanol, for example, conserves energy, but mass is lost (CO_2 is lost). This puts an additional burden on using biomass in the chemical feedstock industry (22). Chemical purity is required for the chemical industry; fuel uses generally tolerate greater contamination. Chemicals obtained from biomass sources generally have a higher level of contamination than those derived from petroleum cracking (10).

The potential to replace the largest quantity of petroleum is to develop substitutes for transportation fuel. Use of biomass as a fuel source, in general, is impeded by the size of the United States fuel industry, low energy content, seasonality, the dispersed geographic location of supply, and lack of supply infrastructure (22,53). Potential fuel replacements derived from agricultural commodities include ethanol to replace gasoline and vegetable oils to replace diesel fuel.

[13] **Strategic materials are defined as those materials that would be needed to supply the military, industrial, and essential civilian needs of the United States during a national emergency, and are not found or produced in the United States in sufficient quantities to meet such needs. Castor oil and natural rubber are strategic materials. Essential materials are those required by industry to manufacture products depended on daily.**

At this time, corn is the least expensive biomass feedstock to use for ethanol production. Current ethanol production replaces less than 1 percent of total U.S. gasoline consumption (62).[14] Significant replacement of gasoline using ethanol derived from corn would require an increase in ethanol production of several orders of magnitude. This would result in many energy, environmental, and economic effects, some of which will be positive and some negative (see box 3-A).

A recent OTA study found that these concerns, coupled with the high direct costs of ethanol production from corn, imply that the prospects of substantial increases in ethanol use in transportation are not favorable (53). A mitigating factor might be the recent passage of the Clean Air Bill, which mandates use of oxygenates (compounds high in oxygen content such as ethanol among others) in fuel for some cities that do not meet Clean Air Standards. Additionally, improvements in the conversion of lignocellulose to ethanol, instead of starch to ethanol, might improve the economics of ethanol use for transportation fuels. These technical advances are not expected to occur prior to the year 2000, and the implications of this development for the farm sector are not clear at this time.

The potential for vegetable oil-based diesel fuel is similarly difficult to predict. The United States consumes approximately 40 billion gallons of diesel fuel each year, with approximately 10 percent of this total used in agriculture (23). Using soybean oil, just for agricultural uses, would require an additional 15 to 20 million acres of production over current levels. This would increase the price of soybean oil for food uses. The increased meal produced would likely saturate the soybean meal markets. If the oil is converted to monoesters for use, then the glycerol byproduct will also need to be marketed. Using crops that produce more oil per acre, such as sunflowers and possibly rapeseed, could potentially improve the situation, as could finding uses for the meal other than for livestock feed.

Alternatively, new and traditional crops can be used to produce commodity chemicals, rather than fuel. Currently, about 7 to 8 percent of the petroleum used in the United States is used to produce commodity chemicals (10). Five compounds derived from petroleum account for 70 to 75 percent of all primary feedstocks (table 3-15). These compounds and their derivatives represent 50 to 55 percent of all organic feedstocks produced by the chemical industry (8).

Table 3-15-Major Primary Feedstocks Derived From Petroleum

Feedstock	U.S production, 1989 billion lbs)
Benzene	11.7
Ethylene	35.0
Propylene	20.0
Toluene	5.8
Xylene	5.8

SOURCE: *Chemical and Engineering News,* Apr. 9, 1990.

The extent to which petroleum is replaced by chemicals derived from agricultural commodities will depend on economic competitiveness, superior performance, availability of other substitutes, and on the net energy balance of crop production (i.e., the ratio of energy output relative to the energy used for agricultural production and processing). Today, economics do not favor using agricultural commodities to derive most commodity chemicals, but rising petroleum prices and improvements in processing technologies could alter that situation (12,22,33).

Replacement of petroleum-derived chemicals with plant-derived chemicals can be done in two ways: direct or indirect substitution. Direct substitution involves the replacement of a petroleum-derived chemical with an identical biomass-derived chemical. This strategy has the advantage of having acceptable products and markets that already exist. The disadvantage is that it is difficult for plant-derived chemicals to compete economically because the petroleum chemical industry is highly integrated, is flexible in the chemical mix produced, and has large economies of scale. Additionally, the chemical industry may be able to adjust prices substantially in response to threatened competition.

