A Technology Assessment of the Commercialization of Mexican Guayule

Final Report

Office of Arid Lands Studies

Centro de Investigacion en Quimica Aplicada

1982

TECHNOLOGY ASSESSMENT OF
THE COMMERCIALIZATION OF MEXICAN GUAYULE

FINAL REPORT

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Ruins of old Guayule processing plant, Cedros, Zacatecas

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FINAL REPORT

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PREFACE

A technology assessment (TA) of the commercialization of guayule (Parthenium argentatum) as a domestic source of natural rubber for Mexico has been conducted by the Office of Arid Lands Studies (OALS), University of Arizona, and the Centro de Investigacion en Quimica Aplicada (CIQA) (Applied Chemistry Research Center), Saltillo, Coahuila, Mexico. This final report presents the findings of that project. The OALS study has been supported by the National Science Foundation (NSF), Grant Number PRA-8007498. Dr. G. Patrick Johnson is the NSF project officer. The Mexican effort is supported by the Consejo Nacional de Ciencia y Tecnologia (CONACYT) (National Council on Science and Technology) and the Comision Nacional de las Zonas Aridas (CONAZA) (National Commission for Arid Lands).

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SUMMARY

This technology assessment of Mexican guayule rubber commercialization reviews world and Mexican elastomer consumption and production, technical data on Mexican guayule wildstands, harvesting, guayule farming and processing; outlines two possible commercialization scenarios and analyzes potential impacts; reviews prospects for guayule commercialization; and analyzes federal policy related to a potential guayule industry.

Overview of Elastomer Consumption and Production

In recent years natural rubber has filled an increasing percentage of the worldwide demand for elastomers. Much of the increase is due to a greater market for rubber products in which natural rubber is an indispensible component, especially radial tires and large commercial vehicle tires. With the current economic downturn, there has been a decrease in natural rubber consumption, an accumulation of rubber stocks, and a concomitant decrease in rubber prices. However, even with lowered world rubber demand projections, if natural rubber maintains its current 30 percent share of the world elastomer market, natural rubber demand is projected to exceed production significantly in the late 1980s. The natural rubber shortage is expected to continue through the end of the century.

The rubber products industry is expected to be extremely dynamic. Mexican consumption of natural rubber is projected to grow at about 6 to 10 percent annually for the rest of this century. Because nearly all natural rubber is imported, this creates a large flow of money out of Mexico. Synthetic rubber production in Mexico is projected to grow at an annual rate of 8 to 10 percent, closely matching domestic synthetic rubber consumption.

Guayule Technology

Guayule grows abundantly throughout much of Mexico's Northern Arid Region in the area usually designated as the Chihuahuan Desert. Guayule

grows best on rocky foothills below 7,000 feet. This area is characterized by low mean annual rainfall, often as little as 8 inches, very hot summers, and cool winters. Deep roots and other water conserving adaptations allow the plant to grow in the hot and dry seasons. This strategy of competing effectively for water and nutrients enables guayule to exist or thrive after it is established, but the plant is not an effective invading or colonizing species.

Guayule has a long history of commercial use and study. Private companies have maintained records of harvests since the early 1900s. Although large guayule stands occur in central Coahuila, most of the commercial activity developed in northern Zacatecas and southern Coahuila. Overharvesting guayule populations, along with a shrinking market, contributed several times to declines in the fluctuating guayule industry. Regrowth of natural stands over a span of a decade or more and a revived natural rubber market resurrected the guayule industry.

In the 1970s the National Commission on Arid Lands and the National Institute for Forestry Research initiated major inventories of guayule standing biomass and studies of potential sustainable harvest. Recent efforts centered on northern Zacatecas. Much is now known about the distribution, abundance, and ecology of guayule, but differences in early reporting procedures and the technical difficulties of measuring population parameters have produced a wide range of variation of biomass and yield estimates.

With the declared federal government policy of maintaining renewable natural resources, analysis of guayule populations for commercial use has concentrated on potential biologically sustainable and economically feasible harvest. Estimates of sustainable yield in the Mazapil Region have varied widely. High estimates indicate that stands are more than adequate to support indefinitely a 5,000 metric tons of rubber per year processing plant; the low estimate predicts that producing 5,000 tons of rubber per year would exhaust local populations within about 8 years. Detailed monitoring and population ecology studies during harvest are recommended to determine more accurately population characteristics.

The state of guayule technology development for sustained wildstand harvesting, dryland farming, and shrub processing is summarized in Figure 1. Each level of knowledge or technology indicated in the figure is linked to an action needed to carry that item toward the level of development that would allow guayule commercialization to occur. The necessary actions are summarized following the figure.

Figure 1 shows that most elements in guayule production technology are at the stage where demonstration projects are needed to test and refine the technology. Agricultural dryland production and sustainable wildstand production through reforestation both need research and development. The technology of aqueous processing is well advanced. Figure 1 indicates that the next step is to operate a small-scale production processing plant.

Prospects for Guayule Commercialization

Commercial production of guayule in Mexico will depend on government support, which in turn depends on numerous political and economic factors which will interact with the technical, agronomic, social, and economic aspects of harvesting, growing, and processing to determine the course of commercialization.

Forces operating to promote commercialization of guayule include stated federal goals and plans; regional development programs; and governmental and academic research programs.

Forces that could constrain guayule commercialization are the economic uncertainties of the program and its federal funding base; the changing definition of development agencies and potential conflicts between them; land use and land tenure conflicts; incomplete planning at the national and regional level; and environmental concerns.

Scenarios for the Future

Two development scenarios are proposed to represent feasible alternatives for developing a Mexican guayule industry: Scenario A is

Figure 1. State of Guayule Technology Development

PLANT NAME
GUAYULE
Parthenium argentatum

LEVEL OF KNOWLEDGE/TECHNOLOGY

	UNKNOWN	TO BE DEVELOPED	IN DEVELOPMENT	NEEDS REFINEMENT	KNOWN/OPERATIONAL				
					X	Climate	Growth Conditions	TECHNOLOGY	PRODUCTION
					X	Soils	Growth Conditions	TECHNOLOGY	PRODUCTION
				X		Water	Growth Conditions	TECHNOLOGY	PRODUCTION
			X			Pest/Weed Control	Growth Conditions	TECHNOLOGY	PRODUCTION
			X			Genetic Variability	Growth Conditions	TECHNOLOGY	PRODUCTION
				X		Growth Characteristics	Growth Conditions	TECHNOLOGY	PRODUCTION
				X		Propagation	Agronomics	TECHNOLOGY	PRODUCTION
1				X		Seedling Production	Agronomics	TECHNOLOGY	PRODUCTION
			X			Alternative Propagation	Agronomics	TECHNOLOGY	PRODUCTION
					X	Site Selection	Agronomics	TECHNOLOGY	PRODUCTION
					X	Land Preparation	Agronomics	TECHNOLOGY	PRODUCTION
				X		Planting	Agronomics	TECHNOLOGY	PRODUCTION
				X		Cultural Practices	Agronomics	TECHNOLOGY	PRODUCTION
			X			Dryland Practices	Agronomics	TECHNOLOGY	PRODUCTION
				X		Crop Yield	Agronomics	TECHNOLOGY	PRODUCTION
2				X		Irrigation Practices	Agronomics	TECHNOLOGY	PRODUCTION
				X		Pre-Harvest Conditioning	Agronomics	TECHNOLOGY	PRODUCTION
				X		Methods/Machinery	Harvesting	TECHNOLOGY	PRODUCTION
				X		Timing	Harvesting	TECHNOLOGY	PRODUCTION
				X		Conditioning	Harvesting	TECHNOLOGY	PRODUCTION
			X			Storage	Harvesting	TECHNOLOGY	PRODUCTION
				X		Fixed Costs		ECONOMICS	PRODUCTION
				X		Variable Costs		ECONOMICS	PRODUCTION
			X			Profitability		ECONOMICS	PRODUCTION
				X		Parboiling	Aqueous	TECHNOLOGY ALTERNATIVES	PROCESSING
					X	Grinding	Aqueous	TECHNOLOGY ALTERNATIVES	PROCESSING
				X		Pulping	Aqueous	TECHNOLOGY ALTERNATIVES	PROCESSING
				X		Flotation	Aqueous	TECHNOLOGY ALTERNATIVES	PROCESSING
					X	Acetone Extraction	Aqueous	TECHNOLOGY ALTERNATIVES	PROCESSING
					X	Acetone Recycle	Aqueous	TECHNOLOGY ALTERNATIVES	PROCESSING
					X	Acetone Recovery	Aqueous	TECHNOLOGY ALTERNATIVES	PROCESSING
					X	Hexane Dissolution	Aqueous	TECHNOLOGY ALTERNATIVES	PROCESSING
					X	Filtration	Aqueous	TECHNOLOGY ALTERNATIVES	PROCESSING
					X	Polymerization	Aqueous	TECHNOLOGY ALTERNATIVES	PROCESSING
					X	Hexane Recovery	Aqueous	TECHNOLOGY ALTERNATIVES	PROCESSING
			X			By-Product Processing	Aqueous	TECHNOLOGY ALTERNATIVES	PROCESSING
	X					Biomass Storage	Solvent	TECHNOLOGY ALTERNATIVES	PROCESSING
				X		Grinding/Flaking	Solvent	TECHNOLOGY ALTERNATIVES	PROCESSING
				X		Acetone Extraction	Solvent	TECHNOLOGY ALTERNATIVES	PROCESSING
				X		Acetone Recovery/ Recycle	Solvent	TECHNOLOGY ALTERNATIVES	PROCESSING
				X		Cyclohexane Extraction	Solvent	TECHNOLOGY ALTERNATIVES	PROCESSING
				X		Cyclohexane Recovery/ Recycle	Solvent	TECHNOLOGY ALTERNATIVES	PROCESSING
			X			Rubber Clean-Up	Solvent	TECHNOLOGY ALTERNATIVES	PROCESSING
		X				Bagasse Handling	Solvent	TECHNOLOGY ALTERNATIVES	PROCESSING
		X				By-Product Process	Solvent	TECHNOLOGY ALTERNATIVES	PROCESSING

(1) Economics of seedling production needs refinement

(2) Agricultural costs need field demonstration

Matrix conceptual design by Mortensen, Foster et al. 1980

Actions Needed at Different Levels of Development to Achieve Commercialization

Levels of Knowledge/Technology	Actions Needed to Achieve Commercialization
Known/Operational	Form Commercialization Linkages, Provide Assurances
Needs Refinement	Support Demonstration/Pilot Projects
In Development	Support Applied Research and Development Projects
To Be Developed	Support Basic Research
Unknown	None Possible

Source: Foster, et al., 1980

based on harvesting wildstands of guayule to produce 5,000 metric tons of rubber per year and is motivated by social needs; Scenario B assumes cultivation of guayule in extensive dryland farming operations in order to meet one-third of Mexico's natural rubber demand. Maximum annual rubber production under Scenario B will be about 45,000 metric tons. The scenarios are designed to give a structure from which to generalize regarding possible impacts of commercial guayule development and resultant policy conflicts and policy needs. The scenarios share a set of state-of-society and rubber market assumptions, but each is constructed around a unique set of sociopolitical and guayule technology assumptions. Both scenarios are set in the Mazapil region in northern Zacatecas. The area was chosen because impacts resulting from development there, one of the most marginal and economically depressed areas in northern Mexico, should represent impacts from developing guayule in nearly any part of the guayule zone. These two scenarios present small-scale and large-scale development possibilities and form bounds to the range of development possibilities. Impacts and policy options relevant to new conditions can be inferred from this assessment.

