Another development is in the formulation of heat-set soy inks for magazine and periodical publishers. Although available since 1989, heat-set soy inks have yet to make a mark in the magazine market. In a heat-set printing process, the printed paper is dried in an oven where the mineral oil portion of the vehicle is quickly evaporated. Because soy inks dry by oxidation, current heat-set formulations take over 2 hours to dry in the same oven that dries conventional inks in 15 to 30 minutes.

In order to improve the drying time and the overall quality of heat-set soy inks, new formulations containing resins and special solvents have been introduced. However, price is a problem. Since resins are expensive, costing as much as $2.00 to $3.00 per pound, even a small percentage incorporated into a formulation pushes the cost of soy inks beyond a competitive price range. Even so, formulas are being improved, and many companies are beginning to produce and market heat-set soy inks.

Why do printers use soy-based inks?

- Improved press operation and clean up.
- Lower worker exposure to harsh petrochemicals.
- Reduced emissions of volatile organic compounds. VOC's are one of the principal components in chemical reactions in the air that form ground-level ozone, a pollutant in the lower atmosphere that can cause respiratory problems. Compared to petroleum-based inks that have VOC ratings of 25 to 40 percent, all soy ink manufacturers report VOC ratings of less than 10 percent. Most color soy inks are in the 2- to 4-percent range.
- Great marketing benefits--highlighting the environmental advantages of soy inks.

Soy inks also have an advantage in recycling paper. When paper is recycled, the pulp must de-inked. Researchers at Western Michigan University have found that soy inks de-ink faster and more cleanly than conventional petroleum-based inks. The soy oil releases more easily from the paper, resulting in longer fibers and a higher quality of recycled paper.

Biodiesel Is a Reality

Biodiesel, a substitute for petroleum-based diesel fuel, can be made from vegetable oils, animal fats, and waste grease. It can be used in unmodified diesel engines in either pure form (i.e., neat) or blended with petroleum-based diesel. Biodiesel has been commercially produced in Western Europe for the last 3 years. Biodiesel's environmental and technical qualities have pushed it closer to commercialization in the United States.

Transesterification produces biodiesel. An alcohol is mixed with a catalyst that is then blended with the vegetable oil or animal fat. Each 100 gallons of vegetable oil combined with 26 gallons of methanol and 8 pounds of sodium hydroxide will make about 100 gallons of biodiesel, about 8 gallons of glycerine, and some mixed fatty acids.

Biodiesel was first commercially made in Austria in 1990 with government support. Recent reforms in the European Community's Common Agricultural Policy and other incentives provided by the individual EC members are likely to encourage increased output of crops used to make the fuel. Methyl ester, the most common type of biodiesel in Europe, is made primarily with rapeseed and sunflowers. Both blended and unblended biodiesel is burned in Europe.

Biodiesel production and use is well advanced in France, Italy, and Germany. The EC now can produce 150,000 to 200,000 metric tons per year of biodiesel. Additional plants are planned that could raise capacity to over 600,000 tons per year. Production of biodiesel in the EC has been estimated at 80,000 tons in 1992.

European government policies are encouraging biodiesel production and use. The governments are using biodiesel as an outlet for agricultural products, a source of rural employment, a substitute for petroleum imports, and to reduce most "greenhouse gas" emissions. However, a recent EC study estimated that the cost of biodiesel exceeds the cost of conventional diesel by an estimated 0.19 to 0.21 ECU per liter (86 to 95 cents per gallon). Still, recent and proposed policy changes of the EC and its member countries can alter the costs considerably:

- ***Member countries' tax policies***. Italy and France, for example, exempt biofuels from taxes levied on hydrocarbon-based fuels. This is a big break, since about 50 percent of the French fuel-pump price is tax.
- ***CAP reform***. Now, most producers must set aside a portion of their cropland to be eligible for a support payment. However, farmers may plant on set-aside land certain crops for industrial uses. This policy could provide an incentive for the production of oilseeds for biodiesel. In 1993, total EC area sown to rapeseed for industrial purposes on set-aside land is estimated to be 250,000 hectares.
- ***EC tax policy***. The EC has proposed permitting its members to give a 90-percent fuel-tax break to biofuels. In addition, the EC has proposed taxing carbon dioxide emissions and the energy content of fuels. Renewable sources of energy would be exempt. Member countries are far from an accord on this tax.
- ***Other programs***. These include research and development funding for industrial uses of agricultural materials, assistance for developing improved varieties, and funding for pilot projects testing biodiesel's viability for public transport.

Biodiesel production and use should grow in the EC over the next several years. But this has also come up in the international trade talks. The "Blair House" agreement between the United States and the EC limits the set-aside area planted to industrial oilseeds to the equivalent of 1 million tons of soybean meal--approximately 2.3 million tons of rapeseed. That would be about 900,000 tons of biodiesel, far above current or planned capacity.

U.S. Use of Biodiesel Depends on Testing, Certification

Several advances are needed before biodiesel is commercialized in the United States: exhaust emissions must be documented using EPA's protocol, the fuel must be certified for use in diesel engines by the American Society for Testing and Materials (ASTM), and the fuel must be accepted by diesel engine manufacturers--to maintain engine guarantees--and the private sector. Coordinated efforts by industry, government, trade associations, and businesses are making rapid progress in each of these areas.

Current testing and research centers around the emissions and long term durability of engines fueled with biodiesel. Groups involved with conducting EPA Transient Cycle engine tests are the National Institute for Petroleum Energy Research (NIPER, Bartlesville, OK), the Southwest Research Institute (SwRI, San Antonio, TX), ORTech (British Columbia, Canada), and FEV of America (Detroit, MI).

NIPER will be starting engine durability tests on engines commonly found in city bus fleets, pickups, and tractors. Testing, which was funded by the National SoyDiesel Development Board (NSDB) and DOE, began in May. SwRI will begin testing SoyDiesel's (biodiesel from soybean oil) effects on engine wear and emissions on another engine that is commonly used in bus fleets in an EPA-approved laboratory. This research was funded by the NSDB and the AARC Center.

Preliminary testing on biodiesel blends was recently completed by ORTech. They showed that a 80/20 blend of clean diesel/SoyDiesel will be capable of meeting all CAAA guidelines for 1995. ORTech will continue their work with biodiesel to determine if retarding engine timing will allow for a reduction in NOx emissions. Results should be available by late summer.

Blend and emissions testing at the University of Missouri show that emissions are influenced by the different design variables of an engine. So each engine on the market today will have different emission reductions with biodiesel. The research also shows that, in general, a diesel/biodiesel blend will reduce harmful emissions and help meet future environmental regulations. FEV of America will begin testing engines this fall. Limited testing of dual-fueled engines has also taken place. Detroit Diesel has been working with a combination of biodiesel and compressed natural gas.

Fuel certification by ASTM could be in one or more of the following categories: as a fuel substantially similar to petroleum-based diesel fuel, as an additive, and as a separate ASTM fuel standard. Although a dedicated biodiesel plant has yet to be built in the United States, biodiesel is currently being marketed. In August 1992, Procter & Gamble agreed to produce up to 15 million gallons of biodiesel for Interchem Industries, Inc. (Kansas City, KS). The biodiesel will be produced from soybean oil and/or animal fats.

Biodiesel sales have been made to bus fleets and maintenance vehicles at airports. Preliminary results from limited bus-fleet tests have prompted more extended studies in some cities, including St. Louis, MO. In Gardena, CA, engine durability and emissions will be examined for city buses to see if California's clean air guidelines can be met with biodiesel. [Lewrene Glaser (202) 219-0085, Irshad Ahmed (202) 232-4108, Donald Van Dyne (314) 882-4512, and Mary Anne Normile (202) 219-0620]

Supercetane Increases Diesel's Punch

Supercetane, derived from plant and tree oils by high-pressure hydrotreating, is a fuel additive used for increasing diesel's cetane value. The cetane value measures the fuel's ability to self-ignite, like the octane value for gasoline. Supercetane derived from plant oils has a cetane value of 90 to 100, and from tree oils a value of 70 to 75. The cetane value of #2 diesel is about 45, while biodiesel has a value of 50 to 55. The minimum cetane value for a fuel used in a U.S. diesel engine is 40. Currently, most petroleum diesel fuel contains synthetic additives to increase its cetane value above 40.

Supercetane is cost-competitive with synthetic cetane enhancers and does not have the diminishing marginal effectiveness of synthetics. Supercetane appears to be more effective than synthetic additives on low cetane-base fuels. The only problem with supercetane is that it has a high pour point (or freezing point); this can be alleviated when the additive is diluted in conventional fuel.

Canola, soybean, rapeseed, palm, sunflower, coconut, and tall oil have all been processed into supercetane. Tall oil, a byproduct of the kraft paper-making process, appears to be the most cost-competitive. Although the tall-oil converted supercetane has a lower cetane value (around 70), tall oil is inexpensive enough to make it an economically viable cetane enhancer.

Production would use petroleum refineries' hydrotreating facilities. Since there are several underutilized facilities in North America, only minimal capital investments would be necessary to begin production. Currently, Arbokem Inc. (Vancouver, British Columbia) is evaluating the costs of building a demonstration plant. [David Pace (202) 219-0085]

Natural Fibers

Kenaf, a tropical fiber crop, is now being commercially grown in the United States. Over 4,300 acres have been planted this year in the South and West. Kenaf is used for *packing materials, bond paper, horticultural mulches, potting mixes, seeding mats, animal litter and bedding, and oil absorbents. Potentially, it could move into the newsprint and paperboard markets.*

Erosion-control products are promising to increase the demand for natural fibers in general. In addition, some countries are increasingly turning to nonwood fibers for paper as local supplies of trees become tighter. Most traditional uses of these fibers--cordage and sacking--have been declining due to the increased use of synthetic fibers and changes in transporting and storing grain. This issue covers kenaf, jute, abaca, hemp, sisal, coir, and milkweed.

In the United States, natural fibers occupy various niche markets, including specialty papers, some cordage uses, horticultural mulches and mixes, and down comforters (figure 8). As environmental concerns heighten, natural fibers are finding their way into new markets, such as manufactured erosion-control products.

Jute, hemp, sisal, abaca, and coir fibers and products are imported. Kenaf and milkweed are produced and processed in this country. (Wood fibers are discussed in the Forest Products Section. Information on cotton and wool is available from *Cotton and Wool Situation and Outlook*; to order call 1-800-999-6779.)

Throughout the world, natural fibers are primarily used for rope, twine, sacking, and mats. Jute, kenaf, and hemp yield bast (stem) fibers that are used for rope, sacking, coarse fabrics (burlap), and mats. Depending on the application, these bast fibers may be substitutes for each other. Sisal is used for twine. Coir, the fiber from coconut husks, is used for mats, brushes, and brooms.