The indirect replacement strategy requires developing plant-derived chemicals that have a slightly different chemical composition, but the same functions as petroleum-derived chemicals. In this case, benefits in terms of superior performance, improved storage or supply characteristics, or improved envi-

[14]One bushel of corn produces approximately 2.5 gallons of ethanol. U.S. production of ethanol uses approximately 350 to 400 million bushels of corn (approximately 5 percent of corn production).

Box 3-A—Social and Market Impacts of Ethanol

For crops that are in surplus, it is hoped that the development of new uses will increase demand and raise prices for the commodity, increase farm income, decrease surpluses, decrease Federal commodity payments, increase job creation in rural communities, and in some cases, have positive environmental impacts. An example will help to illustrate some of the complications that might occur. The analysis is taken from a USDA/ERS study on the potential impacts of increasing ethanol production from corn (51,52). The analysis assumed that commodity price supports would remain similar to those in the 1985 Food Security Act, the Federal excise tax exemption would be extended, and continuing export markets for corn gluten meal would exist. Estimation of impacts is based on an expansion of ethanol production to about 2.7 billion gallons of ethanol per year by 1995, which would require an additional 800 million bushels of corn annually. Such a scenario is unlikely to occur without changes in economic incentives of ethanol production or possibly government legislation mandating increased use of ethanol. Additionally, the price and policy scenarios used in the model may change, resulting in different outcomes than those predicted. However, the analysis is illustrative of the types of impacts that can occur when new uses for traditional mops are developed, and is valuable in showing how complex the interactions in the agricultural commodity markets are.

***Commodity** Prices*—Increasing the production of ethanol using corn as a feedstock will result in higher corn prices. It is estimated that corn prices will increase approximately 2 to 4 cents per bushel, for each additional 100 million bushels used to produce ethanol. However, corn is not the only commodity that will be effected Corn is used primarily as a livestock feed. As the price of corn rises, livestock producers may switch to other feed grains such as wheat or sorghum. The increase in demand could result in some increase in prices for these grains. Ethanol production from corn requires only the starch. Produced as byproducts are corn oil and distillers dried grains (from dry mill processing) or corn gluten meal and feed (from wet mill processing). Corn oil competes in the edible oil market with the oil obtained from oilseed crops such as soybeans and sunflowers. Additionally, distillers dried grains and corn gluten meal and feed compete with soybean meal as a high-protein livestock feed. Thus the value of soybeans decreases. In the short run, prices could decrease as much as 20 percent. In the long run, it is expected that farmers will shift out of soybean production to the production of other crops, particularly corn, and the decreased supply of soybeans will help raise the price again.

Livestock Sector--Changing prices for grains and protein meals could affect livestock production. Ethanol production below 3 billion gallons is not expected to significantly affect Livestock production because higher grain prices will likely be offset by lower protein meal prices. The impacts on livestock production will depend on how easily ethanol byproducts can be substituted for corn in the feed rations. Limited opportunities for substitution could result in higher feed prices and lower livestock production. Substitution opportunities are likely to be different for beef, pork, and poultry. *Lower* livestock production could result in higher meat prices for consumers. Estimates are that at 2.7 billion gallon production, food rests may increase an additional $150 million annually (51,52).

Farm Income—Higher corn and grain prices will affect the income of farmers producing those commodities. Fanners who produce corn and who do not participate in commodity programs will benefit the most from higher corn prices. The benefits to corn producers enrolled in *the* corn commodity program will not be as high because the commodity program to some extent buffers the effect of higher market prices (i.e., higher market pr.ices result in lower deficiency payments to farmers). In general though, corn producers will experience a higher income from

ronmental conditions, must outweigh any potential cost disadvantages (10,22). Indirect substitution using primarily oils and resins does occur, but the high variability of supply and price has restricted these uses.

Technically, starch derived from corn (or other sources) could be used to make several commodity chemicals, many of which are intermediates in the production of other chemicals. The markets for some of these chemicals (e.g., ethylene) are large. Some smaller markets (e.g., ketones and alcohols) might be more likely candidates for development. Other potential substitution opportunities lie with chemi cals with high oxygen ;&tents, since plant-derived chemicals usually contain oxygen, while petroleum-derived chemicals do not. Examples include sorbitol (food processing), lactic acid (thermoplastics), and citric acid (detergents) (12). Starch can also be used to produce polymers used either alone or in combination with other compounds such **as** plastics. Currently, biomass-derived plastics are not economically competitive except in a few specialty high-value markets (e.g., surgical sutures). Major technical advances are still needed (10).

increased corn prices. Additionally, producers of other grains, for example wheat, may also experience higher incomes if the prices of these grains also increases. Soybean farmers will lose income because of the competition in the oil and high-protein meal markets. The differential price changes for grains and soybeans could result in interregional income shifts. Farmers in the Corn Belt can switch soybean acreage to corn. Producers in the Southern United States, particularly the Delta region cannot. It is estimated that farm income in that region could decrease by 5 to 7 percent. Total gross receipts from crop production are expected to increase $1 to $2 billion if ethanol production is increased to 2.7 billion gallons (51,52).