Impact Forecast of Guayule Commercialization

Efforts were concentrated on determining guayule commercialization impacts on the Mazapil region of northern Mexico. The Mazapil area has a history of commercial use of guayule, and since it possesses both wildstands of guayule and the work force necessary to harvest it, this is a likely place for guayule development to occur.

The Mazapil region encompasses an area of about 20,000 square kilometers (7,725 square miles) and includes four municipios in the state of Zacatecas and one in Durango. The 1970 population of 60,000 declined by 0.1 percent by 1977. In general the region is characterized by low income, few economically rewarding opportunities, substandard housing, few basic community services in education and health care, and high rates of outmigration.

Most activities in the region involve natural resource exploitation. Important economic sectors include desert plant collecting, herding goats and sheep, small-scale agriculture, and mining. Substantial income is sent or brought back by workers who have migrated temporarily outside the region to a Mexican city or to the United States. Working primarily as family production units, many of the residents engage in several seasonal part-time economic activities throughout the year as it is only through a combination of these activities that the family can maintain itself.

Social impacts: Guayule industry development in the Mazapil region will generate new employment opportunities resulting in direct and indirect economic benefit to residents of the area. Guayule commercialization will be especially important to the groups that depend most heavily on harvesting native plants.

Because there is a mixed land tenure with both ejido (peasant collective) and private land in the region, optimum use of the wildstands will require agreements between landholders. Reforestation and improvement of wildstands could create conflicts among ejidos and between ejidos and private landowners regarding who will benefit from these programs. Intensive reforestation of wildstands and farming on new land may dramatically affect land use patterns and land tenure.

A new law, the Ley de Fomento Agropecuario (LFA), if implemented, would facilitate associations of ejidatarios (members of peasant collectives) with private landholders and could aid guayule commercialization. Critics of the law point out that it could encourage ejidatarios to rent their lands, hire out their labor, and curtail small-scale farming. It appears that guayule development would alter regional demographics although not enough data are available to say precisely what form this impact might take.

Guayule development will probably affect migration. The decision to migrate into or out of the Mazapil or remain in the area is essentially a decision made by family production units and is based upon job opportunities and income. It is possible that the number of people attracted to the region by the new job opportunities of a guayule industry could exceed the number of jobs available. Other developments in the area may drastically alter the labor pool. The rapid expansion of the industrial sector in Saltillo, especially the opening of General Motors Corporation and Chrysler Corporation automobile plants, could lure many potential guayule workers from the Mazapil region.

The guayule program could increase, decrease, or not alter migration patterns. It is probable that the programs under both scenarios will do all of these to different degrees in different areas. The net effects on migration cannot be predicted.

Under Scenario A, impacts on small-scale agriculture, native plant harvesting, or livestock herding would be minimal. A serious potential problem lies in the uncertainty of a long-term shrub supply. Overharvesting contributed in past decades to the demise of a guayule industry and could do so again without monitoring and harvest control. Development under Scenario B could be detrimental to agriculture, native plant harvesting, and possibly to herding (mainly due to competition for land, labor, and resources). Impacts in the mining industry would be minimal under either scenario. Bagasse-derived forage could offset grazing land loss. Potential impacts include conflict for land and labor with the Mexican Food System (SAM) and with native plant industries.

Many potential impacts are not unique to the guayule program but result from any substantial development in a rural setting. Development changes the rural nature of the region by improving communication, bringing new ideas and people into the region, and concentrating population. In general, guayule development should directly raise the standard of living in the region by creating new jobs, however, indirect benefits of infrastructure development may be realized by other government regional development programs, especially those of COPLAMAR. An especially difficult problem in a development program is to assure that the target population benefits most from the program. It is common for another group, in this instance the rural elite, to benefit disproportionately, resulting in a greater income disparity between the target group and others than previously existed.

Environmental impacts: Several major areas of potential environmental impacts were identified. Under the broad umbrella of desertification there are dangers of overharvesting the natural stands, largely through incomplete knowledge of maximum possible sustainable harvest of guayule shrub; drought caused crop failure leading to soil erosion; and concentration of land use in sensitive areas. Excessive wildstand shrub harvest may be averted by careful study and monitoring, but high rainfall variability and the present stage of development of dryland farming technology create an unknown, but possibly substantial, risk of crop failure, which exposes cleared land to weathering and erosion.

The process of transforming shrub into rubber and byproducts creates several potential sources of pollution and health risks. The solvents used are flammable and toxic, and the process water waste is caustic. Treatment of caustic water is possible and will be economically necessary for a profitable operation. Proper engineering can maintain the amount of solvents escaping into the atmosphere at a very low, non-hazardous level.

Harvesting and processing create some health and safety risks to the workers. Resins in guayule are irritating and slightly caustic. Harvesters will need protective clothing. Harvesting will involve the use of cutting and bailing machinery that could injure workers. Numerous potential safety hazards exist in the processing plant: toxic chemicals, boiling water, and cutting and pressing machinery. Good safety procedures properly carried out will minimize dangers.

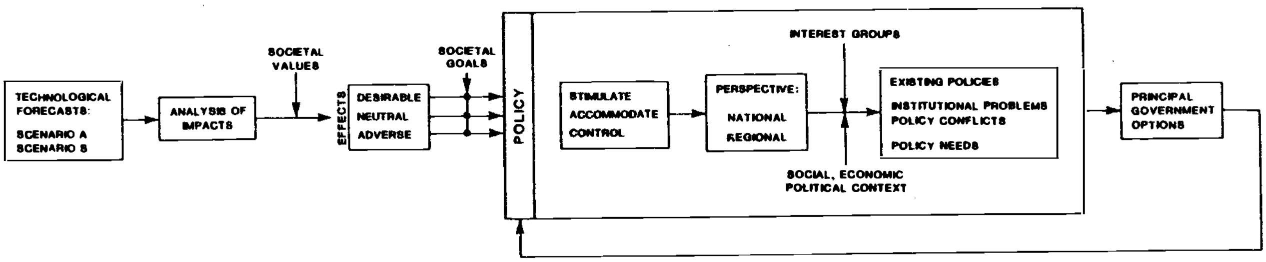
Impact workshop: Representatives of the federal, state, and local governments and research institutions participated in a workshop in which they determined what they believed to be the principal areas of impact of a wildstand harvest program in the social, economic, environmental, and political sectors and established the order of importance of the impacts for each area. The attendees considered the guayule program to have strong positive economic benefits, mixed but slightly positive social benefits, and strong negative environmental impacts.

Impacts on a national scale: A wildstand harvest program would have little impact beyond the region. Large-scale guayule farming would involve federal, state, and local governments as well as many industries. Operation and the success of the guayule industry at a large volume operation could greatly advance the process of regional development and federal government decentralization; failure of the industry could seriously set back both efforts.

Policy Analysis

This analysis focuses on public policy issues that might accompany guayule agroindustrial development and on the agencies and groups that shape, implement, and endure policy in Mexico. The social, economic, and political context in which development can occur are defined. The chapter examines current policies from a national and a regional perspective, and then identifies interest groups, critical questions underlying the main emergent issues, and existing legal instruments. This examination reveals policy needs, policy conflicts, and institutional problems that might stimulate, accomodate, or restrict commercialization.

A brief analysis of organizational structure presents possible options for a guayule agroindustrial system. The general approach to the analysis is graphically shown below.



Policy Context

Mexico is a country characterized by centralization. Historical and cultural precedents have contributed strongly to a centralized political structure supported by a concentration of weatth, population, educational and scientific institutions, planning for national and regional development and the ultimate concentration of political power in one political party and one president. Recent administrations have all tried to resolve the fundamental conflict between the perceived need to decentralize the federal government and the need to coordinate a multitude of overlapping and sometimes conflicting programs and projects.

The Global Development Plan forged by the Lopez-Portillo administration has guided development. It is a schema of centralized planning to guide expansion of heavy industry and oil and gas exploration. A substantial amount of the income derived from petroleum is to be used to generate employment and stimulate natural resource development among marginal groups and in economically depressed regions. Some of the most important national level policies that may affect the formation and operation of a guayule agroindustry are:

- Agricultural Promotion Law (LFA);
- Food Production Policy, especially the Mexican Food System (SAM);
- Agroindustrial Development Plan;
- National Plan for Industrial Development;

- National policies for strategic materials (implicit within other policies);
- National rubber policy;
- Employment policy, especially COPLAMAR:
- Science and technology policies.

Many of the national policies are expressed directly at a regional level through various dependencies and delegations. Most planning and integration at this level operates through state delegation of the Ministry of Programming and Budget (SPP) and State Planning Committees (COPLADES). Policy areas that may interact significantly with guayule agroindustry are:

- Food production;
- Exploitation of forestry resources;
- Industrial development;
- Social concerns and benefits;
- Employment;
- Science and technology.

Development of arid and semiarid lands has been an enduring concern of the Mexican government. Plans and programs have stressed land reform, investment, and technical assistance for these regions. However there are no explicit regional policies, no clear long-term strategies for development and investment in these regions; this lack has hindered the acceptance and implementation of projects such as guayule agroindustry.

Analysis of the Issues

Policy analysis centers on the issues that arose during public meetings and group discussions of the two scenarios. Four policy areas were studied in detail: identifiable issues (and the three following areas as they relate to issues) critical questions, parties-at-interest (or actors) and existing policy instruments and studies. The following tables, taken from the policy analysis chapter, compare policy implications at five levels in each scenario (Table 1) and summarize policy needs and potential conflicts for each issue in Scenarios A and B

(Tables 2 and 3). Policy needs and potential policy conflicts were deduced from the detailed study.