In developed countries, two factors have led to the decline of natural fibers in cordage and sacking. First, plastics and metals have made large inroads into the coarse textile and cordage markets. Second, the shift to bulk grain transport and storage has eliminated much of the need for sacking materials.

Paper is another major use of natural fibers around the world. In countries that are short of wood, paper and paperboard can be made from agricultural residues, natural growing plants, and fiber crops (table 10). In 1990, 21 countries, including China and India, depended on nonwood fibers for more than 50 percent of pulp production, according to Joseph E. Atchison, an expert in the use of nonwood fibers for paper production.

In the United States, flax is the most extensively used nonwood fiber employed in papermaking, except for cotton. The decorticated straw, called flax tow, from oilseed flax varieties--grown for linseed oil and meal in many parts of North America--is the primary raw material used by two U.S. manufacturers for cigarette paper. Byproducts of textile flax varieties--which are grown for their linen fibers--are imported to enhance the properties of cigarette paper and for use in currency paper. Standard U.S. currency paper is 80 percent cotton and 20 percent flax.

Table 10--Nonwood fibers that can be used to make paper

Fiber type	Example
Agricultural residues	Sugar cane bagasse
	Sorghum
	Corn stalks
	Cotton stalks
	Rice straw
	Cereal straws
Natural-growing plants	Bamboo
	Esparto
	Elephant grass
	Reeds
	Sabai grass
	Johnson grass
	Papyrus
Nonwoody fiber crops	
Bast (stem) fibers	Jute
	Ramie
	Crotalaria (sunn hemp)
	Hemp
	Kenaf
	Flax tow and byproducts
	Old rope or rags made from bast fibers
Leaf fibers	Abaca (manila hemp)
	Sisal
	Henequen
Seed hair fibers	Cotton fiber
	Cotton linters
	Cotton rags and textile waste

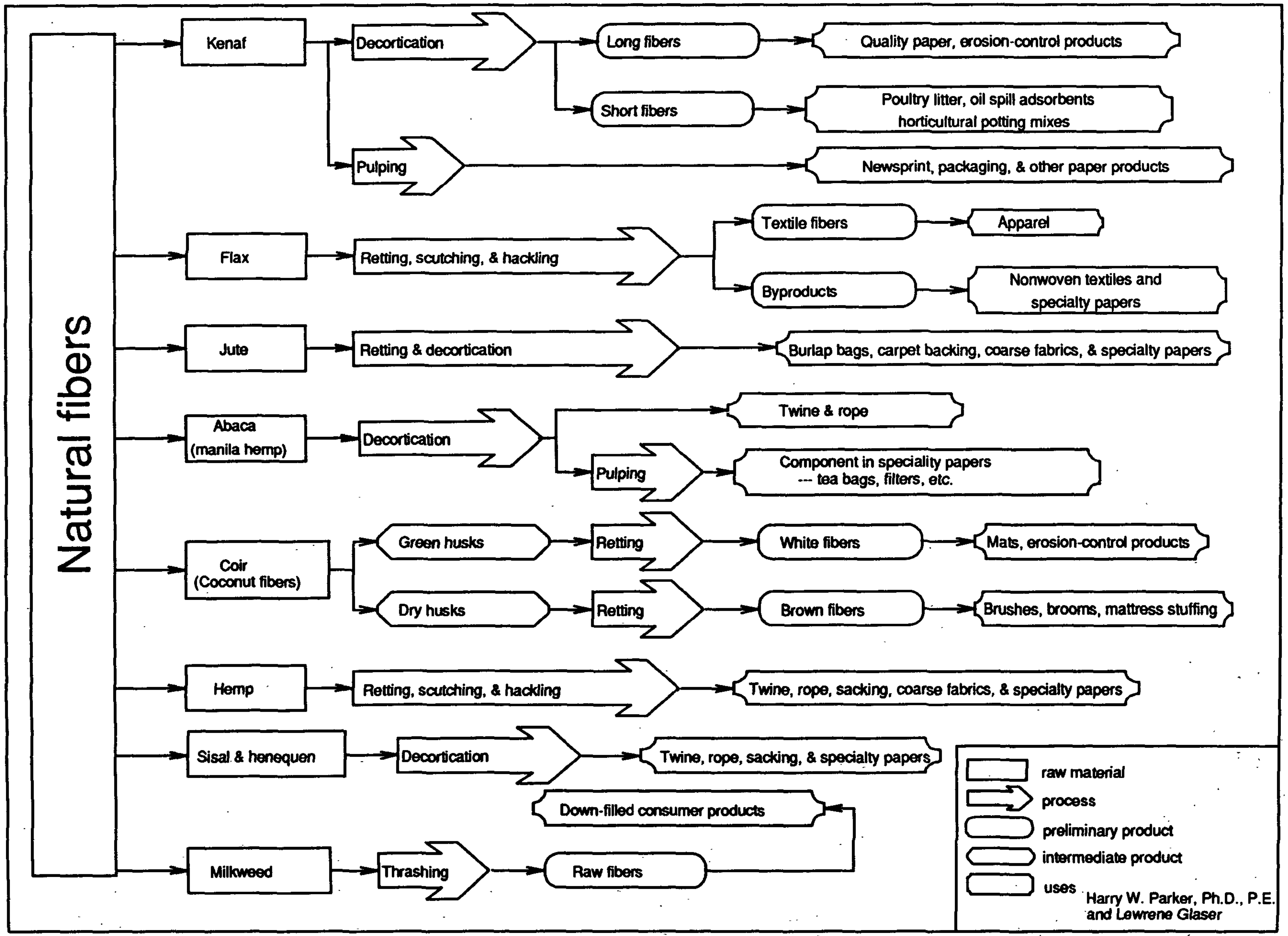
Source: Joseph E. Atchison and John N. McGovern. "History of Paper and the Importance of Non-Wood Plant Fibers." Pulp and Manufacture, Third Edition: Volume 3, Secondary Fibers and Non-Wood Pulping. Joint Textbook Committee of the Paper Industry, 1987, p. 3.

Nonwood fibers have a vast potential for use in many new and expanded product areas. However, each fiber has intrinsic characteristics that make them more or less suitable for various applications. A large-scale shift from wood to nonwood fibers, as some have advocated, would require significant research, development, retooling, and industry restructuring.

Kenaf: A New U.S. Fiber Crop

Kenaf is an annual crop native to the tropics that has traditionally been used as a source of bast fibers. India, China, Taiwan, the former Soviet Union, Iran, Mozambique, Cote d'Ivorie, Nigeria, Guatemala, Thailand, and El Salvador have

Figure 8
Processing Natural Fibers into Industrial and Consumer Products



all grown kenaf in commercial quantities in recent years. About 5,000 acres will be grown in Europe during 1993, mostly in Italy.

Kenaf is a new commercial crop in the United States. Grown mostly in southern and western States, plants can reach 10 to 16 feet in height after a 5-month growing season. In 1992, 1,391 acres were harvested and 4,345 acres are being planted this year for fiber, seed, and forage production (table 11). Another 2,800 acres, planted in Mississippi in 1992, have just been harvested. Yields in 1992 were estimated at 6 tons per acre in Louisiana and 7 tons in California and Texas.

Like flax, jute, and hemp, kenaf stems consist of an outer bark of bast fibers and an inner core of shorter fibers. In kenaf, the bast fibers make up about 30 to 40 percent of the stem, on a dry-weight basis, and the shorter core fibers make up the remainder.

Four companies are now operating fiber separation facilities in the United States. Kenaf International, Ltd. (McAllen, TX) sells bast to companies for making cordage, twine, and bond paper and sells the core for use in soil-less potting mixes, animal litter and bedding, and feed products.

Natural Fibers of Louisiana, Inc. (Jeanerette, LA) sells horticultural mulches, potting soils, packing materials, burlap, and bedding materials. The company also markets a line of oil and chemical absorbent products--compressed bags, burlap pillows, land booms, flotation booms, and loose material--that can be used to clean up land or water-based spills. These kenaf-based products are now listed in the General Service Administration's Federal Supply Schedule, thus allowing Federal agencies to purchase these materials.

Agro-Fibers, Inc. (Angiola, CA) sells bast to manufacturers for packing materials and high-grade pulp and core for animal bedding and as an ingredient in potting mixes. The company uses bast fibers in the production of nonwoven mats that are impregnated with grass seed and polymers for use in landscaping. A wildflower mat and an erosion-control blanket will be introduced later this year or next.

Table 11--Kenaf acreage, United States, 1992-93 1/

State	1992	1993
	--Acres--	
California	560	560
Georgia	--	130
Louisiana	300	260
Mississippi	2,800	2,000
New Mexico	50	205
Texas	481	1,200
Other 2/	--	20
Total	4,191	4,375

-- = Not applicable.
1/ Data for 1992 represents harvested acreage. Data for 1993 represents planted or projected acreage, including acreage for fiber, seed, and forage production. 2/ Arkansas, Florida, and Hawaii.

The Mississippi Delta Fiber Cooperative (Charleston, MS) is replacing a major section of their separation system with modified cotton-ginning equipment. The plant is expected to be up and operational during June. The cooperative is planning to sell bast to specialty pulp and nonwoven manufacturers and core for animal bedding and absorbents.

Both researchers and businesses point to paper and paperboard as major markets for kenaf. Several large-scale demonstration runs have shown that kenaf produced excellent newsprint. USDA research indicates that 25 percent kenaf pulp blended with 75 percent recycled newsprint yielded newsprint with acceptable properties. Successful experiments also have produced bond, surface-sized, and coated papers from kenaf. The bast fiber also has a number of potential applications where high strength and low permeability is required, such as package and wrapping papers.

KP Products Incorporated (Albuquerque, NM) has set up a business to manufacture and sell a high-grade premium printing paper made with kenaf bast fibers. Gridcore Systems International (Carlsbad, CA) is planning to use kenaf fibers in their structural composite panels (see box in Forest Products Section). Kenaf International plans to construct a paper mill to manufacture newsprint made of the entire kenaf stalk combined with recycled fibers.

In the United States today, nonwood fibers are mainly used in specialty applications, including cotton fiber for currency paper, flax tow for cigarette paper, bagasse for insulating board, and abaca for porous-plug wrap paper (the paper that surrounds and holds cigarette filters), tea bags, filter papers, and sausage casings. Wood fibers have made inroads into cigarette paper markets, thus affecting competing fibers.

Another potential market is nonwoven mats and other products. Kenaf and other natural fibers can be used to make nonwoven materials, such as interior automotive paneling and landscaping mats. The technology is similar to that used to make disposable diapers and other textiles.

Milkweed Reaches Niche Markets

Milkweed is being grown in Nebraska for its floss, the hairy fibers attached to the seed. Natural Fibers Corporation (Ogallala, NE) was formed in 1987 to commercialize products using milkweed floss. Milkweed is a perennial; commercial stands should last 5 to 10 years. A modified self-propelled corn picker is used to harvest milkweed pods. After harvest, the pods are cracked open and the floss is dried and separated.