Farm Program Costs—Increases in ethanol production will decrease farm program costs because of the increases in grain prices, but will be offset by tax losses resulting from the Federal excise tax exemption for ethanol. Higher grain prices result in fewer participants in the farm commodity programs, decreased deficiency payments, and decreased storage costs. These changes would occur not only in the corn program, but also in the programs for other grains such as wheat, sorghum, oats, and barley. It is estimated that if commodity supports remain at the same levels established in the 1985 Food Security Act, then ethanol production levels of 2.7 billion gallons by 1995 could result in commodity program savings of about $9 billion between 1987 and 1995. However, there is a possibility for increases in Commodity Credit Corporation stocks of soybeans if the price of soybeans decreases sufficiently. Soybeans are covered by non-recourse loans, but generally soybean farmers have not enrolled in the program because market prices have been higher than the loan rate. Between 1987 and 1995, it is estimated that Federal tax losses due to the excise tax exemption on a 2.7 billion gallon ethanol industry would be about $5 billion. This estimate is for the Federal Government only and does not include the exemptions given by many States. Thus, between 1987 and 1995, the Federal Government could save approximately $4 billion from expanded ethanol production. However, if the analysis is continued to the year 2000, the tax losses from exemption of ethanol exceed the gains from lower commodity payments, and cumulative tax losses from 1987 to 2000 exceed the cumulative commodity program gains over that time (51,52).

Rural Development—The ethanol industry will contribute to rural development mainly through the construction and operation of ethanol production plants. It is difficult to estimate precisely what the impact will be. Ethanol production is not labor-intensive; large plants employ approximately 50 to 150 permanent workers. It is estimated that expansion of ethanol production to the 3-billion-gallon level could potentially directly employ an additional 3,000 to 9,000 workers. Additional community jobs to provide services could be of the same magnitude (51,52).

Environmental Impacts—Using ethanol in fuel blends and as an octane enhancer could help reduce carbon monoxide (CO) levels in the atmosphere, and potentially increases hydrocarbon emissions (51,52). Additionally, increasing prices for corn will cause farmers in the Corn Belt to switch acreage from soybean production to corn production. Corn is a fairly chemical-intensive crop, so there may be groundwater contamination issues to consider, as well as the impacts from a potential increase in monoculture production in this region.

Due to the complexity and extent of interaction among agricultural commodity markets, developing a new use for one commodity can have significant, and perhaps unexpected impacts on other commodities. Because different crops predominate in different geographical regions of the United States, there could be significant interregional impacts.

Potential candidates (other than those derived from corn starch) for petroleum replacement are the fatty acids and resins discussed in this report. Opportunities for vegetable oils to replace linear alcohols and olefins derived from petrochemicals (e.g., ethylene and propylene) depend on improved yields of olefins from oils, and the development of new products in the detergent (12 to 18 carbon range) and the plasticizer (6 to 10 carbon) ranges. Also important is the potential of biomass-derived glycerin to replace petrochemically derived glycerin, because the first step in preparation of fatty alcohols and olefins involves the conversion of triglycerides to methyl ester and glycerin (22). The extent to which petroleum replacement has already occurred and the potential for further replacement needs additional analysis, but industry trends and expectations can be discussed for some industries.

Detergent Industry

Vegetable oils (coconut and palm kernel) and petroleum-derived ethylene can be used to produce linear alkylate and alcohol surfactants, chemicals used in the production of soaps and detergents. Global production and percent of linear alkylate

increased corn prices. Additionally, producers of other grains, for example wheat, may also experience higher incomes if the prices of these grains also increases. Soybean farmers will lose income because of the competition in the oil and high-protein meal markets. The differential price changes for grains and soybeans could result in interregional income shifts. Farmers in the Corn Belt can switch soybean acreage to corn. Producers m the Southern United States, particularly the Delta region cannot. It is estimated that farm income in that region could decrease by 5 to 7 percent. Total gross receipts from crop production are expected to increase $1 to $2 billion if ethanol production is increased to 2.7 billion gallons (51,52).