One of the central issues that emerged from the policy analysis is the organizational structure of the guayule agroindustrial system (SAIG). Figure 2 summarizes some of the structural options for organizing SAIG. Management may be composed of the six elements at the top which direct and integrate the activity of the three sectors in the productive chain. Figure 3 shows a suggested level of control/risk in each sector for Scenario A and Scenario B.

Table 1

COMPARISON OF SCENARIO A AND B
POLICY IMPLICATIONS

LEVEL	SCENARIO A	SCENARIO B
ECONOMIC	Economic aspects are fundamentally regional, included within the economic development policies for marginal regions. Economic objectives generate income and increase regional output through production of small quantities of rubber (5,000 tons per year). Policies include occasional subsidy. SPP, CONAZA, and other dependencies such as COPLAMAR will be key agencies.	Economic aspects are fundamentally national, immersed in the national policy for natural rubber supply. Seeks regional economic specialization through cultivation of guayule and large-scale production of significant quantities of natural rubber (50,000 tons per year). Includes national price and tax policies, formation and implementation of a National Rubber Policy concerning guayule, hevea and synthetic polyisoprenes. Roles of SEPAFIN, SPP, Banrural and SARH will be important at this level
SOCIAL	Strong social orientation seeks to increase employment, raise income, canalize direct benefits, promote indirect social benefits, and promote organizational capacity to innovate and plan, especially reforestation, transportation organization and harvesting. Could be an element of a more complete regional development plan where guayule exploitation initiates a chain of actions to generate income and employment and attracts investment. Important roles for COPLAMAR, CONAZA, CONASUPO, IMSS.	Profound changes and innovation throughout the scenario: gradual increase in mechanization and technical sophistication in cultivation and industrial processing. Need social organization in productive units with consequent social constraints. Promotes larger rural settlements and increases internal and external migration. Need for clear and well-coordinated public service policies, especially health and regulation of commerce. Important roles for the same general actors in Scenario A.
POLITICAL	Probable development of quasi-governmental organization with integral control over supply, processing and distribution. Predominant influence of existing local political organizations could inhibit transfer of political controls and diffusion of innovation needed to increase and maintain productivity; many policy interactions with instuments such as the Agriculture Promotion Law are unclear. Need: policy clearly defining institutional roles, and instruments to promote organizational innovations and renewable resources policies. Important roles for the President, State Planning Committees, state governors, SPP. At the regional level, CONAZA, FONCAN, SRA. SARH, CNC/PRI will be important, as well as peasant organizations (CNC/PRI) and opposition parties.	Close links with national policies, especially industrial development and commerce; eventually tied to potential changes in federal policy toward transnational rubber companies. Serious conflicts among guayule, livestock, and food crop-producing actors and policies supporting them. Definite displacement of political organizations' renewable resources activities. Need for a clear policy framework for agro-industry and intensification of highly technical productive units. Most active participants: the President, industrial development groups, SEPAFIN, SPP (including COPLADES), SARH, Chamber of Rubber Producers and Consumers, SECOM, SRA, SAM, FIDHULE, labor unions (CTM and others), peasant organizations (CNC), and small property owners (CNPP).

COMPARISON OF SCENARIO A AND B
POLICY IMPLICATIONS

LEVEL	SCENARIO A	SCENARIO B
ENVIRON-MENTAL	Strict organization control required to reduce ecological risk of deforestation and to assure resource sustainability. Need 7-10 year plan; without replanting programs, resource economic availability will diminish. The requirements greatly limit the type of organization and system required. Need: integrated exploitation system for the principal economic activities (plant, harvest, livestock heading, farming); monitoring and control of processing wastes. Important actors: guayule organizations, FONCAN, La Forestal, ejiditarios, small land owners, SARH, SSA, environmental research institutes and research centers.	Scenario initiation through wildstand exploitation requires a policy of resource maintenance via revegetation. Proposed guayule farming activities require studies of erosion control methods, since clearing thousands of hectares of erosion-susceptible land is envisioned. Policies and plans for land clearing, erosion control, and combating desertification should follow these studies. Needed policies include controls of water use and pollution associated with guayule farming and processing. Planning policies will be required for nursery establishment and maintenance of genetic diversity. Important roles for the same actors as in Scenario A, but with greater involvement of research institutions
RESEARCH AND DEVELOP-MENT	Needed: studies oriented toward optimizing harvests to assure sustainable yields; monitoring guayule populations; reforestation plans. Management oversight to coordinate sectors of guayule production, processing, and transportation will be important. Scenario A project size will permit internal R & D; this to be conducted by existing research centers. Principle research organizations involved will include CONAZA, CONACYT, CIQA, INIF, and SPP.	Intensive research programs in nursery irrigation and dryland cultivation; genetic improvement; use of bioregulators; machinery development; and innovative plans for increasing guayule product to be established. Industrial process innovation will require research, especially in optimization of material and water use; utilization of wastes; and identifying uses and markets for resin products. Scenario's magnitude will require intensive R & D efforts through establishment of professional research units concentrating on guayule agronomics, cost reductions, optimization of soil and water use. Needed: long-term plan with fixed goals; participation of institutions specializing in various aspects of guayule development. Principle agencies and research organizations should include CONAZA, CONACYT, CIQA, SARH, INIA, CIANOC and SPP.

Table 2

POLICY NEEDS AND POTENTIAL POLICY CONFLICTS
SENARIO A

A. Economic Feasibility

- Conflicts may result from natural resource policy shifts (from subsidy to self-sufficiency).
- Federal assistance programs may conflict with private industry desires and operations.

B. Regional Economic Development

- Create a program to implement, manage, and monitor guayule program as part of a regional natural resource-use program.
- Competition among agencies over priorities and management of regional development programs.
- Clear definition of how regional development programs and LFA will be implemented.
- Integrated regional investment policy.

C. Distribution of Benefits

- Federal/private disagreement over where benefits should flow.
- Need a Collective Work Contract

D. Structure and Capability of the Guayule Organization (SAIG)

- Presidential Decree: Recommendations for SAIG defining involved parties and their responsibilities and goals.

E. Institutional Conflict/Coordination

- Resolution of roles of private/federal sectors in planning, implementing, and operating SAIG.
- Policies for integrated management of forestry resources.

F. Integration of Guayule With Other Natural Resource Activities

- Coordination of natural resource development program.
- Promotion of natural resource industries in ways that are detrimental to other such industries.

G. Land Tenure

- Conflicts among land owners, land holders, and federal agencies over implementing LFA and guayule program.

H. Migration, Manpower and Employment

- Coordination of guayule program objectives and campesino needs for job security, and adequate wage levels.

I. The Role of Labor Organizations

- Integration of workers' activity in wild plant harvest and representation of industrial workers.
- Collective Work Contract.
- Competition among labor organizations for representation on SAIG.

J. Infrastructure Development

- Regional development plan integrating SAIG and infrastructure support.
- Competition among federal agencies and programs for funds.

K. Environmental Pollution

- Definition of health and safety standards for harvesters and industrial workers.
- Economic feasibility of guayule program conflicts with cost of implementing health and safety standards.

L. Ecological Concerns

- Create a sustained yield guayule harvest program based on monitoring of resources and a reforestation program.
- Conflict between goals of SAIG and resource and environmental protection laws (due to technological or ecological limitations) of harvest and reforestation program.

M. Management of Water Resources

- Competition for water--human consumption or food production versus for guayule production.

N. Science and Technology Capability

- NO policy conflicts foreseen

Table 2

POLICY NEEDS AND POTENTIAL POLICY CONFLICTS
SCENARIO B

A. Economic Feasibility

- Conflicts regarding devaluation and exchange related to the price of imported natural rubber.
- Conflicts between international rubber stockpiling policies and internal Mexican rubber pricing policies.
- Need for national rubber plan that addresses rubber prices, subsidies, taxes on domestic and imported rubber and differences in production costs of hevea, guayule, and synthetic rubber.
- Need for coordination of financing for production and processing sectors.

B. Regional Economic Development

- Conflicts between price guarantees for guayule and food crops.
- Need to consider policies regulating minimum wage for industrial work outside urban areas and minimum wage for non-industrial work. Need for industrial wages in rural areas.
- Conflicts between guayule production and processing wage policies.
- Possible need for regional planning to govern conflicts for guayule development among states/regions.

C. Distribution of Benefits

- Conflicts between national guayule rubber development policies and regional policies for development and social programs such as COPLAMAR.
- Need for profit distribution policy to apply to agricultural and processing sectors in the guayule development program.

D. Structure and Capability of Guayule Organization

- Presidential decree needed to establish SAIG.
- In the absence of SAIG, conflicts between policies for agricultural and industrial development.

E. Institutional Conflicts/Coordination

- Conflicts between planning policies at different governmental levels e.g. COPLADES vs. National Rubber Plan.

F. Integration of SAIG with other Renewable Natural Resource Activities

- Conflicts between guayule development policies and existing rangeland improvement policies.
- Conflicts between guayule development policies and ixtle and candellia policies.

G. Land Tenure

- Conflict between policy expressed by the LFA and the Agrarian Reform Law expressing the traditional support for agrarian ideals.
- Possible need to enforce the intent of the LFA to increase production without abandoning the ideals of agrarian reform.

H. Migration, Manpower, and Employment

- Possible need to adapt COPLAMAR employment policies to the new policies created by SAIG.

I. The Role of Labor Organizations

- Conflicts may develop among labor organizations for political control of guayule labor groups.

J. Infrastructure Development

- Possible competition among agencies with existing development programs like PIDER (Projects for Development in Rural Areas), and SAIG for funds and authority to operated in the rural area.

K. Environmental Pollution

- Need to enforce existing laws concerning environmental pollution.

L. Ecological Concerns

- Need to address desertification. (Policies emerging from IPES [Institute for Political, Social, Economic Studies] to define ecological protection of Mexico's natural resources may meet this need.)

M. Management of Soil and Water Resources

- Need to integrate management of SAIG agriculture with policies of SARH and SAHOP to limit water use and define permissible uses in the regional water districts.

N. Science and Technology Capability

- Need for a research and development policy that includes INIA, INIF, CIQA, and regional universities.

O. National Economic and Industrial Development

- Same conflicts and policy needs as for Regional Economic Development (B).

P. National Rubber Plan

- Need for a national rubber plan.

Q. Competition with Food Production

- Possible conflict of SAIG policies promoting guayule rubber production and SAM policies and other policies that support food production through price supports and indirect subsidies of agricultural production supplies.

R. United States Interest in Mexican Guayule Commercialization

- Possible policy conflicts in Mexico due to desires or perceived desires of multi-national corporations to invest in guayule rubber production, and concern that the United States Department of Defense will wish to acquire Mexican guayule rubber.