Milkweed floss was used in life jackets during World War II. It has about the same density, slightly higher insulating capacity, and better durability than high-quality goose or duck down. The fibers are water resistant and nonallergenic. These characteristics--combined with the light weight of the floss--make it a good candidate for filler in comforters, sleeping bags, and insulated clothing. Natural Fibers Corpo-

Kenaf Forage a Possibility

In addition to other possible uses, kenaf also has the potential to become a forage crop. Researchers from the Agricultural Research Service laboratory in El Reno, OK, and Oklahoma State University (OSU) began studying kenaf as a potential forage in 1989. Although a long way from commercial production, kenaf forage is an example of a new use in the beginning stages of research and development and is illustrative of how new crops are developed.

In the Southern Plains, the predominant farm enterprise is winter wheat and stocker cattle. The wheat is harvested in early June and the land traditionally remains idle until wheat is planted in September. Thus, the soil is left exposed during the hot dry summer months and wind erosion may be considerable. Livestock graze on warm season grasses from May through August, but additional forage is needed in the fall.

Having access to forage on farm is a major benefit to farmers in the Southern Plains, and kenaf's short growing period for forage offers an advantage over other annual forages, like sorghum, cow peas, and mungbeans. The results of production and feeding trials lend support to the idea of using immature kenaf as a quality forage. In addition, an enterprise budget developed by OSU researchers indicated that the addition of kenaf to the wheat-stocker enterprise could increase net returns by $16.24 per acre.

Kenaf is being analyzed as a potential livestock forage because of its high protein content, ability to withstand heat and drought, multiple harvesting times, and relatively high yields. Although some farmers have already begun to experiment with kenaf as a forage, widespread commercialization must wait for more precise production and use information including:

- Selection and development of forage varieties,
- Identification of proper planting conditions for forage,
- Development of optimal cultural practices,
- Determination of the effect of forage production on soil moisture,
- Determination of the optimal harvesting time,
- Identification of the best harvesting methods, and
- Identification of feeding methods that may improve palatability and digestibility.

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ration is manufacturing comforters filled with a mixture of milkweed floss and goose down. Virtually all goose and duck down is imported.

The company is developing markets that match its 40,000-pound production capacity. Low yields are an obstacle to developing milkweed as a commercial crop for high-volume uses. Company and university researchers are working together to overcome the technical barriers to milkweed production and use, including yield improvement and product analysis.

As market demand, yields, and production increase, milkweed floss could be competitive in higher volume, lower value markets, such as nonwoven textiles and absorbent pulp products. Because the floss absorbs 75 times its weight in liquid once stripped of its wax coating, possible uses include disposable diapers and other super-absorbent products.

Many Natural Fibers Are Produced in Tropical Countries

Jute is a tropical crop grown mainly in India and Bangladesh. The plants are annuals, which take 3 to 5 months to mature. At harvest, stems are cut and taken to retting pools or ditches. Retting loosens the bast fibers from the inner part of the stem. Retting can last 1 to 4 weeks, depending on conditions. The bast fibers are then separated from the rest of the stem, usually manually, and dried.

According to a November 1992 report of the Intergovernmental Group on Jute, Kenaf, and Allied Fibers (an entity within the U.N. Food and Agriculture Organization [FAO]), the percentage of jute products traded internationally in 1990 was about 27 percent of estimated total use, compared to 42 percent in the mid-1960's. This decline resulted from increased use of jute in producing countries and a decrease in overall utilization. Between 1980 and 1990, imports of jute products into developed countries fell by 23 percent. Some rise in imports of yarn was offset by declines in imports of sacking, hessian cloth, and other products.

Abaca (manila hemp) is obtained from the leafstalks of a member of the banana family. A few stalks may be cut from each plant every 4 months for several years. The fibers are stripped from the leaves either by hand or mechanically. The major producing countries are the Philippines and Ecuador, with the Philippines accounting for nearly 85 percent of world output. In a reversal of historic trends, Philippine abaca has been more expensive than Ecuadorian in the past few years due to unstable socio-political conditions, recent natural disasters, and poor climatic conditions.

Like jute and hemp, abaca was widely used for cordage. However, following the development of man-made fibers in the mid-1960's, demand for abaca cordage declined markedly. FAO's Intergovernmental Group on Hard Fibers estimates cordage uses at less than 20 percent of world abaca output. Today, abaca fibers are mainly used in the manufacture of high quality specialty papers, such as porous-plug wrap paper, tea bags, stencil-base tissue, meat sausage casings, dust filters, and a number of other applications. The variability of quality supplies and periodic high prices have hampered abaca's use in other grades of paper. Specialty paper manufacturers have undertaken the search for alternative materials, such as sisal.

Sisal is a perennial crop grown in Brazil, Kenya, Tanzania, Madagascar, Haiti and other tropical countries. A related plant, henequen is grown in Mexico and in other central American countries. The term sisal generally refers to both fibers as they are used for the same end-products. Leaves are harvested at 6- to 12-month intervals, and the fibers are stripped from the leaves and dried. Sisal is primarily used as a bailing twine. Since the mid-1960's, however, polypropylene twines have progressively taken over the market. Correspondingly, the area under sisal cultivation has fallen. Because of lower prices, growers have converted their fields to pasture or abandoned them.

Coir is the fiber obtained from the husk of coconuts. Its outstanding characteristic is its resistance to rot. Although coconut is grown in a number of countries, commercial coir production in centered in India and Sri Lanka. Immature and mature husks are retted and the fibers separated by hand or mechanically to obtain white (yarn) fiber and brown (bristle and mattress) fiber. Coir yarn is now used mainly for the manufacture of floor coverings, such as door mats, matting, and rugs. Synthetic fibers now dominate traditional cordage markets. Bristle fibers are primarily used in brushes and brooms.

Hemp, which is also called common hemp or marijuana, is an annual that can be grown in both temperate and tropical climates. Like jute, the stalks must be retted after harvest to separate the bast fibers from the rest of the stem. This can be accomplished by water retting in ponds or by dew retting--leaving the stalks in the field for a period of time.

Very small amounts of hemp fiber are imported into this country for use in rope, twine, and other cordage products. A new use under development is fiberboard. C&S Specialty Builder's Supply Inc. (Harrisburg, OR) was incorporated in 1991 specifically to reestablish the use of hemp for industrial purposes. C&S is developing straw/hemp-based medium density fiberboard. The company plans to import the hemp fiber from China. Plant breeders in various parts of the world are reportedly developing varieties that are low in psychoactive compounds. Worldwide, hemp is used for cordage and cigarette paper.

Erosion-Control Products Open New Markets for Natural Fibers

Erosion-control systems are a new product area for natural fibers that have the potential for fast market growth. For civil engineers and landscaping firms, the tools and materials for erosion control have been around for quite awhile, but it is only in the last 8 to 10 years that manufactured erosion-control products have become available.

According to the Industrial Fabrics Association International (IFAI), the erosion-control market can be divided into two broad categories. Synthetic erosion-control materials, including woven plastic fabrics and mats, are used in applications that are meant to last, such as ditch liners and drainage systems. Organic erosion-control materials--including natural fiber mulches, meshes, and mats--offer temporary soil stabilization and vegetative stand establishment.

IFAI estimates that the erosion-control market is growing at an annual rate of 10 to 15 percent. Organic erosion-control systems are estimated to consume 35 to 40 million square yards of material, while synthetic systems use 20 to 35 million square yards. Natural fibers used for erosion control--such as kenaf, jute, and coir--have advantages, according to the IFAI. They generally cost less, hold moisture better, and are easier to sell and promote when compared to synthetic materials. Also, when the fibers decompose, they add organic matter and nutrients to the soil.

Several companies across the country are using natural fibers in erosion-control and nursery applications. For example, Belton Industries, Inc. (Atlanta, GA) offers a range of coir-based meshes and fabrics for soil stabilization, reinforcement, and landscaping. B&M Packaging Co., Inc. (Charlotte, NC) sells jute mesh for erosion control in landscaping applications. [Lewrene Glaser (202) 219-0085]

Animal Products

According to industry estimates, the value of the beef-byproduct industry is $3 billion a year, with most of that going for industrial uses. In 1992, almost 5.8 billion pounds of inedible tallow was produced in the United States--half was exported. During 1990-92, U.S. production of inedible rendered products rose very slightly. Domestic use slipped *over 12 percent, while exports rose nearly 13 percent. That partly reflects a switch by U.S. consumers to liquid soap from bar soap.*

During 1990-92, poultry byproducts processed in the United States increased almost 21 percent. Most went to the domestic feed industry.

In 1993, at least seven plants are using cheese whey to produce ethanol. They have a combined annual capacity to make 7.5 million gallons of ethanol. Wash water solids (WWS), another waste product of the cheese industry, is showing promise as a feed.

Use of animal products in pharmaceuticals is on the upswing. And use of genetically engineered animals for human medical products is just beginning. Use of manure to make methane as an alternative energy source is also being evaluated. These topics will be covered in the December issue. See figure 9 for a description of how animal products move from the farmgate to the industrial marketplace.

U.S. Processing of Hides Is Rebounding

In 1989, about 70 percent of U.S. cattle hides were exported for processing. That's because processing hides with traditional techniques domestically was very costly. Those techniques generated hazardous waste products with high disposal costs. As new, more environmentally friendly technologies have been developed, domestic hide processing in the United States has begun to rebound.

By 1992, domestic processing increased to about 35 percent. Through the first quarter of 1993, the share processed domestically increased from 40 to 46 percent. Cattle hide exports in 1992 were slightly over 19.1 million pounds valued at $1.04 billion.

Hides come from cattle, hogs, horses, goats, and sheep, as well as other more unusual animals including deer, kangaroo, buffalo, dog, salmon, seal, walrus, shark, porpoise, whale, sturgeon, alligator, crocodile, and lizard. The estimated value of the hide from an average beef steer in 1992 was $43.08. Value of other byproducts included: $2.16 for edible tallow, $8.04 for inedible tallow, and $18.60 for variety meats. Hides account for most of the total byproduct value.

Hides are used in making leather, as a base for many ointments, and as an insulation material. Ten years ago, about 70 percent of animal hides were used in making shoes in the United States; this has decreased to about 50 percent today. Leather for automotive upholstery now accounts for about 25 percent of animal-hide use. Hair from the hide can be used to make rug pads and high-quality brushes. Hides are also a source of gelatin.

Domestic Inedible Uses of Rendered Products Declines

Edible animal fats may be produced only from edible carcass parts maintained under approved USDA conditions. The beef and pork fats in margarine are two examples of how edible fats are used. All other fats are classified as inedible--not for human consumption. In 1992, almost 5.8 billion pounds of inedible tallow were produced in the United States, with about 2.3 billion pounds being exported (table 12). An additional 2.5 billion pounds of lard and edible tallow were produced in the United States.