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Environmental lmpacts--Using ethanol in fuel blends and as an octane enhancer could help reduce carbon monoxide (CO) levels in the atmosphere, and potentially increases hydrocarbon emissions (51,52). Additionally, increasing prices for corn will cause farmers in the Corn Belt to switch acreage from soybean production to corn production. Corn is a fairly chemical-intensive crop, so there maybe groundwater contamination issues to consider, as well as the impacts from a potential increase in monoculture production in this region.

Due to the complexity and extent of interaction among agricultural commodity markets, developing a new use for one commodity can have significant, and perhaps unexpected impacts on other commodities. Because different crops predominate in different geographical regions of the United States, there could be significant interregional impacts.

Potential candidates (other than those derived from corn starch) for petroleum replacement are the fatty acids and resins discussed in this report. Opportunities for vegetable oils to replace linear alcohols and olefins derived from petrochemicals (e.g., ethylene and propylene) depend on improved yields of olefins from oils, and the development of new products in the detergent (12 to 18 carbon range) and the plasticizer (6 to 10 carbon) ranges. Also important is the potential of biomass-derived glycerin to replace petrochemically derived glycerin, because the first step in preparation of fatty alcohols and olefins involves the conversion of triglycerides to methyl ester and glycerin ***(22). The*** extent to which petroleum replacement has already occurred and the potential for further replacement needs additional analysis, but industry trends and expectations can be discussed for some industries.

Detergent Industry

Vegetable oils (coconut and palm kernel) and petroleum-derived ethylene can be used to produce linear alkylate and alcohol surfactants, chemicals used in the production of soaps and detergents. Global production and percent of linear alkylate

potentially cultivate an additional 100 to 140 million acres. Some of this land is planted to pasture used for livestock grazing. Some is held in small or fragmented holdings and faces competition from nonagricultural uses; conversion to crop production will be relatively expensive and expected returns need to be high enough to offset the conversion costs (4,44). Additionally, much of the land removed from crop production is fragile and subject to soil erosion. Through 1990, 33.9 million acres of land had been enrolled in the Conservation Reserve Program[15] (50,56). If these acres are to be returned to crop production, extreme care in crop selection will be needed.

The acreage required[16] to grow crops that would significantly reduce U.S. petroleum fuel use would be substantial (table 3-18). To replace U.S. petroleum-derived ethylene with cornstarch-derived ethylene, would require production of approximately 27 million acres of corn.[17] Current U.S. production levels of ethanol from cornstarch replace no more than 1 percent of the gasoline used in the United States. Using soybeans to replace just the agricultural uses of diesel fuel would require increasing soybean production by nearly 10 million acres over current production levels.[18] Using crops such as sunflowers or the new crop rapeseed, which produce substantially higher levels of oil per acre than soybeans, would decrease the acreage needed, but even so, a significant portion of U.S. crop acreage would need to be devoted to fuel production.

Crop acreage needed to supply total demand for commodities which would substitute for those currently imported (i.e., oils and resins), will be determined by domestic demand and export potential. A rough approximation needed to satisfy current U.S. demand can be made (table 3- 19). Calculations are based on *current* imports of oils, resins, and fibers for which the new crops could substitute, and include demand for both food and nonfood uses.[19] Hence, some calculations may overestimate the acreage needed to satisfy industrial uses. Acreage needs may also be overstated because yields of new crops are based on levels currently obtainable, not necessarily those that would be needed for economic viability .20 (See app. D, table D-1 for calculation details.)

Table 3-18-Estimated Acreage Needed To Supply One Billion Gallons of Fuel[a]

Crop	Fuel replaced	Acreage
Soybeans	Diesel	22 million
Sunflowers	Diesel	16 million
Rapeseed	Diesel	8 million
Ethanol	Gasoline	3.5 million

[a]oestimate petroleum replacement, calculations must reestimated on an energy basis rather than a volume basis (vegetable oils and ethanol have a lower energy content than diesel fuel and gasoline respectively, and would therefore require a greater volume to achieve the same energy content) and energy requirements needed to grow and process the agricultural commodities need to be considered. Agricultural commodity yields were assumed to be the U.S. average, 1984-88.

SOURCE: Office of Technology Assessment, 1991.