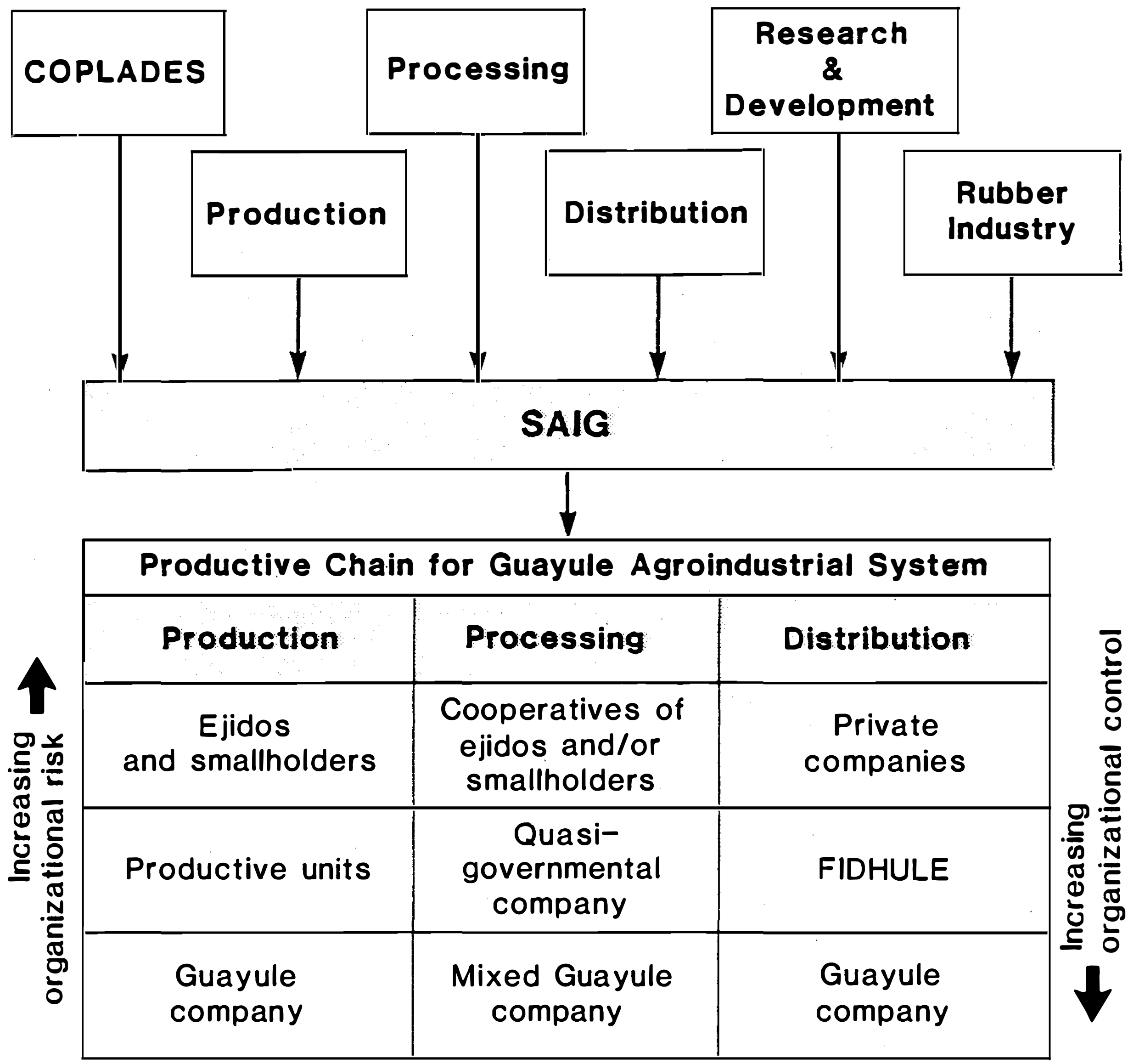


Figure 2. Some Options for SAIG Organizational Structure

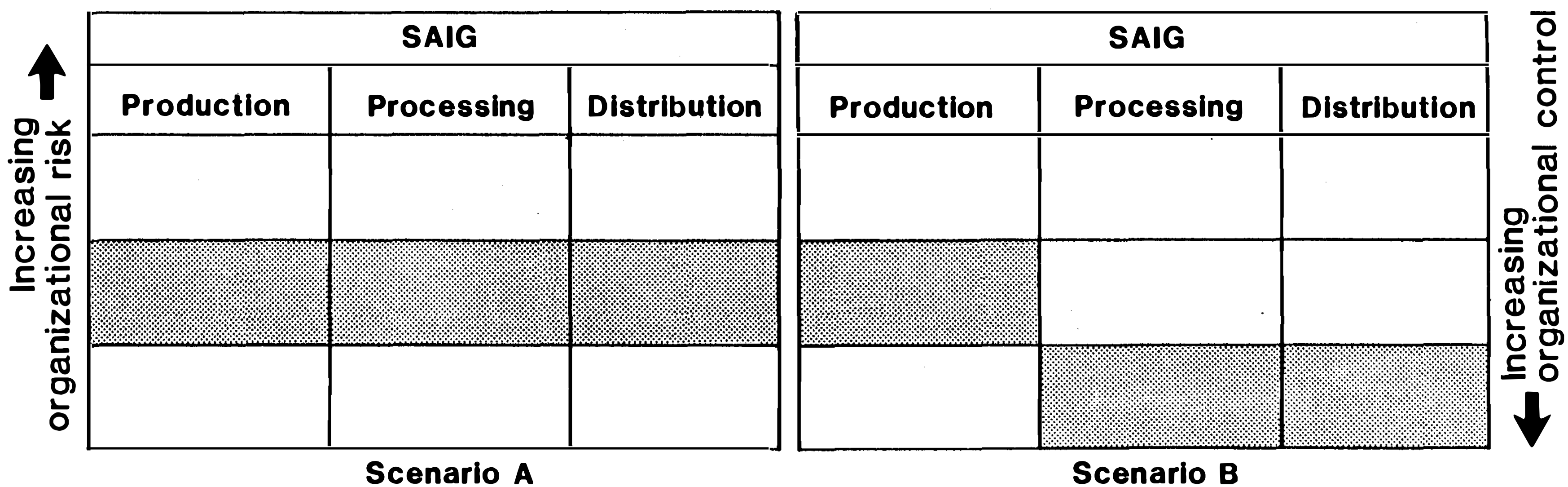


Figure 3. Suggested levels of Levels of Control/Risk in SAIG Operation for Scenarios A and B

I. INTRODUCTION

Rubber has become a key element in transportation, agriculture, and industry and literally keeps modern economies rolling. The rubber tree (*Hevea brasiliensis*) and the guayule shrub (*Parthenium argentatum*) are the only major biotic sources of rubber, but it is *Hevea* upon which the rubber products industry currently relies for its supply of natural rubber. However, rubber from the two species is very similar in quality, and for most uses guayule rubber is directly interchangeable with hevea rubber.

Mexico contains extensive wildstands of guayule. In addition, the plant could also be plantation grown to yield commercial quantities of high quality rubber at a price potentially competitive with hevea rubber or synthetic cis-polyisoprene.

Approximately 50 percent of the two million square kilometers of the land area of Mexico is arid or semi-arid. In the two northern deserts (the Chihuahuan Desert and the Sonoran Desert), the scarcity of water and the harshness of the climate are such that a substantial proportion of the population in rural areas lives at the subsistence level. Many peasants migrate temporarily or permanently to surrounding cities or the United States in search of employment or higher wages.

The development of a Mexican guayule industry in Mexico's northern arid regions would create an economic base and promote a more stable local economy where unemployment is high and job potential is limited. But, harvesting native stands or development of plantations could have profound and widespread effects on the social and economic fabric of the regions in which guayule is grown and processed.

An increasing number of organizations and individuals throughout the world, but especially in Mexico and the United States, are studying the technology of growing and processing guayule. However, except for one technology assessment (TA) (Foster et al., 1980), little attention has been paid to the social, economic, and political consequences of further developing these technologies. The objective of this study has been to perform a comprehensive technology assessment of the effect of guayule commercialization in Mexico. This TA examines the technical, economic, social, and political forces that might stimulate or inhibit the development of a guayule rubber industry, the impacts or consequences of this commercialization, the alternative approaches that are open to government and the private sector, and the consequences that might be expected from following various policy options.

The study was conducted by the Office of Arid Lands Studies (OALS), University of Arizona, and the Centro de Investigacion en Quimica Aplicada (Applied Chemistry Research Center) (CIQA) in Saltillo, Coahuila. Work was divided into several phases.

Phase I consisted of a meeting of the two teams in Saltillo in July 1980. This phase included brainstorming on potential guayule issues, refining the project tasks, and developing a tentative outline of the final report. The completion of Phase I was the publication of A Technology Assessment of the Commercialization of Mexican Guayule: Orientation Report, in November 1980.

Phase II, the sociotechnical survey of guayule development, consisted of an extensive review of future world and Mexican demands for elastomers, the socioeconomic situation in Mexico's northern arid zone, and present agricultural and industrial state-of-the-art aspects of guayule technology. This review involved the examination of native Mexican guayule distribution, sustained yield, dryland farming, propagation, processing, and prospects for commercialization.

In Phase III, two alternative technology development scenarios were developed. Scenario A is motivated by social needs. It is designed around a modest set of social and economic improvement targets that require minimal improvement in regional organization and management. No extensive research and development is needed, and the existing infrastructure used in current native plant wildstand harvesting and marketing needs only modest expansion to accommodate the requirements of commercial guayule rubber production from wildstands. The greatest change in existing patterns is the need for a single 5,000 metric tons of rubber per year processing facility that is machinery and capital intensive. Guayule commercialization requires organized and coordinated harvesting, transportation, and processing systems. The amount of rubber produced under Scenario A is less than 5 percent of the projected 1995 Mexican natural rubber demand.

Scenario B assumes intensive regional guayule development efforts through wildstand harvest and dryland culture of guayule in order to supply a significant portion (about 30 percent) of the Mexican natural rubber demand. Two driving forces motivate this scenario: 1) a desire for national self-sufficiency in rubber, due in part to the anticipation of an international shortfall of natural rubber and subsequent price rise, coupled with rapid growth of natural rubber demand in Mexico; and 2) a national policy promoting economic development in the northern arid zone.