Almost 5 billion pounds of edible and inedible tallow and lard were consumed domestically, with the largest single use as an ingredient in livestock and poultry feeds. However, tallows and fats are used as feedstocks in many industrial oils and lubricants. Specifically, they are used for tanning, soap, and to produce glycerine used in cosmetics.

The domestic consumption of inedible tallow for soap was 398.4 million pounds in 1989/90 (table 24). By 1992, consumption had decreased to 334.4 million, or over 15 percent. This reflects consumers shifting from bar to liquid soap, which is made from plant, rather than animal products.

Domestic use in lubricants slipped 42 percent during the same period. However, feed use rose more than 11 percent between 1991 and 1992. Use of lard for inedible purposes rose to 134.6 million pounds, up nearly 70 percent from a year earlier (table 25).

Fatty acids from animals are being used in increasing quantities in a variety of products, including abrasives, shaving cream, asphalt tile, lubricants, candles, caulking compounds, cement additives, cleaners, cosmetics, deodorants, paints, polishes, perfumes, plastics, printing inks, synthetic rubber, and water-repellent compounds.

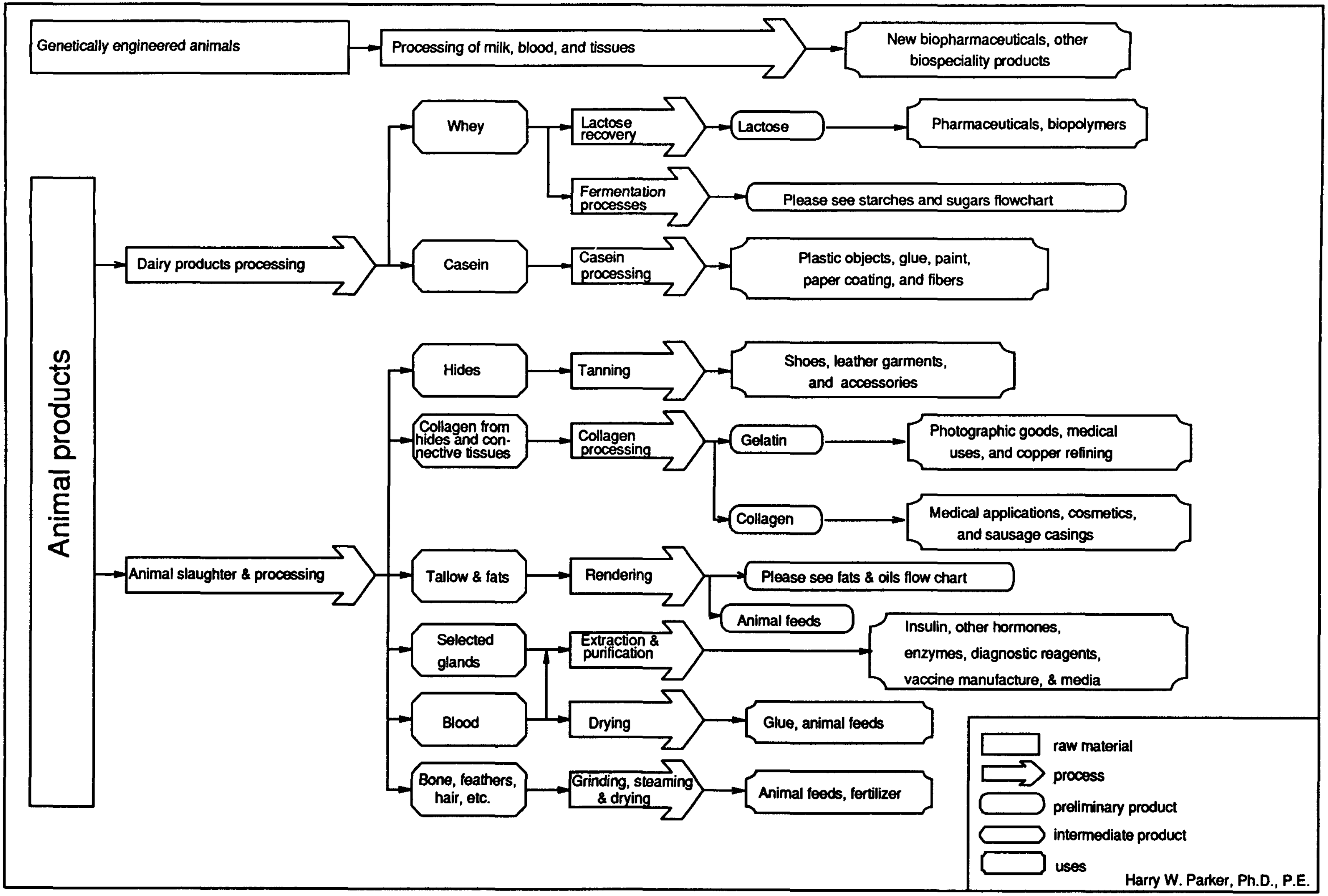
Table 12--Production and distribution of rendered products in the United States, 1990-92

Year	1990	1991	1992
	--Million pounds--		
Production			
Inedible tallow	5,723	5,718	5,775
Edible tallow	1,207	1,255	1,530
Lard	880	914	987
Meat and bone meal	5,060	5,240	5,230
Feather meal	564	617	682
Poultry byproduct meal	902	987	1091
Total	14,336	14,731	15,295
Domestic consumption			
Inedible tallow	3,285	3,078	2,888
Edible tallow	930	938	1,220
Lard	807	816	872
Total	5,022	4,832	4,980
Exports			
Inedible tallow	2,028	1,939	2,291
Edible tallow	252	285	332
Lard	87	120	136
Meat and bone meal	207	216	336
Feather meal	75	62	76
Total	2,649	2,622	3,171

Source: Render, April 1993, p. 12.

Figure 9

Processing Animal Products into Industrial and Consumer Products



Bones and bone meal are valuable animal byproducts used in a variety of products. Bone meal is used primarily in specialty fertilizers, but also as a feed ingredient in various animal rations. In 1992, over 5.2 billion pounds of meat and bone meal (MBM) were produced in the United States. Most was used domestically, with an estimated 336 million pounds being exported (table 12). Bones are also used to make: buttons, bone china, glues, adhesives, gelatin for photographic film, paper, emery cloth, sandpaper, and combs.

Inedible blood is used to make shoe polish and in leather sizing. It is also used as a feedstock for glues and animal feeds. Dried blood contains about 87 percent protein. It can also be used by calico printers in fixing certain pigment colors in cloth. Dried blood imports were valued at $619,000 in 1991/92.

Poultry Waste Recycling Is on the Rise

Most poultry processing byproducts are recycled as feed. This includes byproducts from processing plants, prematurely dead birds, and hatchery wastes. Waste products from poultry rendering plants (poultry tankage) includes feathers and the remainder of products not used for other purposes. From 1990 to 1992, the volume of poultry byproduct meal produced in the United States increased from 902 million pounds to over 1.1 billion pounds, an increase of almost 21 percent. Most of this was used in the domestic feed industry.

Feather meal is a concentrated source of protein. It is the richest common source of the amino acid cystine. The amino acids in feather meal have been shown to be 94- to 98-percent available to chicks in feeding trials. Feather meal has become a widely accepted and dependable feed ingredient. Properly processed feather meal is very uniform because it is a single-source protein. Such proteins have a relatively constant composition and amino acid profile.

Most of the protein is keratin, which in the raw or natural state is not readily digestible by animals. Modern processing methods that cook the feathers under pressure with steam partially hydrolyze the protein, breaking apart some of the chemical bonds that account for the peculiar structure of the feather fibers. The resulting feather meal is a free-flowing palatable product that is easily digested by all classes of livestock and poultry.

Feather meal and poultry byproducts have been fed to broilers, composing 7 percent of the total ration, with no adverse impacts on weight gain or mortality. Recent research suggests that byproduct feed could be increased to 12.5 percent of the diet and still support excellent broiler growth; however, bird performance during the growing period may be variable.

Feather meal production in the United States increased from 564 to 682 million pounds from 1990 to 1992, an increase of almost 21 percent. As with poultry byproducts, most feather meal is used domestically. Still, about 76 million pounds were exported in 1992.

Hatchery waste has also been identified as a valuable feed ingredient. The composition of broiler-chick hatchery waste indicated the significant amounts of protein, calcium, phosphorus, and fat. The amino acid availability from eggshell meal was found to be compatible with that from a combination of wheat middlings and meat and bone meal or soybean meal. Calcium from eggshell meal was readily utilized in feeding trials.

A substitute for camel-hair brushes is made from the delicate hairs on the inside of the ears of cattle. Hog bristles for making brushes were formerly imported from China, but are now being produced in the United States in increasing amounts.

Recycled Dairy Processing Waste Boosts Industrial Uses

Whey from dairy processing plants can be fermented and used to produce ethanol. At least seven ethanol production plants in the United States use whey as their primary feedstock material, with an average production capacity of over 1 million gallons a year.

Lactose can also be recovered from whey for use as a feedstock in making various types of pharmaceuticals. It is a white, sweet, crystalline, water-soluble compound that can be used in infant formulas, confections, other foods, bacteriological media, and as a diluent and excipient in pharmaceuticals.

Wash water solids (WWS) are small amounts of cheese that can be recovered from the cleanup waste stream. Results of a recent turkey feeding trial show that during 18 weeks, birds fed a diet with 10 percent WWS that had been processed through a twin screw extruder weighed an average of 32.2 pounds, compared with those receiving a traditional soybean protein diet weighing an average of 31.4 pounds. The cost per pound of gain was similar for the two diets. So, instead of a tipping fee for disposing of WWS, a valuable animal feed can obtained. Research on more efficient extraction of WWS and additional feeding trials are continuing.

All Casein Is Imported

Casein is the principal protein in milk, accounting for approximately 3 percent of the weight of whole milk, and 80 percent of the total protein content. Prior to World War II, all casein was used for industrial applications, such as for glues, adhesives, paper coatings, and paints. Food use increased after the war. In 1970, about half was still used for industrial products. But by the 1980's, industrial use had slipped to about 15 percent. There is some evidence that the share stabilized in the 1980's, and may have increased recently.

Casein is used as a combined dispenser and binder of pigments in leather finishes, and to furnish a glaze and a protective shield for many leather products, like shoes. It also serves as a dispensing agent in the manufacture of rubber-dipped goods, such as gloves, medical supplies, and balloons; and as a stabilizer for resin-emulsion and latex paints.

Casein has not been produced in the United States since 1968. The structure of the Federal dairy support program that favors nonfat-dried-milk production and subsidized dairy production abroad means that the entire U.S. supply is imported.