Table 3-19—Estimated Acreage Requirements for Selected New Crops To Replace Imports[a]

New crop	Imported crop	Estimated acreage (million of acres)
Cuphea	Coconut oil	1.40
Cuphea	Palm kernel oil	0.56
Lesquerella	Castor oil	0.33
Stokes aster	Converted soybean oil	0.49
Vernonia	Converted soybean oil	0.68
Crambe	Rapeseed oil	0.29
Rapeseed	Rapeseed oil	0.24
Guayule	*Hevea* rubber	3.60
Kenaf	Newsprint	1.00
Soybean oil	Printing inks	1.01

[a]Estimations were based on 1987 levels of U.S. imports and yields of new crops obtained in experimental plots. Calculations involving-oilseeds are based on fatty acid equivalents.

SOURCE: Office of Technology Assessment, 1991.

[15]The Conservation Reserve Program removes highly erodible and/or environmentally sensitive cropland from production for a period of 10 years. It is authorized to remove 40 to 45 million acres.

[16]A thorough estimation of acreage needs to displace petroleum-derived fuels using agricultural products would require calculations breed on energy content (rather than volume), net energy requirements (energy required for production and processing subtracted), and average crop yields that could be expected if production significantly expanded (rather than current U.S. averages). If these factors were included, acreage requirements would likely be greater than those estimated.

[17]This calculation assumes that 34 pounds of starch can be obtained from a bushel of corn, and 3 pounds of starch are required to produce 1 pound of ethylene.

[18]The United States annually consumes approximately 40 billion gallons of diesel fuel, and about 3 billion gallons are used in the agricultural sector.

[19]Calculations for soybean inks are breed on current U.S. use of 400 million pounds of printing inks (~&~@ *of Food and Agriculture*, ''sOybWIl Oil Inks," vol. 2, No. 2, July 1990).

[20]To be economically competitive, many new crops will require higher yields per acre than are now obtained in experimental plots. Higher yields per acre mean fewer acres are needed to produce the output. For example, currently obtainable guayule yields (500 lbs/ac) are less than the 1,200 lbs/ac estimated to be needed for economic competitiveness.

Rough calculations of U.S. acreage needed to replace current world production levels for some of these imported agricultural commodities can approximate export potential (table 3-20).

These estimates represent upper levels based on *current* world demand. Total acreage needs would depend on the potential to expand demand for these commodities beyond current levels, and the ability of the new crops to capture a significant percentage of the world market share. One would not expect U.S. production of new crops to displace world production completely. New crops will, in many cases, be substitutes for these imported crops and, therefore, they will compete with each other for many of the same markets. Large supply increases (without sufficient demand increases) will decrease the price of all substitutes and affect the production levels and market share of all substitute commodities.

Increasing global capacity to produce, process and manufacture products from agricultural commodities will affect the potential for U.S. exports of these products. Other countries (e.g., Argentina and Brazil for soybeans and Canada and the European Community for edible quality rapeseed) have demonstrated a capacity to increase production in response to favorable prices. Guayule can readily be grown in Mexico. Supply of lauric acid oils is expected to increase to 7.1 million tons by the year 2000 (i.e., 3.7 million tons of coconut oil and 3.4 million tons of palm kernel oil), due primarily to the maturation of high yielding palm trees planted in Asia (1,14). The International Agricultural Research System and multinational seed companies are increasing the ability to rapidly transfer and adapt new seed varieties to many countries in the world (35).

Developing and newly industrialized countries are increasing their capability to produce products from agricultural commodities for their own domestic use, and in some cases are beginning to capture market share in world markets. For example, most of the new capacity to produce natural oil surfactants has been built in Third-World or newly industrialized nations; the industry has overcapacity, and is still expanding. Prior to 1986, U.S. producers supplied the linear alkylate and alcohol surfactant demand in the United States and Canada. Now, 5 to 10 percent is supplied by imports from Western Europe and Third World nations (14). Analysis of the U.S. potential to capture market share for both raw and processed products derived from agricultural commodities is needed.