Scenario A was discussed by the research team with a diverse group of parties-at-interest in Saltillo on April 1-3, 1981. The objective of the meeting was to present the scenario, explore potential issues and conflicts, and gain a preliminary insight into impact and policy implications.

Phase IV projected impacts based upon implementation of the two scenarios developed in Phase III. The impact forecasts were developed from information generated at the April 1981 meeting and at a second meeting with the parties-at-interest in Saltillo in July 1981, from interviewing key personnel and individuals in the potential guayule growth region who might have interest in guayule production, and from sociological and environmental data.

Phase V consisted of an assessment of public policy issues, the primary focus of the report. In this phase the national and regional policy-making process in Mexico was examined and issues and critical questions for each scenario defined. Existing policies, policy conflicts, and policy needs were identified. A meeting was held with the parties-at-interest in Saltillo in November 1981 to discuss and refine the policy analysis. Appendix A provides a list of the attendees at the three meetings of the parties-at-interest.

A more detailed description of the United States - Mexico cooperative research approach to the guayule technology assessment and the mutual benefits derived from conducting the TA is provided in Appendix B.

The value of the Mexican peso changed greatly in the last year. To provide a constant value for comparisons, all costs originally stated in pesos were converted to U.S. dollars at an assumed exchange rate of 23 pesos to the dollar.

II. OVERVIEW OF ELASTOMER CONSUMPTION AND PRODUCTION

As a background and context for discussion of guayule commercialization, this chapter describes historic and recent developments in the synthetic and natural rubber industries. Trends in world and Mexican elastomer supply and demand are discussed and extrapolated to the year 2000. Major points in this chapter are also summarized in the Rubber Market Assumptions (Table V-2), in Chapter V, Scenarios for the Future.

A. Synthetic and Natural Elastomer Development

Until World War II, natural rubber dominated the world elastomer market. The primary source for natural rubber was *Hevea brasiliensis*, native to the Amazonian rain forests of South America. In the late 19th century *Hevea* was successfully planted in Ceylon and the Malay Peninsula, and natural rubber plantations began to flourish in Southeast Asia. By 1912 cultivated rubber production equaled wild rubber production, then soon doubled and redoubled. *Hevea* plantings in Asia increased from 2,500 hectares in 1900 to 500,000 hectares in 1910 (Allen, 1972). A fungus disease, the leaf blight *Dothidella*, destroyed South American *Hevea* rubber plantations early in the century, and East Asia became the major geographical location of natural rubber production. At that time, Mexican guayule was providing 10 percent of the world's natural rubber and 50 percent of the total U.S. rubber consumption (Sekhar and Pee, 1980).

During the 1920s a substantial amount of guayule rubber was produced in Mexico, and some in the United States as well. The guayule industry in Mexico was curtailed during the Mexican Revolution, and guayule rubber production was slowed in the United States and Mexico during the Depression in the 1930s, but by 1936 approximately 67,000 metric tons of guayule had been produced in Mexico (Velazquez et al., 1978). In the

United States, 1,400 metric tons of guayule rubber were produced by the Intercontinental Rubber Company between 1931 and 1941 (U.S. Forest Service, 1946a).

During World War II Southeast Asian rubber supplies, the main sources of natural rubber for Western Europe and the United States, were cut off by the Japanese. Major efforts were initiated to develop alternative sources of rubber. In the United States, under the U.S. Emergency Rubber Project (ERP), an additional 32,000 acres of guayule were planted in California and Texas. Between 1941 and 1946, approximately 1,400 metric tons of guayule rubber were produced. During the same period Mexico produced more than 47,000 metric tons of guayule rubber for export to the United States.

Concurrently, substantial efforts were being undertaken in both the United States and Germany to develop synthetic rubber. German synthetic rubber research had been in progress as early as 1910. Russian research in the 1920s and 1930s and U.S. development of neoprene rubber in 1932 were major contributions. The industry developed rapidly during World War II, and synthetic rubber consumption began to exceed that of natural rubber. By 1945 production processes for several types of synthetic rubber had been developed, and U.S. industry was producing 0.7 million metric tons annually.

At the end of the war, hevea rubber again became available on the world market, and the newly developed synthetic rubber technology was successful in helping to meet the increasing rubber demands of the booming automotive industry. As a result, U.S. and Mexican guayule production was virtually abandoned.

In the 1950s technological breakthroughs in production and processing of styrene-butadiene rubber, the major type of general purpose synthetic rubber, improved both the quality and profitability of synthetic rubber. The development of polybutadiene and polyisoprene in the late 1960s also contributed to the growth in synthetic rubber usage. Natural rubber producers were unable to keep pace with the increasing growth in world rubber demand and when cheap monomers, the raw material for synthetic rubber, became readily available, the synthetic rubber industry expanded rapidly. Synthetic rubber commanded a progressively larger fraction of the world rubber market, claiming more than half the market by 1960. It now constitutes about 70 percent of the total world elastomer market.

B. Current World Elastomer Consumption and Production

The synthetic rubber industry has benefited from relatively stable supplies and prices of raw materials. In contrast, natural rubber plantations are vulnerable to disease, a major consideration in South America, and adjustment to fluctuations in the world elastomer market is made difficult by the five-year lag between *Hevea* plantings and initial rubber production. However, major improvements have been made in hevea rubber production, including increased yields due to development of higher yielding clones, stimulation, and better exploitation methods. In addition, the quality and standardization of the finished product have been improved. All these factors have been helpful in maintaining natural rubber's present 30 percent share of the total world elastomer market.

Synthetic and natural rubber are chemically different. Natural rubber continues to be preferred where high elasticity, resilience, tackiness, and low heat buildup are required. It is an indispensable component of airplane tires and of radial auto, bus, and truck tires. Because production of tires and other automotive products accounts for 65 percent of world elastomer consumption, continued or increased popularity of radial tires is a significant factor in stimulating the demand for natural rubber (Grilli et al., 1978).

1. World rubber market: Total world elastomer consumption increased from approximately 1.7 million metric tons in 1946 to 12.8

million metric tons in 1979. This represents an average yearly growth rate from the 1950s to the 1970s of about 6.3 percent, almost paralleling the growth of world industrial production. During that same period the natural rubber supply grew at an average yearly rate of less than 3 percent a year, while synthetic rubber use increased at an average yearly rate of 9.3 percent a year, filling the widening gap between elastomer demand and the supply of natural rubber (Grilli et al., 1978).

Since 1972, synthetic rubber use has been growing at a reduced rate. Radial tires, becoming increasingly popular, require approximately twice as much natural rubber and one-third less synthetic rubber than do bias ply tires. Increasing costs of the petrochemical feedstocks used in synthetic rubber production are also beginning to have an impact on synthetic rubber consumption.

Total world elastomer consumption in 1980 was estimated by the International Institute of Synthetic Rubber Producers (IISRP) as being approximtely the same as in 1979, 12.8 million metric tons (Elastomerics, 1980). This reflects the recent slowed growth in rubber demand resulting from the decrease in world economic growth induced by the oil crisis. Other recent estimates of 1980 elastomer consumption have been somewhat lower. The Economic Intelligence Unit, Ltd. (EIU) estimates that world elastomer consumption declined 1 percent during the first half of 1980, and 4 percent in the second half (Schultz, 1981).

World consumption of natural rubber has been decreasing more than one and one-half times faster than has rubber manufacturing. During the 12-month period ending in February 1981, world natural rubber demand fell 3.7 percent while production fell only 1.2 percent (Rubber and Plastics News, 1981). This production/consumption difference has resulted in a 15 million metric ton increase in natural rubber stocks in the first two months of 1981, raising the surplus from 25 million tons to 40 million tons. This contrasts with the 15 million ton shortage at the end of 1979 (Rubber and Plastics News, 1981).

2. <u>Synthetic rubber production</u>: Total world synthetic rubber production capacity in 1978 for all types of synthetic rubber, as reported by the International Rubber Study Group (IRSG) (1979), was 10.5 million metric tons. An estimated 12.1 million metric tons of worldwide synthetic rubber capacity was expected by 1981.

Most of the world's synthetic rubber production is in the Western industrial countries and Japan, although a large quantity of synthetic rubber is produced in Eastern Europe and the USSR About 4 percent is produced in developing countries -- Mexico, Brazil, Argentina, India, and Korea. Outside of the centrally planned economies, tire manufacturers and petrochemical producers dominate synthetic rubber production and together control 90 percent of existing production capacity (Grilli et al., 1978).

Expansion of synthetic rubber production capacity in the industrialized countries has stopped almost entirely, due to the uncertainties created by the oil crisis, the general slowdown in world economic activities, and growing pressures and concerns over environmental and health issues related to the industry. However, expansion is continuing rapidly in the developing countries and in the centrally planned economies of Eastern Europe and the USSR.

Many believe that world synthetic rubber production capacity will be considerably increased in the Arab States and the Republic of China, where surplus crude oil reserves are available. Some large petrochemical complexes have been built, and others are being planned. This would have a significant impact on the world export market, as rubber not consumed in tire and other rubber products plants would be available for export (Ruebensaal, 1978).

3. <u>Natural rubber production</u>: Hevea rubber production, a labor intensive industry, is carried out primarily on farms and plantations of Southeast Asia. Over 40 percent of all the world natural rubber supply

is produced in Malaysia; much of the remainder is produced in Indonesia and Thailand. About 12 percent of the world total is produced in other parts of Asia (Sri Lanka and India) and in Africa (Liberia and Nigeria). Most of the rubber is grown on small farms. The percentage of small farm production ranges from 67 percent in Malaysia to over 95 percent in Thailand (Sekhar and Pee, 1980). Ninety percent of all the hevea rubber produced is exported, mainly to the Western industrial countries and Japan in a semiprocessed state (Flavin, 1980).

Hevea will probably grow in the Western Hemisphere within a band 25 degrees north and south of the equator wherever rainfall, topography, and soil conditions fulfill *Hevea's* requirements. However, this does not necessarily mean it could be grown profitably in all areas within that region due to possible slow growth and low yields. Also, *Hevea* production is labor intensive, and therefore, plantations must be located where there is an ample supply of available labor.