Recently, however, two small companies have begun evaluating the production of casein to make casein-based paints. In 1992, 74,600 metric tons of casein were imported, up from 65,400 tons in 1989. With value slipping from $310.8 million in 1989 to $295.6 million in 1992, prices are coming down. This makes casein more attractive for industrial applications.

Wool Grease and Collagen Used by Industry

The degreasing of sheep's wool removes an oil that amounts to about 15 percent of the weight of the wool. This oil is a source of lanolin, which is used as the basis for ointments, cosmetics, leather dressings, and fiber lubricants.

Collagen is found in hides, sinews, horn piths, pizzles, mammary glands, lips, ear tubes, knuckles, feet, and bones, as well as in the heads of cattle, calves, and sheep. The collagen in these animal parts is a source of glue. It is similar to glue in composition, but is insoluble in water at ordinary temperatures. However, in boiling water, collagen breaks down to form a water-dispersable glue or gelatin.

Collagen can also be used in medical applications, such as for burn dressings, and to treat severe acne. Once collagen has been extracted from the animal hide, it is processed into a form that permits it to be injected under the skin of acne patients. Beneath the skin, the product gradually polymerizes into an elastic, semisolid state. The mass is quickly "colonized" by blood vessels and is thus permanently incorporated into body tissues, smoothing the skin's surface. Collagen also can be used to make sausage casings.

The two types of gelatin, according to their source, are hide gelatin and bone gelatin. Gelatin is used in both edible and inedible products. It is used widely in pharmaceutical preparations and capsules for medicine, and for coating pills. Gelatin is quite important in photography, which requires a very high grade for use as a coating on the film and developing paper to obtain high-quality photos. Gelatin is also used in making audio, television, and video tapes; x-ray and movie film; computer discs; and computer tapes. [Donald Van Dyne (314) 882-4512 and Gregory Gajewski (202) 219-0085]

Forest Products

New products that conserve forest resources are on the rise. They are made from new technologies that produce paper, chemicals, and construction products, often from recycled wood wastes and underutilized forest byproducts. Using recycled wood fibers to make construction products reduces landfill needs and generally requires less energy than comparable products from metal, plastics, and concrete.

Biopulping and other advances in making paper are more efficient and generate less chemical waste. New lumber composites are reducing the demand for old-growth wood and offer improved performance and design characteristics. New uses of lignocellulosic plants also hold promise for increased energy and chemical production. These will come about through direct combustion, thermochemical conversion or saccharification, and fermentation.

Timber Markets Tighten

Traditional sources for lumber and plywood from the western United States and Canada have been reduced, reflecting shrinking inventories of old-growth forests and growing environmental concerns about maintaining ecosystems. For example, harvests from Federal forest lands dropped about 75 percent between 1988 and 1992, and are expected to remain down. The forest industry has increased production in the southern United States, but growing demand for forest products has caused rising timber prices and concern about long-term shortages of timber.

Composites account for 20 percent of the forest product industry, and are growing 10 percent per year. Output of other timber products has been fairly stable. Advances in combining wood and nonwood materials, such as plastic and metal, permit manufacturers to develop new products that have beneficial properties from both materials.

New uses for nontraditional products include producing industrial chemicals and fuel ethanol from woody cellulosic biomass. The use of wood wastes or recycled fibers to displace coal for electricity generation is also being improved.

The total harvest of timber products is about 365 million tons, of which about 300 million come from roundwood. About 200 million tons are softwoods, such as pines and firs, while the remainder are hardwoods. About 10 percent of the harvest is residuals. About half of the residuals could be converted into a variety of chemicals, ranging from fuel ethanol and methanol to organic adhesives, plastics, or synthetic rubber. Most mill residues are either being used for reconstituted products, woodpulp, or as fuel (figures 10 and 11).

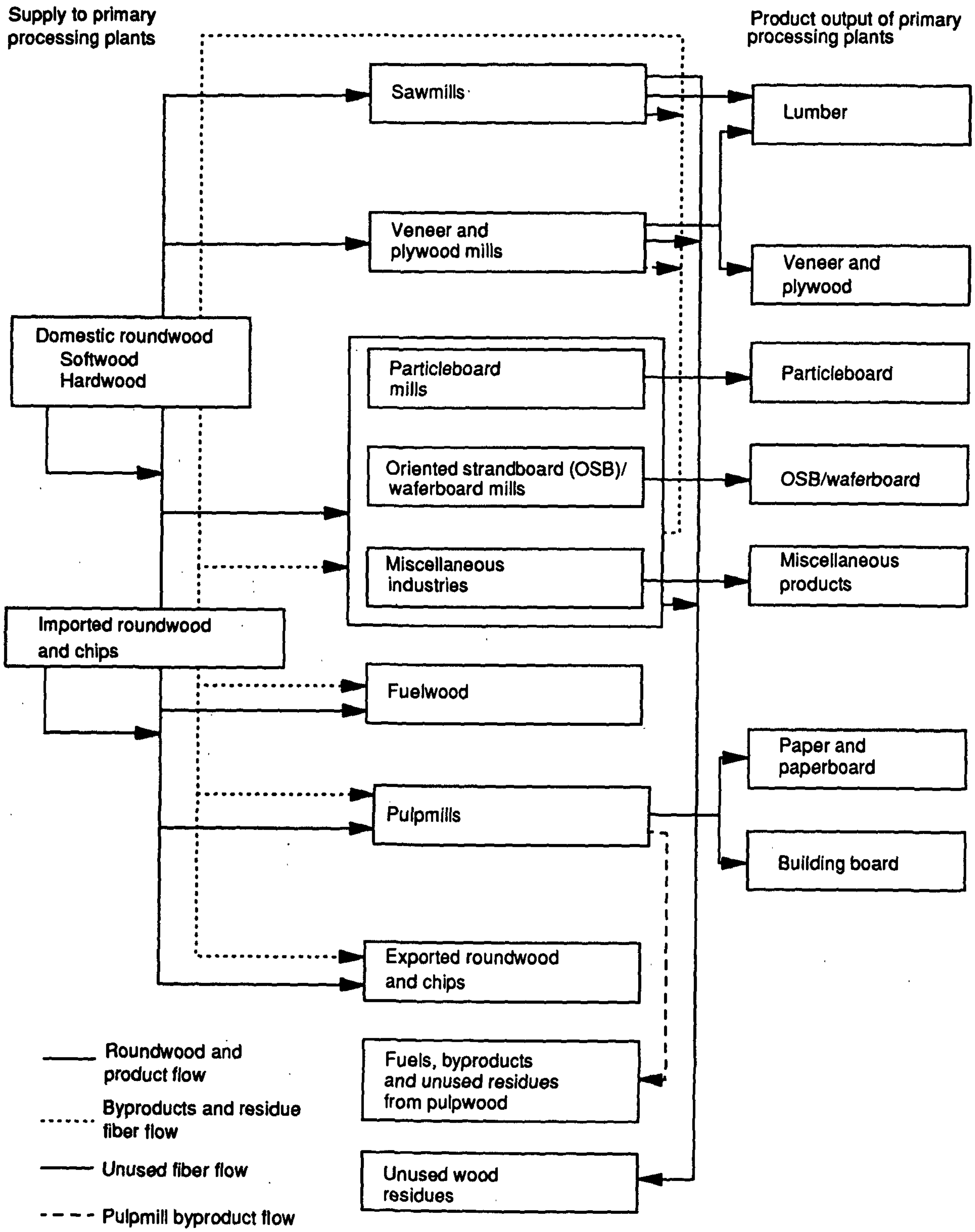
Housing Industry Takes Most Lumber and Wood Products

Lumber and other products made from solid wood account for 5 percent of U.S. Gross National Product. New home construction takes about 40 percent of timber products, while residential repairs and alterations account for 25 percent. Furniture and other household uses take another 10 percent. Pallets and other shipping materials have become a major use of lumber in recent decades, growing at 5 percent per year.

Lumber shipments were $18.3 billion in 1992, about equal to 1988 and 1989. Most wood products made in the United States today use virgin (i.e., first-cut, not recycled) timber.

Figure 10

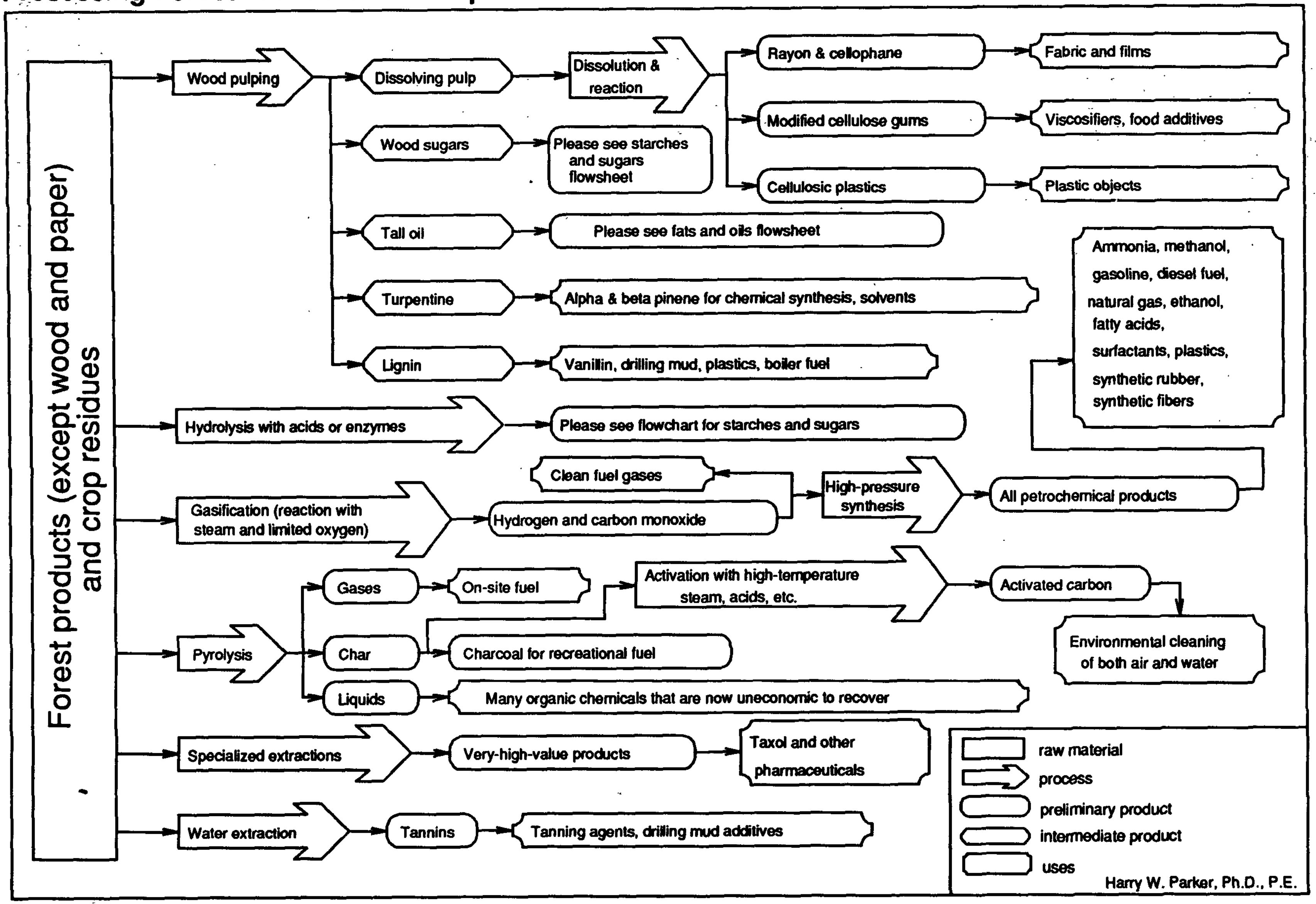
Timber Supply to and Product Output from Primary Processing Plants



Source: An Analysis of the Timber Situation in the United States, 1989-2040, USDA, Forest Service, December 1990.