Table 3-20-Estimated Acreage Needed To Replace World Supplies

Imported crop	New crop	World production (million lbs.)	Acres needed (millions)
Coconut[a]	Cuphea	2.77	7.6
Palm kernel[a] . .	Cuphea	1.48	4.5
Rubber	Guayule	9,250	18.5
Castor[c]	Lesquerella	1,705	1.1
Newsprint[d]	Kenaf	33[a]	4.7

[a]world production levels are 1989/1990 preliminary estimates of coconut and palm kernel oil in million metric tons. Acreage calculations based on acres needed to obtain an equivalent amount of lauric acid as would be obtained from the coconut and palm kernel oil. Source: U.S. Department of Agriculture, Foreign Agricultural Service, World Oilseed *Situation and Outlook,* November 1990.

[b]World production level is in million pounds and is based on 1990 estimates of world rubber production of 25 billion pounds, 37 percent of which is natural rubber. Source: Stephen Stinson, "Rubber Chemicals Industry Strong, Slowly Growing Despitee Changes," *Chemical and Engineering News,* May 21, 1990, pp. 45-66.

[c]World production level is in million pounds of castor beans, and is based on 1984 to 1986 production of selected countries (including Brazil and India). Calculation is based on pounds of Lesquerella seed needed to replace castor beans. Source: U.S. Department of Agriculture, Economic Research Service, "World Indices of Agricultural and Food Production, 1977-86," March 1988.

[d]world production is in million tons and based on U.S. consumption of 12.3 million metric tons being 41 percent of world consumption. source: Fred D. Iannazzi, 'The Economics Are Right for U.S. Mills To Recycle Old Newspapers, *Resource Recycling,* July 1989, p. 34.

SOURCE: Office of Technology Assessment, 1991.

Future increases in recycling efforts may also affect virgin commodity needs. For example, in 1987 the United States consumed approximately 12.3 million metric tons of newsprint (41 percent of world consumption). Approximately 32 percent is recycled. Of the newsprint manufactured in the United States, 24 percent of the fiber used is from recycled newsprint while 76 percent is virgin fiber. Newsprint made from 100 percent recycled newsprint is generally of lower quality than that made with virgin fiber, but room exists for significant increases in recycled newsprint, which could reduce the use of virgin fibers for this use (18). Some studies indicate that mixing kenaf with recycled newspaper pulp improves the strength and brightness of the recycled paper; the role that kenaf could play in recycling needs further study.

Determination of the acreage needed to produce agricultural crops for industrial uses has implications for the U.S. Gross National Product (GNP) which would be affected by additional production and use of idled resources. Replacing imports with domestic production could increase U.S. income.

The average value of U.S. vegetable oil imports[21] for the fiscal years 1986 through 1988, was $591 million per year. The value of U.S. imports of rubber and gums for the same time period was approximately $759 million per year (58). Annual U.S. imports of newsprint are valued at approximately $4.5 billion (11).

Additional impacts could result from value added in the agricultural sector. The agricultural sector consists of the farm sector, upstream activities related to farming (i.e., firms that supply agricultural inputs and services) and downstream activities (i.e., firms engaged in the storage, processing, transport, manufacturing, distribution, retailing, consumption, and export of agricultural products). The food and fiber system accounts for about 18 percent of the U.S. GNP; farming accounts for 2 percent, upstream activities account for about 2 percent, and the remaining 14 percent results from the downstream activities (16,21). Currently, excess capacity exists in the farm sector and many of the downstream activities. This implies that the impacts of small changes in price and production volume would be limited to the farm sector. Changes in upstream activities occur at higher prices and volumes than in the farm sector, and downstream activities require highest levels of change.

Ultimately however, it is necessary to decide whether using all excess capacity is wise or whether it is better to maintain some excess capacity. Recent dry weather has reduced surplus stocks to minimum levels. Rebuilding stocks will require planting additional acreage. Without some excess capacity, the ability to respond to factors beyond our control would be hampered. Maintaining at least some excess production capacity may provide a measure of food security.

Premature Commercialization

Premature commercialization of new industrial agricultural products can indefinitely delay successful marketing. The development of degradable plastics to alleviate solid waste and litter problems illustrates this point. In the early stages, environmentalists supported these products for some specific uses, such as six-pack beverage rings. However, as product types and claims of effectiveness multiplied, criticism emerged. The products were marketed without a clear definition of, or standards for, degradability. Lawsuits have been filed against some manufacturers of these products for false and misleading advertising. Additionally there have been calls for an end of public sector research on these products, and some states have considered legislation banning their use. Potential markets for degradable plastics are estimated to be declining. Apparently, research for second-generation degradable plastics has been continuing, but confusion and doubts about the appropriateness of these technologies remain with the public and environmental community. It remains to be seen what effect these doubts will have on future efforts to market degradable plastic products (46,49).