Hevea is currently being grown commercially in the Western Hemisphere in Mexico, Brazil, Bolivia, Peru, Ecuador, and Guatemala. It could possibly be grown successfully in Paraguay, Colombia, Venezuela, the Guyanas, Panama, Costa Rica, El Salvador, Honduras, and many of the Caribbean Islands (Riedl, 1980). Brazil and Guatemala are producing the greatest amounts of hevea rubber in the Western Hemisphere. According to the IRSG (1979) Brazil produced almost 24,000 metric tons of hevea rubber in 1978 while importing more than 56,000 tons. Brazil expects its rubber demand to double by 1990 and plans to increase its 10,000 hectares of *Hevea* plantations by planting an additional 120,000 hectares (Latin America Commodities, 1978a). Hevea rubber production has been growing steadily in Guatemala, reaching 9,700 tons in 1977 (Latin America Commodities, 1978b). However, political problems emerging in Guatemala may create an unfavorable environment for further expansion of *Hevea* plantations in that country. In the past, the South American Leaf Blight (*Dothidella*) has been a serious constraint to *Hevea* production in South and Central America. Chemical control of this disease now seems possible, but this will increase the production cost (Riedl, 1980).

The hevea rubber industry is just beginning to reap the benefits of long-term research and development programs carried on during the past 20 years, and productivity increases are expected over the next 30 years through tree breeding and selection. Comprehensive programs to expand natural rubber production are underway in many of the traditional hevea rubber-producing countries.

4. Rubber production costs: Crude oil prices tripled between 1973 and 1975, causing a corresponding rise in the price of butadiene, styrene, and polyisoprene, the primary feedstocks for synthetic rubber manufacturing. Similarly, the cost of petroleum-derived energy required for processing and transporting products increased well beyond the existing rate of inflation.

The costs of synthetic rubber production depend as much as 70 percent on the costs of chemical feedstocks and energy inputs. These costs more than doubled between 1973 and 1975. This, together with increased labor and overhead costs, resulted in a 75 percent to 100 percent increase in direct costs of producing synthetic rubber in all major industrialized countries.

Natural rubber costs were not as affected directly by the oil crisis. The corresponding direct production cost increase for natural rubber was approximately 10 percent (Grilli et al., 1978). Natural rubber production costs were also affected indirectly by the acceleration of world inflation including rising labor costs, which account for 55 percent of hevea rubber production costs, and increasing freight costs. Any increase in the real price of oil would improve even more the long-term cost competitiveness of natural rubber (Grilli et al., 1978).

5. Rubber prices: The price of the highest grade of traded natural rubber ribbed smoked sheets (RSS1) approached $.70 per pound on several occasions during 1979 and exceeded $.80 per pound in 1980. In 1981, it dipped below $.46 per pound and has not risen substantially above $.47 per pound in the first quarter of 1982. The market price of natural

rubber is influenced by changes in the supply and demand balance and is sensitive to sales and strikes in the automotive and tire industries, transportation problems, and political uncertainties. For example, prices peaked during the Korean War and again in response to the 1973-74 oil crisis, and to various "boom" conditions in the automotive industry in 1955 and 1959-60 (Grilli et al., 1978).

The synthetic rubber industry is structured in such a way that prices can easily be differentiated between markets, but according to Grilli et al. (1978) it is almost impossible to reconstruct a "world price" even for a specific type of synthetic rubber. They suggest, however, that for styrene-butadiene rubber the long-run trend in world prices is approximated by the trend in U.S. export unit values and that the declining trend in natural rubber prices between 1950 and 1970 was influenced by the decline in general purpose synthetic rubber prices. Price jumps experienced between 1973 and 1981 are related to cost increases that coincide with major changes in the price of feedstock for synthetic rubbers due to increases in crude oil prices.

In the past, natural rubber prices have been subject to a great deal of fluctuation. The recently negotiated International Natural Rubber Agreement mandates the establishment of a 550,000 metric ton buffer stock of natural rubber. The stated purpose is to help stabilize prices. An initial reference price has been established at about $.45 per pound. If the price falls to 20 percent below the reference price, the manager is required to buy. In a similar way, the manager may sell from the stockpile when the natural rubber price rises to more than 15 percent above the reference price; he is <u>required</u> to sell if the price increase is more than 20 percent above the reference price. The agreement was negotiated in the hope that a floor price would thereby be established that would offer enough incentive for small rubber farmers to expand and replant, but critics maintain that the agreement bears no practical relationship to today's natural rubber prices (Anderson, 1980).

6. Natural rubber/synthetic rubber competition: The market interaction between natural and synthetic rubbers is complex. They are close substitutes for each other. Natural rubber, styrene-butadiene, and synthetic polyisoprene compete wherever a general-purpose rubber with standard characteristics is needed and when the choice between elastomer types is largely determined by relative prices and availability. Careful compounding can yield a tremendous number of combinations of rubbers with a predetermined set of properties, but relative compounding costs must be considered as well as relative rubber prices.

Grilli et al. (1978) report that expert opinion is widely divergent regarding the potential for switching from synthetic to natural rubber use. At one end of the spectrum the prospect is viewed as quite limited, probably no more than 5 percent of total elastomer use, even when economically advantageous. Political factors are deemed more important than economic ones in realizing this potential. The Malaysian Rubber Research and Development Board (MRRDB) view has been that except for specialty markets (15 percent) and the market for styrene-butadiene and polybutadiene blends in passenger-car tires (another 15 percent), the world rubber market is technically open to isoprenic rubbers (natural rubber and synthetic polyisoprene). Allowing for processability and price differences in natural rubber and polyisoprene and considering end uses, an MRRDB study concluded that the normative share of natural rubber in total elastomer use is 43 percent.

A survey of rubber users conducted by Grilli et al. (1978) indicated that at least 15 percent of the styrene-butadiene rubber and 50 percent of the polyisoprene market could switch to natural rubber. Using 1975 consumption figures (excluding centrally planned economies) natural rubber could have had a market share of 42 percent as opposed to an actual share of 34.5 percent. Although current year relative market prices influence rubber choice only slightly, in the longer run relative price is clearly an influencing factor.

The choice of the types of rubber utilized in manufactured products is influenced by technical, economic, and market-related factors, and the substitution of one type of rubber for another is constrained by both technical and non-technical factors. Rubber users tend to delay mix changes in response to relative prices because technical adjustment costs are involved. In addition, tire makers, the largest users of rubber, often have their own synthetic rubber production facilities. These companies tend to use their own inputs whenever possible and try to operate their rubber production facilities at capacity. Other users who do not have their own production facilities are often tied to specific domestic suppliers of synthetic rubbers by contract, or other customary relationships. Government policies aimed at maintaining a favorable balance of trade tend to favor the use of domestically produced rubbers. National security is another factor influencing protection and encouragement of domestic rubber production (Grilli et al., 1978).

C. Projected World Elastomer Consumption Through the Year 2000

Oil prices are rising much faster than world inflation. Between 1972 and 1981, the contract price per barrel of oil rose from approximately \$3 to \$32. The latter figure undoubtedly will increase after this report is published. This rate of growth is equivalent to an average annual increase of more than 30 percent. The full, long-term impact of this trend on the world economy and elastomer demand remains to be seen.

Nearly two-thirds of the rubber consumed in the world is for transportation uses. Tires account for 51 percent of world rubber consumption; other transportation uses, 14 percent. Non-transportation uses account for 35 percent. These market shares are not expected to change significantly in the next 20 years. Modernization of transportation systems in the developing nations and increasing demand in the centrally planned economies is expected to offset slowed rubber demand in industrialized nations. The World Bank forecast of the annual elastomer demand increase for 1976 to 1990 for developed countries was 4.3 percent; for developing countries 7.9 percent; and for countries with centrally planned economies 6.5 percent (Grilli et al., 1978).

Riedl (1980), formerly with Goodyear Rubber Company, estimated that the world natural rubber supply will increase by 3.2 percent per year to 1990, growing from approximately 3.8 million metric tons in 1979 to over 5.3 million metric tons in 1990. This estimate is lower than the 4 percent growth rate for the period 1976-1990 projected by the World Bank study in 1978 (Grilli et al.). That study acknowledges, however, that the future production capabilities of Indonesia and the smaller producers are uncertain and that "the short-term production potential of the smaller producers may be overstated."

The growth rate projected by the World Bank for world demand for all elastomers is 5.5 percent per year from 1980 to 1985, then 4.8 percent between 1985 and 1990, more than 1 percent below the historical rate. Applied to an estimated total demand for 1980 of 12.8 million metric tons (IRSG, 1979; Riedl, 1980), a 5 percent growth rate indicates a total world demand for all elastomers of 34.0 million metric tons by the year 2000. This is almost 2.7 times the present world demand. Many forecasters now believe an annual growth rate of about 3.5 percent, resulting in a world demand of 25.5 million metric tons in 2000, is more realistic (Riedl, 1980).

As world demand for natural rubber continues to grow, it is likely that hevea rubber supplies will fall behind the increasing demand for natural rubber and will no longer be able to fill 30 percent of the elastomer market.

Table II-1 shows World Bank estimates (Grilli et al., 1978) of total elastomer demand through 1990 and the decreasing share of the market that would be filled by natural rubber. Table II-2 shows estimates of total elastomer demand through 2000 and the potential natural rubber shortfall

TABLE II-1

PROJECTED WORLD RUBBER DEMAND AND NATURAL RUBBER (NR) SHORTFALL THROUGH 1990 BASED ON WORLD BANK PROJECTIONS*

Year	Total Rubber Demand	NR (Hevea) Production	Calculated Market Share	Potential NR Demand**	Potential NR Shortfall**
	10^6 Metric Tons		Percent	10^6 Metric Tons	
1980	14.500 (5.1% growth)	4.350 (3.8% growth)	30.0	4.350	—
1985	18.600 (4.8% growth)	5.245 (3.2% growth)	28.2	5.580	.335
1990	23.500	6.135	26.1	7.050	.915

* Grilli et al., 1978
** Based on 30% market share.

TABLE II-2

PROJECTED WORLD RUBBER DEMAND AND
NATURAL RUBBER (NR) SHORTFALL THROUGH 2000
BASED ON 3.6% TOTAL DEMAND GROWTH RATE

Year	Total Elastomer Demand (3.6% growth/annum)	*Hevea* Production (3.2% growth/annum)	Calculated Market Share	Potential NR Demand*	Potential NR Shortfall*
	10^6 Metric Tons		Percent	10^6 Metric Tons	
1979	12.820	3.755	29.3		
1980	12.820	3.755	29.3	3.846	0.091
1981	13.282				
1982	13.760				
1983	14.255				
1984	14.768				
1985	15.300	4.396	28.7	4.590	0.192
1986	15.851				
1987	16.421				
1988	17.012				
1989	17.625				
1990	18.259	5.145	28.2	5.478	0.333
1991	18.917				
1992	19.598				
1993	20.303				
1994	21.034				
1995	21.791	6.023	27.6	6.537	0.514
1996	22.576				
1997	23.389				
1998	24.231				
1999	25.103				
2000	26.007	7.050	27.1	7.802	0.752

* Based on 30% Market Share

based on more recent estimates. These estimates place total 1980 elastomer consumption at approximately 12.8 million metric tons (IRSG, 1979; Riedl, 1980) and 1979 hevea rubber production at 3.755 million metric tons (IRSG, 1979). We have no final statistics for actual consumption and production in 1980, but consumption estimates are close to the 1979 actual figures, so we have assumed no change in consumption and production from 1979 to 1980 (Table II-2).