Figure 11

Processing Forest Products and Crop Residues into Industrialand Consumer Products



More than half of the timber is from land owned by farmers and other individuals, more than a third is from forest-industry land, and the remainder is from public lands.

Wood-derived fuels produced 2.7 quads (quadrillion Btu's) of energy in 1986, which was 3.7 percent of the U.S total, up from 2.1 percent in 1970. Over half of the wood harvested in the early 1980's ultimately was burned for energy. Much of that was pulpmill and sawmill wastes that were used for power. Residential and commercial fuelwood use has moderated in recent years because energy prices have declined and stabilized. In some areas, use is down because of concerns about air quality.

Recently, the Department of Energy has studied the possibility of large-scale liquid fuel production from large, intensive forest plantations. With practices similar to modern agriculture, high-yield plantations of fast-growing trees could produce up to 10 tons of biomass per acre. Such plantations could provide a steady renewable source of fuel for cogeneration power plants to produce electricity and steam, or of raw materials for chemical or alcohol production. DOE's Short Rotation Woody Crops Program has been developing technologies to produce woody biomass and herbaceous energy crops at a price competitive with other alternatives.

Silvichemicals account for about $1 billion of forest product shipments. These include naval stores--rosin, turpentine, fatty acids, and pine oil. Rosin is used for sizing paper and to produce synthetic resins and adhesives. Turpentine is used as a paint solvent, and increasingly as a chemical raw material for synthetic pine oils, polyterpene resins, and adhesives.

Most silvichemicals are now derived as byproducts of the sulfate (kraft) pulping process, rather than the traditional oleoresin (gum) collection from southern pine trees. Crude tall oil production rose from 715,600 metric tons in 1982 to 901,400 in 1989, before declining to 855,700 in 1991. That drop was likely due to the recession. Crude tall oil is a major source of fatty acids (figure 5 and table 30). Other byproducts of chemical pulping processes (sulfate and sulfite) derived from spent pulping liquors include various lignin derivatives, ethanol, acetic acid, and vanillin.

Laboratory work has shown that petroleum-derived phenolics in adhesives can be replaced with phenol substitutes from wood. DOE and private firms are now developing pilot-scale projects to demonstrate commercial feasibility.

Some scientists say that unique chemicals that are not now commercially available can be derived from wood. For example, trees and other forest products contain biopharmaceuticals like taxol that are waiting to be discovered and isolated (see the Specialty Plant Products Section).

Biotechnology may also increase the production of chemicals and biopharmaceuticals from wood and other biomass. For example, wood-derived sugars fermented by yeast produce roughage for animal feeds and some human foods, wood molasses, and single-cell proteins for human and animal nutrition. Biotechnology also promises to lower the cost of producing ethanol from woody crops.

Biotechnology also has provided methods of bioremediation in waste disposal. Bioremediation is the use of microorganisms, such as bacteria and fungi, to degrade hazardous wastes to harmless products. Recently, lignin-degrading fungi have been shown to be helpful in breaking down harmful chemicals, such as the wood preservatives pentachlorophenol and creosote.

Modest Growth Ahead for the Pulp and Paper Industry

The U.S. pulp and paper industry has grown about 2.5 percent per year in the last decade and is likely to continue to grow at about that rate for the next decade, in tandem with world production. Competition in world markets is likely to increase as pulp output rises in Brazil and other Latin American countries and, in the future, from Siberia. For the next several years, increases in domestic paper production are likely to come primarily from recycling. After 2000, increases in mechanical pulping and perhaps biopulping are expected to help meet the growth in paper demand.

Woodpulp is the primary raw material for nearly all paper products. Typically, paper and paperboard products are grouped according to use, such as newsprint, printing and writing papers, tissues, linerboard in corrugated containers, and kraft papers. About 80 percent of paper is made through chemical pulping, while the remainder is made through mechanical and semi-chemical pulping. Recent technological advances have increased the range of species used in pulping to include a larger share of hardwoods.

Pulp produced by the kraft process is the major papermaking raw material in the United States. Residual brown-colored lignins that remain after the pulping process must be removed by a bleaching process, to increase the pulp's brightness, prior to papermaking. This process uses chlorine chemicals that have unfavorable environmental effects.

Several methods are under investigation to lower environmental impacts and pulping costs. A 1983 report by the Office of Technology Assessment mentions enzyme treatments as a technologically feasible alternative. DOE-funded work at the National Renewable Energy Laboratory (Golden, CO) is developing pulping technologies, such as the "organosolv" clean fractionation processes and steam explosion technologies for paper, biofuels, and chemical feedstocks. Steam explosion technologies are also showing promise as pretreatments for lignocellulosics. These and other technologies are receiving support from USDA and DOE.

Another new technology is biopulping, the pretreatment of wood chips with white-rot fungi. Examples of its benefits include reduced chemical use, increased strength properties, decreased energy and waste treatment costs, and lower capital investment per unit increase in production capacity. Biopulping has been successfully demonstrated using aspen and loblolly pine. In the future, biopulping may be adapted to more species by developing designer biopulping organisms using genetic engineering techniques.

Since the late 1980's, concerns about solid waste disposal and the environment have increased the amount of wastepaper recovered for recycling. The amount of wastepaper recovered has risen from 26 percent to 38 percent in the last 10 years and is expected to continue to rise to 45 percent or more. The paper industry has instituted a program of recycling to increase the utilization of waste paper. Most of the new mills added in 1992 use recycled fibers as a major input for papermaking.

Wastepaper supplies are centered in metropolitan areas, which may be far from existing mills in forest areas. As a result, prices for wastepaper, like old newsprint, have been negative in many cities in the Northeast. To foster markets for recycled materials, many local governments have passed mandatory recycled-paper-content rules for many types of paper. In addition, voluntary use of recycled products by large corporations, such as McDonalds, and mandated procurement policies by Federal and State government agencies have helped expand the use of recycled products. Large quantities of wastepaper also are exported.

Wood Composites Show Rapid Growth

Over 70 percent of all finished wood-based products used today contain some type of adhesive, and that figure is expected to grow rapidly as new products and processes are developed. Composite products include laminated beams, plywood, laminated veneer, various fiberboards, waferboard/oriented strandboard (OSB) panels, particleboards, overlays, composite lumber substitutes, and composite matrix materials that combine wood and nonwood materials.

Low-density fiberboards are used for insulation, sound deadening, and carpet backing. Medium-density fiberboards are often used in furniture. High-density fiberboards find their way into wood I-beam webs, furniture, and paneling substrates. Wood-based composites offer optimized performance, minimized weight and volume, cost effectiveness, fatigue and chemical resistance, and controlled biodegradability.

The large potential for technological change in forest products comes largely from advances in composite technology. In the last 50 years, solid-sawn lumber and timber construction have given way to this composite evolution. The introduction of waterproof petroleum-based adhesives gave impetus to the development of the plywood industry. Plywood became a superior replacement for 1-inch lumber in sheathing of housing frames.

Structural lumber substitutes are a rapidly growing segment of the wood products market today. This includes laminated-veneer lumber and parallel-strand lumber. These products have enhanced properties that exceed conventional sawn-timber products. Laminated wood is 3 times as strong as conventional timber, and could challenge steel and concrete as a building material.

For example, Trus Joist MacMillan (Boise, ID) is making a composite that reduces the need for old-growth lumber. They manufacture wood I-joists made from smaller-diameter, second- and third-growth timber. The company uses resins to laminate smaller pieces of trees into structural beams comparable to those milled from older, larger trees.

The industry has produced mainly price-sensitive commodity composites. Insulating board, hardboard, and structural panels--which include plywood, OSB, and waferboard-type products--have shown steady growth but have lost some market share to competing products made from steel, aluminum, vinyl, and plastic expanded foams. Similarly, particleboard and hardwood plywood have lost some market share to competitors in recent years. Without cost-saving technical advances, opportunity for growth will be limited in the next 20 to 30 years.

New Uses of Composites Rely More on Recycled Products

High-speed processing is making composite-wood products more competitive by lowering cost and improving quality. Now, for example, thermoplastic resins are thoroughly mixed with finely ground wood particles or flour using extrusion or injection molding technology.

In another new composite, a high percentage of natural fibers are blended with synthetic thermoplastic or thermosetting fibers to form a nonwoven mat that can be made into panel products or deep-drawn molded configurations. Because of the increased processing flexibility inherent in the new technologies, they can be used to make packaging, manufactured products, and building materials.

Great potential exists for developing products for housing made from recycled wood waste and wastepaper, which will also reduce demand for landfill space. Wastepaper is the single largest component of municipal solid waste (MSW). At approximately 73 million tons per year, wastepaper accounts for 38 percent of all landfilled material. Excluding paper, about 8 percent of landfilled material is wood waste. According to EPA, by the year 2000, about 10 million tons of wood waste will enter the municipal solid waste stream each year.

The types of wood waste that have potential uses in housing products include full-sized used lumber salvaged from razed buildings, wood broken up during building demolition, old wood pallets, scrap wood from new construction sites, preservative-treated wood waste from treating facilities and building construction, old wood utility poles and railroad ties, wastepaper, and wood fibers in paper-mill sludge. Most of these raw materials will require chipping, grinding, or fiberizing to reduce the nonuniform waste into a uniform material for processing.

Several technologies with the greatest potential for success include dry-formed reconstituted wood products from fibers, flakes, chips, or particles; wood/plastic combinations;

Recycled Fiber Composites Will Soon Hit the Market

Several companies are moving ahead with recycled wood products. Wood Recycling, Inc. (Peabody, MA) uses a patented process to convert urban wood waste into wood fiber with applications in composite boards and pulp and paper. The company's primary facility can take in, separate, and sort as much as 1,000 tons per day of demolition and construction waste, and convert the wood fraction into wood chips. Their secondary facility converts the recycled wood chips into wood fiber, and then formulates and packages it for sale.