Triticale, a wheat-rye hybrid that is high in protein, is an example of a new crop that was introduced (in the 1950s) without clearly establishing its market. From the beginning, triticale was viewed as another wheat, even though its processing qualities were different from wheat and it could not directly substitute for wheat. This problem, combined with yields that were lower than wheat, lead to the foundering of triticale as a new grain crop. Today, triticale is grown in the United States in small quantities, primarily as a forage crop in the Southeast, with some use in specialty baking products (19).

It is enticing to try to commercialize a product as quickly as possible to obtain any potential benefits the product might yield, and unnecessary delays should be avoided. However, commercializing a new crop or product prematurely risks destroying the potential of that new product. A clear marketing strategy that analyzes potential problems is needed.

Summary and Conclusions

The lack of studies evaluating the potential impacts of new industrial crops and uses of traditional crops precludes making definitive statements on what these impacts will be. This chapter is a preliminary attempt to analyze potential impacts, but more detailed analysis is needed. Based on this initial analysis, several conclusions are suggested.

Examination of rural employment impacts during the 1970s when agricultural production rapidly expanded, suggest that development of new crops and uses may result in modest rural employment

[21] Vegetable oils imported include palm, palm kernel, coconut, olive, rapeseed, castor, tung, and linseed oils.

growth in agriculturally related industries. Agriculturally dependent communities would be most affected. However, the majority of the agriculturally related jobs created are likely to be located in metropolitan, rather than rural communities. Additionally, many of the industries that will use chemicals derived from agricultural commodities are already located in metropolitan areas, and in several cases, may require highly skilled labor. Location of new manufacturing facilities in many rural areas will be difficult to achieve.

Development of new industrial crops and uses of traditional crops does have the potential to provide a domestic source of strategic and essential industrial materials. Technically, biomass-derived chemicals could also potentially replace many petroleum-derived chemicals. The major constraint is economics. The chemical industry is highly integrated, flexible, and has large economies of scale. Penetration of many of these markets is difficult. Additionally, some of these markets are large (i.e. fuel and primary chemical feedstocks) and significant replacement would use millions of acres of cropland, have far-reaching environmental implications, and could significantly increase food prices.

The benefits of new technologies are captured by those who first adopt the technology. A strong correlation exists between early adoption and size of farm enterprise. It is likely that operators of large farms will adopt new crops before operators of small farms and, therefore, capture these benefits. For traditional crops covered by Federal commodity programs, market prices must increase enough to exceed price support levels to have a large impact on farm income. The extent to which small farm operators are enrolled in commodity programs will determine how changing market prices affect their income levels. Programs that help small farm operators become early adopters of new technologies will improve the chances of these farmers benefiting from new industrial crops and uses of traditional crops.

The development and production of new industrial crops and uses in the United States could, in some cases, replace major exports of some developing nations, some of which are considered to be of strategic importance to the United States. Additionally, attempts to increase exports of some of the products has the potential to increase trade frictions between the United States and the European Community.

The United States currently has excess agricultural production capacity. Large scale replacement of U.S. fuel use or primary chemical feedstocks would require significant acreage for crop production, however, economics do not favor these developments at the current time. Use of agriculturally derived chemicals to replace some of the oils and resins currently imported is not likely to reduce excess agricultural capacity significantly given current demand and supply conditions.

The ability of new crops to reduce Federal commodity payments will depend on whether or not acreage is shifted from production of crops that are federally supported to those that are not. New uses of traditional crops that are supported, will reduce commodity payments if the new use is not itself subsidized.

Development of new industrial crops and uses of traditional crops will have many environmental impacts, some positive, and some negative. Potentially, new fuels could improve air quality. New crops that are better adapted to their environments potentially could reduce erosion and demand for irrigation. However, many new crops are not native to the United States and problems can and do arise from the introduction of new species. Additionally, many of the crops may be genetically engineered; several environmental issues are raised by this possibility.

As with any new technology, there will be winners and losers. Many new industrial crops and uses of traditional crops potentially will compete with traditional crops. Improved understanding of these impacts is needed.

The lack of studies evaluating the potential impacts of new industrial crops and uses of traditional crops points to the need to fired social science research in addition to the physical, chemical, and biological research. Interdisciplinary research can provide insights into the likely effects that will result from the development of these new technologies, as well as factors that affect the development of the technologies themselves.

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