The 3.6 percent annual growth rate for elastomer demand in Table II-2 has been selected in view of recent projections (Riedl [1980], 4.3 percent to 1990 and 3 percent from 1990 to 2000; Dr. Clayton Rubensaal, Uniroyal, Inc., 3.6 percent to 2000 [Riedl, 1980]; and the IISRP, 3.6 percent to 1990 [Elastomerics, 1980]). An average annual growth rate for hevea rubber production of 3.2 percent, as estimated by Riedl (1980), is projected in Table II-2. This is slightly lower than the rate projected by the World Bank of 3.8 percent through 1985 and 3.2 percent from 1985 to 1990 (Table II-1).

Potential natural rubber demand in Table II-2 was estimated at 30 percent of the total demand, which is the current natural rubber share of the total elastomer market. The natural rubber demand estimates in Table II-1 were derived from the World Bank projections indicating the maximum natural rubber market share possible to be 30 percent in 1980, 28.2 percent in 1985, and 26.1 percent in 1990 as hevea production fails to keep pace with demand. The differences between hevea production and potential demand based on the 30 percent market are listed in the final column of each table as potential natural rubber shortfall. Assuming the 3.6 percent growth rate for total elastomer demand as shown in Table II-2, the natural rubber supply will be approximately 0.8 million metric tons short of the 30 percent natural rubber share of the market in 2000, dropping to a 27.1 percent market share.

Historically, natural rubber consumption has consistently matched supply. Assessments of the theoretical potential market for natural rubber indicate that if enough natural rubber were available it could account for 40 percent of the total elastomer market, although the price of synthetic.rubber would be a determining factor (Riedl, 1980). Due to end-use applications that require natural rubber, world consumption of natural rubber could probably remain near 30 percent, or possibly increase to 35 percent, through the year 2000 if enough natural rubber were available. However, division of the demand for "isoprenic rubber" beween hevea, synthetic polyisoprene, guayule or some other elastomer yet to be created by new technology is difficult to forecast. A decrease in the natural rubber share of total elastomer consumption to 25 percent or less would probably be due to a shortage of natural rubber. Substitution of more expensive or lower quality synthetic polyisoprene might then become necessary (Foster et al., 1980).

Synthetic cis-1, 4-polyisoprene has nearly the same chemical structure or microstructure as hevea rubber but may differ in average molecular weight, molecular weight distribution, degree of crystallinity, gel content, non-rubber content, and cure properties. Synthetic polyisoprene properties differ according to cis-1,4 content. High-cis polyisoprene (96 percent) closely resembles natural rubber (more than 99 percent) and can be used as a natural rubber substitute in radial tires. Low-cis polyisoprene is not a complete natural rubber substitute but can supplement or partially replace it in a rubber product such as a truck tire. Isoprene, the major ingredient in polyisoprene production, is obtained from crude oil under severe cracking conditions.

As a result of feedstock shortages and high manufacturing costs, polyisoprene is in short supply worldwide. Sources of polyisoprene include Canada, France, Italy, the Netherlands, Rumania, the USSR, and Japan. World annual production capacity of cis-1, 4-polyisoprene; trans-1, 4-polyisoprene; and other 1, 2- and 3, 4-enchained polymers is nearly 1.6 billion pounds. Centrally planned economy countries that are developing cis-1, 4-polyisoprene plants in efforts to become independent from imported hevea rubber include Bulgaria, Czechoslovakia, Poland, and the USSR. World low- and high-cis polyisoprene production capacity is currently 1 million metric tons; production capacity of 1.3 million metric tons is projected for 1982 (Rubber World, 1980).

D. Mexican Elastomer Consumption and Production

Total Mexican rubber consumption in 1978 was estimated to be more than 150,000 metric tons; natural rubber constitutes approximately one-third of that total, more than 50,000 metric tons (CIQA, 1979). Annually, five thousand tons of hevea rubber is domestically produced annually. In 1978, Mexico produced more than 80,000 metric tons of synthetic rubber (IRSG, 1979).

Countries such as Mexico that have large petroleum refineries can solve their feedstock problems. An impure isoprene can be made from streams co-produced when heavy oils are catalytically cracked to produce gasoline. This isoprene would be suitable for low-cis polyisoprene production (Anderson, 1980).

1. Mexican elastomer consumption: Table II-3 shows natural and synthetic rubber consumption in Mexico in the decade following 1968, when the total consumption of both types of rubber was little more than 63,000 metric tons. By 1978, total synthetic rubber consumption had climbed to 100,460 metric tons; natural rubber to 50,685 metric tons. Almost 35 percent of all the rubber used in Mexico is natural rubber, a high percentage compared to natural rubber use in Brazil, which is 25 percent, and Latin America in general, which is closer to 30 percent (Lara M. and Morales A., 1978).

The period between 1967 and 1977 was one of rapid industrial growth in Mexico. The automobile industry, one of the most dynamic, experienced an annual growth rate of 14.5 percent during the seven years between 1967 and 1974, with a temporary slowdown and contraction from 1975 to 1977.

TABLE II-3

Mexican Elastomer Consumption 1968-1978

Year	Total Elastomer Consumption	NR* Consumption	Percent NR	SR** Consumption	Percent SR
	Metric Tons			Metric Tons	
1968	63,060	22,605	36	40,455	64
1969	65,639	26,204	40	43,574	60
1970	77,503	28,215	36	49,288	64
1971	83,443	31,192	37	52,251	63
1972	86,465	28,453	33	58,012	67
1973	98,950	31,690	32	67,260	68
1974	114,475	36,376	32	78,369	68
1975	111,467	37,200	33	74,267	67
1976	125,352	41,628	33	83,724	67
1977	123,517	39,734	32	83,783	68
1978	151,153	50,685	34	100,460	66

* Natural Rubber
** Synthetic Rubber

Source: Derived from Lara M. and Morales A. (1978)

The number of vehicles per capita grew from 46 per 1,000 inhabitants in 1975 to 66 per 1,000 in 1977. The rubber industry experienced growth as demand increased for tires and industrial rubber articles. Hules Mexicanos, a major Mexican synthetic rubber producer, reported a growth rate of 14 percent for polybutadiene, 16 percent for ethylene-propylene and 7.7 percent for polyisoprene and butyl rubber during the period 1968-1976 (Lara M. and Morales A., 1978). There was a slight decline (1.46 percent) in rubber demand in 1977 due largely to contraction in related areas such as the automotive industry. However, the automotive industry has been recovering and is planning expansion. Growth was expected to increase by 18 percent in 1980. It has been projected that by 1982 there would be 6.8 million vehicles in Mexico: 93 per 1,000 inhabitants (Lara M. and Morales A., 1978).

Eight facilities produce rubber-related products such as accelerators and vulcanizing agents. There are eight tire manufacturers in Mexico and 120 other manufacturers of various rubber products. Many are planning expansions due to the increased demand for tires and other products.

2. <u>Mexican elastomer supply</u>: Mexico is in the fortunate position of being able to produce both synthetic and natural rubber. As a major petroleum producer, the country has the potential for meeting its synthetic rubber industry needs for petrochemical feedstocks. In addition, both <u>Hevea</u> and guayule can be grown in Mexico. In 1977 Mexico produced 10 percent of all the natural rubber consumed within the country in that year, and 85 percent of the synthetic rubber. Table II-4 gives import figures for natural and synthetic rubber during the period between 1968 and 1977. Eighty percent of the imported rubber was for tire manufacturing. Table II-5 gives the total number of metric tons per year of synthetic rubber produced annually in Mexico between 1968 and 1979.

a. <u>Natural rubber</u>: The quality of the hevea rubber produced in Mexico does not meet tire industry standards. Production costs are very

TABLE II-4

MEXICAN RUBBER IMPORTS 1968-1977

(Metric Tons)

	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977
SR*	10,025.2	7,729.5	8,837.2	9,646.1	10,099.0	14,432.6	24,374.1	14,529.0	16,048.0	12,889.0
NR**	22,604.7	26,204.5	28,215.2	31,192.3	28,453.5	31,689.8	36,376.3	37,200.0	41,628.0	39,734.0
Total	32,629.9	33,934.0	37,052.4	40,838.4	38,552.5	46,122.4	60,750.4	51,729.0	57,675.0	52,623.0

* Synthetic Rubber
** Natural Rubber

Source: Lara M. and Morales A. (1978)

TABLE II-5

MEXICAN SYNTHETIC RUBBER PRODUCTION

(Metric Tons)

1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979
33,506	41,130	43,700	48,713	53,253	54,304	65,503	60,047	69,450	62,616	80,272	87,750*

* Estimated

Source: IRSG (1979)

high compared to international rubber market prices. This is due largely to competition for available labor in the *Hevea* growing region in Mexico. Total production costs have been estimated at 27.22 pesos per kilogram (in 1979) of rubber, almost 89 percent of which represents the cost of collecting the rubber. Processing costs are approximately 8.5 percent and distribution costs approximately 2.5 percent of the total hevea rubber production cost (CIQA, 1979).

Hevea production is established mainly in the states of Veracruz, Tabasco, and Oaxaca. Approximately 4,800 hectares of plantations are producing about 5,000 metric tons of rubber annually. An additional 3,200 hectares have been planted since 1978. How much more land could be available for *Hevea* plantations is open to question.

An estimated 1.2 million metric tons of harvestable guayule shrub exist in wildstands in northern Mexico (INIF, in CONANZA 1976 and 1977). The total potential rubber yield of these shrubs is 70,000 metric tons. However, this represents a one-time harvest.

The Fideicomiso del Hule (FIDHULE) was established in 1978 to encourage and facilitate natural rubber development and industrialization, including various types of financial aid. FIDHULE relies on a technical committee that examines and approves projects, determines types of financial support needed, and approves annual budget expenditures and investments.