Gridcore Systems International Corp. (Carlsbad, CA) uses recycled wood, paper, cardboard, or any other fiber source (including kenaf) to make Gridcore panels. The panels are molded fibers cast into sheets with one smooth surface and one waffle-textured surface. According to the company, the material forms a lightweight, sturdy panel aimed at the housing and construction industries. The company's first production line, based on the Spaceboard technology licensed from USDA's Forest Products Laboratory, is scheduled to start in mid-summer.

Phenix Composites, Inc. (Mankato, MN) makes Nustone, a composite building material, out of waste paper and soybean meal. According to the company, the material looks like granite but has the construction properties of wood. It can be manufactured into panels, blocks, or veneers and colored to simulate many granite hues. Phenix has samples of Nustone and plans to open a medium-size facility by the end of the summer.

wood/cement combinations; wet-formed wood products from fibers; reuse of old lumber from razed buildings; and remanufacture of lumber from short pieces of construction waste.

One promising process involves crushing the wood into splinters. This offers advantages over other wood-reduction techniques since no cutting is required, eliminating the need to sharpen blades that may be damaged by contaminates. Because splinters have high length-to-cross-section ratios, splinters make strong composites. Dry hardwoods splinter exceptionally well, so this technology seems like a natural outlet for used hardwood pallets. This splintering process has shown potential in Australia where a structural-wood product called Scrimler has been developed.

Another potential technology, making wood-flake-based products from recycled wood, may be more difficult. Wood flakes are manufactured by cutting or slicing flakes from solid wood pieces. The raw material should have a high moisture content and must be properly pre-sized to produce a consistent product. So, flake technology will probably be most useful where the waste stream is very controlled. Flakes are commonly used in sheathing products, such as OSB, which in turn is used as roof, floor, and wall sheathing.

An existing, though not widely used, building product combines recycled wood with an inorganic binder such as portland cement. Considering that over 50 percent of all the southern pine lumber cut today is treated with some sort of preservative, it is conceivable that an increase in this type of material in the waste stream will occur. A cement-bonded product is attractive because it has a long life expectancy.

Paper recycling faces significant barriers, including costs for collection, sorting, transportation, and contaminant removal (ink, clay, adhesives, plastics, etc.). In addition, there is a limit to the number of times paper can be recycled and still retain its original properties. However, these fibers can be converted into housing construction materials.

Research is underway to produce housing components from recycled wastepaper fiber. A pulp-molding process makes a structural housing component called Spaceboard (see box). A pulp-extrusion process has the potential to produce casing and trim products. A third type of wet-formed, fiber-based process involves shaping structural components through the winding of papersheet stock. This process can make round, rectangular, and other desired cross-sectional shapes.

Developing products that can be easily formed or molded may have special application in wind-resistant design, as well as improved energy-efficient design. For example, structures with curved or rounded edges or shapes are more aerodynamic, more energy efficient, and require less material to enclose a given living area than square or rectangular shapes. Moldable structural composites from recycled waste might be used to fabricate stress-skin panel corners to replace the conventional three-stud corner. This would reduce heat loss, improve shear performance, and reduce wind pressures due to turbulence around the building corner in heavy winds. [Thomas Marcin (608) 231-9366]

Specialty Plant Products

Developing alternative sources of the drug taxol is limiting the long-term opportunities to commercially farm the Pacific yew tree, but there may be some opportunities for growing other species of yews. Some experts predict that in 3 years, taxol will be made from laboratory semisynthesis, cell tissue culture, and fungal metabolites. This will take the pressure off the rare Pacific yew.

Today, over 90 percent of natural rubber comes from the hevea tree in Southeast Asia. Guayule, a desert shrub native to the southwestern United States, is also a source of natural rubber, but is now not competitive with hevea for traditional rubber markets. A DOD-USDA project has about doubled guayule yields, and work continues on making this crop more economical. But a new niche market may open up for medical gloves, condoms, other consumer items, and toys

500,000 people in the United States are allergic to hevea-based natural latex products. And the latex from guayule has been shown to be hypoallergenic for people allergic to hevea products.

Pacific Yew Plantations Have Been Planted

Taxol, a compound found in the bark of the Pacific yew tree, was cleared by the Food and Drug Administration in record time for treating ovarian cancer patients who have failed to respond to other treatments. The drug is also being tested for fighting breast, colon, lung, skin, kidney, and prostate cancer.

Even though there are a number of potential sources of taxol, FDA has approved only taxol derived from the bark of the Pacific yew tree for human use. Approximately half of the bark harvested comes from the private sector, with Weyerhauser being the major supplier. According to the National Cancer Institute (NCI), several nurseries and forestry companies have already planted up to half a million trees, and expect to begin harvesting in 1994.

At present, the bark is stripped off of the Pacific yew tree, which is native to the Northwest, and processed into the drug. Bark from three to six mature yews is required to make enough taxol to treat one cancer patient, and the trees take 80 to 100 years to reach maturity. Several environmental groups are trying to get the Pacific yew on the protected species list. The discovery of taxol has, according to USDA's Forest Service, increased the yew harvest to 38,000 trees per year (825,000 pounds of bark). Prior to the discovery of taxol's effectiveness, the Pacific yew was of no commercial interest.

Researchers have found that taxol can be processed from the needles, twigs, and branches of several yew species thus eliminating the need to kill any trees in order to get the drug. Bristol-Myers Squibb (BMS), the sole supplier of taxol to NCI, predicts that no Pacific yews in the wild will be required for taxol production within 3 years.

How Far Along Are the Alternative Sources?

Currently, most production research is focusing on the semisynthesis of taxol. Chemists begin with precursors from the twigs and needles of several common species of yews grown in the United States, including the European yew and the Asian yew, and various ornamental yews. The precursors can also be produced using plant cell tissue culture technology. The existence of these sources has ended supply problems and has put the issue of harvesting wild Pacific yews to rest.

Now, BMS is buying precursors derived from yews harvested in India from an Italian natural products company. BMS predicts that semisynthetic commercial production will provide as much as half of the taxol used for patient treatment in 1994. FDA approval for semisynthetic taxol is expected within the year.

Taxotere, a taxol-like, semisynthetic compound derived from yew needles and twigs, may be even more promising than taxol itself. The drug is produced by RhonePoulenc Rorer. The compound appears to have similar, if not better, results than taxol against all forms of cancer and works in much the same way as its natural counterpart. Unlike taxol, taxotere is water soluble and is thus much easier to administer, requiring only a few hours in the hospital. Now, an overnight stay is required for a taxol treatment.

The newest method of producing taxol is also one of the most promising. Researchers at Montana State University have discovered a fungus in the folds of a single yew tree's bark in Glacier National Park that produces taxol on its own. Field experts have been unable to find samples of the fungus (*Taxomyces andreanae*) on other trees. Many pharmaceuticals, including all antibiotics, are made with fungal metabolites. This method of production has the potential to be the cheapest source of taxol in about 5 years.

Cell tissue culture is another possibility. Now, no pharmaceuticals have been commercially produced in the United States using this new technology, but ESCAgenetics and Phyton Catalytics see potential for this method of production for taxol. Both firms, along with NCI and BMS, foresee large-scale commercial production of taxol (100 kilograms per year or more) from tissue culture technology within 1 to 2 years. The process involves growing yew tree cells, cultured in fermentation vats, to produce taxol and taxol-like compounds.

Complete synthesis of taxol is very difficult. Stanford researchers say they are very close to synthesizing taxol from pinene, a primary component of turpentine. Even though pinene contains half of the molecular structure of taxol, the synthetic form will probably never be commercially produced due to the high cost of the 15- to 25-step chemical process.

A New Niche For Guayule?

According to Scientist Katrina Cornish of USDA's Agricultural Research Service, people who suffer from prickly rashes and other allergic reactions to latex gloves may be helped by using latex processed from guayule. Guayule's natural rubber appears to be free of the allergy-causing proteins found in latex made from the hevea rubber tree. Allergen-free rubber extracted from guayule stems and bark could be used to make gloves for medical and lab professionals, and other latex products, such as toys, condoms, and elastic used in clothing.

In recent years, the demand for latex gloves and condoms has increased dramatically. Sales of prophylactics rose from 61,855,800 dozen in 1982 to 151,231,000 dozen in 1987. The value of prophylactic sales rose from $54.7 million in 1982 to $103.3 million in 1987, to an estimated $117.7 million in 1991. Surgical rubber glove sales rose from 28,666,300 dozen pairs valued at $156.7 million in 1982 to 97,398,900 dozen pairs at $234.5 million in 1987, the latest available data. A private survey of U.S. manufacturers shows that production of medical latex gloves rose by 50 percent between 1987 and 1991. This increased demand opens up the possibility for guayule to fill a niche market for those who are allergic to hevea rubber.

Moving to other parts of the plant, guayule's resin shows the most promise as a high-value coproduct. For every pound of rubber produced, a pound or more of resin is obtained. Guayule resin can be used in termite control for wood, and as a plasticizer/extender for polyvinyl chloride and more expensive epoxies. Another major coproduct, low-molecular-weight rubber, has potential value in rubber cements, adhesives, and low-cost elastomers. Coatings made from guayule coproducts protect against zebra mussels and barnacles, and appear more biodegradable than competing petroleum products. Guayule's bagasse can be shaped into fireplace logs and pressed boards (figure 12). Developing new uses for coproducts will be critical to guayule's commercial success.

Guayule Still a Long Way From Traditional Markets

Natural rubber is a critical material used in tires, medical supplies, resilient mounts, and acoustical applications. Nearly one-third of all rubber produced in the world is natural rubber. The United States imports all of its natural rubber, 92 percent of which comes from Southeast Asia. Natural rubber, either from hevea or guayule, has several distinct properties that give it an edge over synthetics. The properties include higher resiliency, elasticity, and more resistance to heat build-up.

Annual U.S. consumption of natural rubber is about 896,000 short tons and costs $1 billion. The Department of Defense estimates that increased military uses of natural rubber in a conventional war situation would be equal to about 20 percent of current civilian consumption. Synthetic rubber was developed during World War II in response to a cutoff of natural rubber supplies. After the war, synthetics claimed a progressively larger fraction of the world rubber market.

Because synthetic rubber is made from petroleum, a shortage of oil would lead to higher synthetic rubber prices which in turn would lead to higher demand for natural rubber. Recent events in Kuwait and Iraq show that there continues to be a potential for disruptions to the supply of petroleum.

Guayule provided 10 percent of the world's natural rubber in 1910. However, after World War II, cultivation was abandoned. The U.S. consensus in 1946 was that there was little need for another rubber source, because people believed that synthetics could meet all needs.

DOD-USDA Effort Advancing Commerical Potential

Natural rubber's material advantages, combined with national security considerations in the 1970's, sparked renewed interest in a domestic source of natural rubber. The development of guayule in the United States could reduce dependence on foreign supplies of natural rubber and provide a new agricultural industry to the Southwest. In 1986, DOD and USDA signed a 27-month agreement to develop guayule that was extended and is still underway. DOD provided $11 million to maintain and harvest 275 acres of guayule shrubs, build a prototype processing plant, and process the shrub into more than 50 tons of natural rubber. Also participating in the project were the Firestone Tire and Rubber Company, Dravo Engineering Companies, Inc., the Gila River Indian Community, and four southwestern land-grant universities. The purposes of the project are to:

- Determine if natural rubber can be economically produced in this country, and

- Determine if natural rubber from guayule can be used in place of imported natural rubber.

Bridgestone/Firestone has manufactured light truck tires that will undergo vehicle testing at the Yuma Proving Grounds (Yuma, AZ) under the direction of the U.S. Army Tank Automotive Research and Development Center (Warren, MI). Naval F/A-18 aircraft tires will be manufactured by Goodyear and tested at the Naval Air Warfare Center (Patuxent River, MD).

The goal is to have the capacity to produce 25 percent of the United States' natural rubber consumption. On an annual basis, this will amount to 190,000 tons of rubber worth about $210 million. Processing to produce this much rubber would require about 1 million acres of guayule under cultivation, assuming current yields (see figure 13 for potential growing areas). About 5 to 20 percent of the shrub's dry weight is high-molecular-weight rubber. Low-molecular-weight rubber, guayule resin, a water-soluble component, and bagasse make up the remainder of the fractions.

Prior to recent advances, USDA selections of guayule strains produced average rubber yields of about 400 pounds per acre per year. For commercial feasibility at current prices, rubber yields need to be increased to at least 1,200 pounds per acre per year. One goal of the DOD-USDA program is to meet this by 1996.

Recently, several high-yield strains were developed through genetic selection. Cal-6 and Cal-7, two strains developed by the University of California at Davis, produce 810 and 609 pounds per acre per year, although yields vary according to location.

Presently, guayule cannot compete with hevea on a price-per-pound basis in traditional markets. In order for guayule to show a profit, its market price would have to be $1.45 per pound, or 3 times greater than the present market price for hevea (45 cents per pound). Assuming increased yields (from 400 to 800 pounds per acre per year) and decreased costs due to improved technology (particularly direct seeding), guayule could show a profit above 68 cents per pound by 1996. Moreover, if Southeast Asian plantations are not totally replaced as they age, hevea prices could rise beyond 2000. However, rubber from guayule shows economic promise for the new niche market of hypoallergenic medical gloves, condoms, and other consumer items. [David Pace, William Moore, and Gregory Gajewski (202) 219-0085]

Figure 12

Processing Natural Rubber into Industrial and Consumer Products

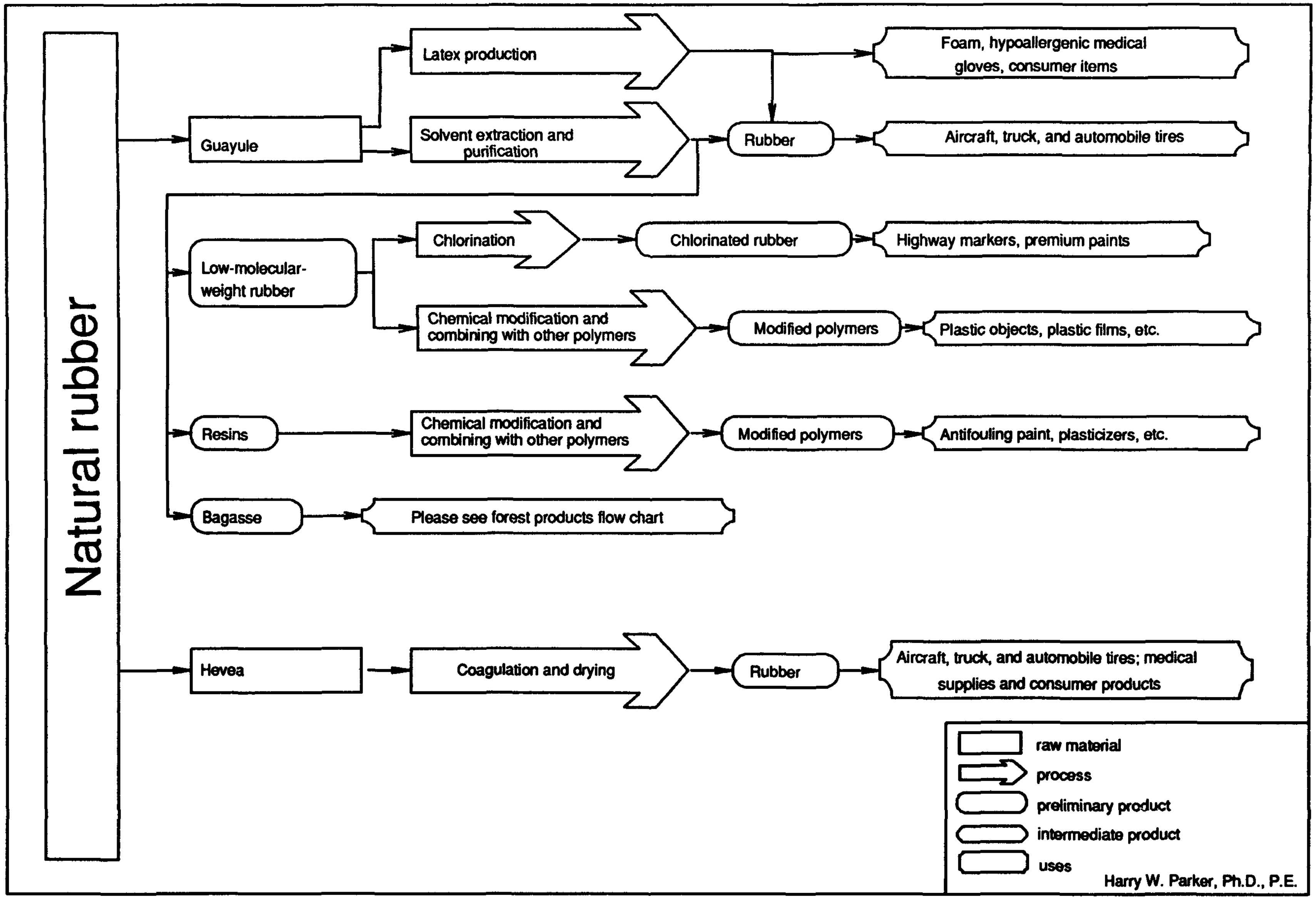
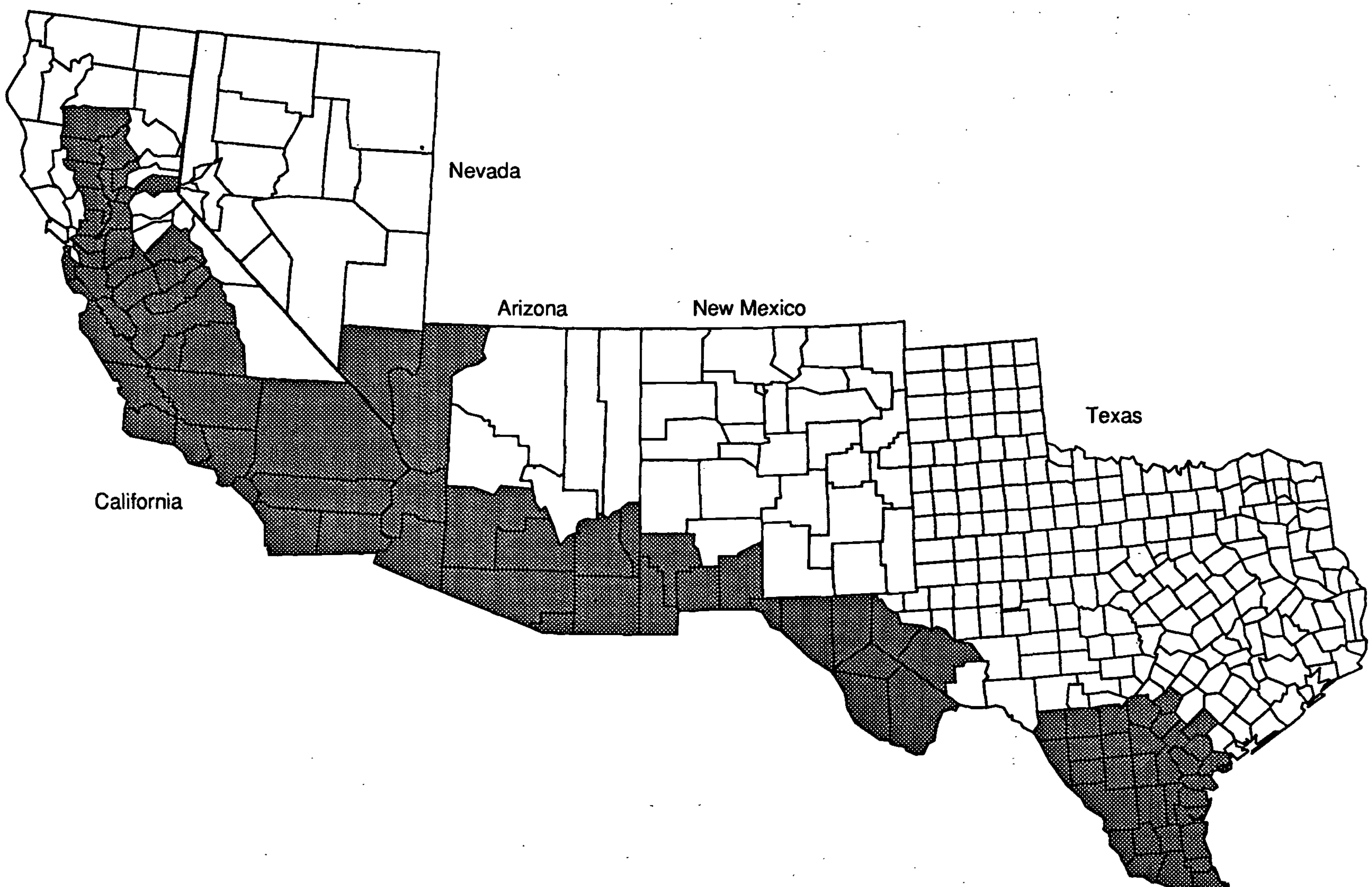


Figure 13

Potential Guayule Growing Regions



Source: Office of Arid Lands Studies, University of Arizona.