To date, only preliminary outlines of possible FIDHULE programs are known. It has been suggested that present hevea rubber production be increased by additional plantings, and by utilizing the production technology used in Guatemala, where with less area in cultivation, greater volumes of rubber have been obtained than in Mexico. It is also recognized that the quality of the rubber must be raised by improving the existing plantations, the systems for extraction and handling of the latex, and the processing facilities. It has been emphasized that *Hevea* cultivation must not replace cultivation of basic foodstuffs or interfere with the goals of self-sufficiency established by the Mexican Food System (Sistema Alimentario Mexicano) (SAM) (MacGregor, 1980).

b. Synthetic rubber: There are two major synthetic rubber producers in Mexico. Hules Mexicanos, S.A., the largest synthetic rubber and carbon black producer in Mexico, was founded in 1967. Sixty percent of Hules Mexicanos is owned by Petroleos Mexicanos (Pemex), Mexico's national oil company, and 40 percent is owned by Polysar, a Canadian-based company. Hules Mexicanos plans an expansion to increase synthetic rubber production and more than double its carbon black production. In 1968 Negromex, Mexico's other major synthetic rubber producer, began to produce styrene-butadiene and polybutadiene. Forty percent of this company is owned by Phillips Petroleum; 60 percent by Mexican interests. In 1977 Negromex increased its production capacity by 50 percent.

The Mexican synthetic rubber industry produces only three types of synthetic elastomers: styrene-butadiene, polybutadiene, and nitrile rubber. Until other types of elastomers such as butyl or polyisoprene are added to its product line, Mexico will remain dependent on synthetic rubber imports. The country has been importing approximately 15 to 20 percent of the synthetic rubber it consumes annually (Table II-4). The exception was in 1974, when imports increased to 31 percent. Imports in 1978 were close to 20 percent, but may have dropped to about 17 to 18 percent in 1980 (Anderson, 1980).

Mexico exports a small amount of synthetic elastomers, mainly styrene-butadiene. In 1978, 1,800 metric tons were exported; in 1979, 2,100 metric tons. An estimated 2,500 metric tons were exported in 1980 (Anderson, 1980).

3. Projected Mexican elastomer consumption and production. Based on trends up to 1979, projections of rubber consumption forecast an annual natural rubber use of approximately 90,000 metric tons by 1990.

Projections based on the expanded industrial production anticipated by the Mexican Government in its National Industrial Development Plan forecast Mexican natural rubber consumption at approximately 140,000 metric tons annually by 1990 (CIQA, 1979). The rubber products industry is seen to be an extremely dynamic sector, second only to petrochemicals. Natural rubber consumption has grown at an average annual rate of 7.5 percent during the past few years (Flores, 1980) and Hules Mexicanos has projected a 6.8 percent growth rate for the period between 1978 and 1987 (Table II-6).

According to Raymundo Danon, National Association of the Chemical Industry, the Mexican synthetic rubber consumption average annual growth rate will be 9 percent, and by 1983 internal demand will be between 155,000 and 160,000 metric tons (Zubryn, 1979). Hules Mexicanos' projection for 1983 is 157,604 tons of synthetic rubber consumption. An average annual growth rate of 8.8 percent is anticipated. The market ratio of synthetic rubber to natural rubber is not expected to change (Lara M. and Morales A., 1978).

Production increases are planned for elastomer types already being produced. Hules Mexicanos operates a 52,000 metric-ton-per-year styrene-butadiene plant at Tampico. A 10,000 metric-ton-per-year expansion was planned for July 1980, another 10,000 in 1981, and an additional 20,000 metric-ton-per-year expansion in 1983 or 1984, bringing the total capacity to 92,000 metric tons per year. Negromex S.A. is adding a capacity of 10,000 metric tons to its 45,000 metric-ton-per-year styrene-butadiene/polybutadiene plant at Salamanca. These expansions should enable Mexico to meet its styrene-butadiene rubber requirements through 1985, but a much greater production capacity will have to be developed to keep pace with Mexican synthetic rubber demands (Anderson, 1980).

Raw materials for Mexican synthetic rubber production should present no problem. Pemex planned expansion in petrochemicals includes feedstock for synthetic rubber. Some scepticism exists, however, regarding Pemex's ability to meet its announced production goals and construction timetable (Anderson, 1980).

TABLE II-6

PROJECTED MEXICAN ELASTOMER CONSUMPTION, 1978-1987

(Metric Tons)

	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
SR*	100,460	109,982	120,370	131,713	144,593	157,604	172,348	188,430	206,306	225,479
NR**	50,685	54,232	57,997	61,993	66,234	70,743	75,532	80,623	86,062	91,880
Total	151,153	164,214	178,367	193,706	210,827	228,347	247,880	269,053	292,368	317,359

* Synthetic Rubber
** Natural Rubber

Source: Lara M. and Morales A. (1978)

Hules Mexicanos reports that if the availability of the basic chemicals necessary for development of the synthetic rubber industry is assured, the Mexican synthetic rubber industry can not only supply the future internal demand for synthetic rubber but will also be in a position to export styrene-butadiene and nitrile rubber (Lara M. and Morales A., 1978).

The projected consumption levels for 1978-1987 in Table II-6 were determined by using correlations with economic indicators such as the Gross Domestic Product (Producto Interno Bruto) (PIB) and with other industries such as auto, truck, and tire production. It is assumed that the rate of population growth will diminish to about 2.7 percent by 1982 and that in future years it will be even lower. It is also assumed that in the future the PIB will regress to growth rates similar to those prior to 1976: an average of 7 percent (Lara M. and Morales A., 1978).

Synthetic rubber consumption is expected to climb to over 225,000 tons by 1990. Taking into account future natural rubber consumption as indicated by the two alternative natural rubber projections reported by CIQA (1979), total Mexican rubber consumption can be expected to be between 315,000 and 365,000 tons by 1990. This latter figure represents an annual increase of almost 10 percent, exceeding the 7.9 percent growth rate projected by Grilli et al. (1978) for developing countries between 1976 and 1990. Projections of Mexican natural rubber consumption between 1979 and 2000 at growth rates of 5 percent, 7 percent, and 10 percent are given in Table II-7, based on figures proposed in the National Industrial Development Plan.

TABLE II-7

MEXICAN NATURAL RUBBER CONSUMPTION PROJECTIONS*

1979-2000

Year	Total Demand (Metric Tons) 5 Percent Growth Rate	7 Percent Growth Rate	10 Percent Growth Rate
1979	53,219	54,233	55,754
1980	55,880	58,029	61,329
1981	58,674	62,091	67,462
1982	61,608	66,438	74,208
1983	64,688	71,088	81,629
1984	67,922	76,065	89,792
1985	71,319	81,389	98,771
1986	74,884	87,086	108,648
1987	78,629	93,182	119,513
1988	82,560	99,705	131,464
1989	86,688	106,684	144,610
1990	91,023	114,152	159,071
1991	95,574	122,143	174,978
1992	100,352	130,693	192,476
1993	105,370	139,842	211,724
1994	110,638	149,630	232,896
1995	116,171	160,105	256,186
1996	121,979	171,312	281,804
1997	128,078	183,304	309,985
1998	134,482	196,135	340,983
1999	141,206	209,864	375,082
2000	148,266	224,555	412,590

* Based on 1978 natural rubber consumption of 50,685 tons.

III. GUAYULE TECHNOLOGY

A discussion of Mexican guayule wildstands and the agricultural and industrial aspects of guayule technology are presented in this chapter.

A. Ecology of Guayule

The climatic conditions in the region in which guayule occurs naturally and the relationship between guayule growth and climate and soils are discussed in this section.

1. Relation to climate: Guayule is native to an arid and semiarid region. The climate affecting guayule in its native range, as discussed by Bullard (1946a), is summarized below and may help explain the importance of climate as a factor in commercial guayule production.

The mean annual rainfall in the region varies from 8 inches to 15 inches. In extremely dry years, there may be as little as 2 inches; in wet years, highs of 25 inches have been recorded. Rainless periods extending for four months are common; drought periods may extend as long as seven months. Rainfall generally is biseasonal, peaking during the spring and fall, although in some areas approximately 90 percent of the rain occurs in the summer and fall, with little during the winter and spring.

Seasonal and diurnal temperature variations in the guayule region are fairly broad. Maximum temperatures of 115°F and minima of 15°F have been recorded. However, the climate is comparatively moderate, and no cold season exists in much of the area. The warm season is the wet season; winter and early spring are dry and sunny, so guayule on southern slopes often is not exposed to extreme cold. Dry winds occur during the winter, but during the growing season humidity is rather high.

Guayule grows in its native habitat with as little as 8 inches mean annual rainfall, but runoff from slopes provides additional moisture. Runoff and percolation from higher areas can increase effective rainfall moisture by as much as 50 percent. Guayule does not grow rapidly in its native habitat; more moisture would be required if tonnage had to be grown quickly for commercial production. Guayule roots extend to depths of 20 feet or more, if moisture is available at that depth, and ultimately deplete soil moisture nearly to that depth if rainfall is insufficient.

Cold injury to guayule is related to growth activity in the plant in response to available soil moisture. High soil moisture, in itself, appears to be no hazard to dormant plants, but injury results when favorable growing temperatures and available soil moisture generate shrub growth just before the onset of critical cold periods. The extent of the injury is inversely related to the degree of dormancy. In Texas, dormant plants on some test plots withstood temperatures of $1^{o}F$ to $4^{o}F$ without appreciable injury, while on other plots considerable damage occurred at temperatures of $14^{o}F$ and $15^{o}F$. Severe injury kills guayule plants outright, but recovery from moderate cold injury is usually rapid. Minor injury does not seem to impair shrub vigor. When cold temperatures cause defoliation, new leaves are produced earlier and in greater abundance than on undamaged plants.

2. Physiography and soil requirements: Lloyd (1911) has described in some detail the physiographic and soil characteristics of the guayule native habitat. His description is summarized in the following paragraphs.

Guayule grows on the high plateau of Mexico, which is broken up into various mountain ranges separated by wide, flat valleys or "bolsones." The middle reaches (playas) of these valleys are nearly level and have a deep, fine, alluvial soil containing a vast amount of available moisture. There are extensive areas within the flats where salts have accumulated and where the salt-bushes (*Atriplex* sp.) are the only vegetation.

A low gradient slope extends from the periphery of these alluvial plains to the foothills of the mountain ridges. The soil of the footslopes is gravelly, becoming more and more stony as the foothills are approached. The soil is frequently very shallow and may be confined to the crevices of the underlying rock. In the hills, the edges of the strata are often exposed and the vegetation grows only in the intervening fissures.

Of the species of Parthenium found in the region, guayule is confined to the footslopes and foothills, and is abundant in hills below 7,000 feet in elevation. It is generally believed to be more abundant on the south slopes. Guayule is an "edaphic" species, found only where the ground is stony, although a few isolated plants may exist in the alluvial plains. On the other hand, mariola (Parthenium incanum) and the annual species P. hysterophorus grow in abundance in the fine soil of the plain, and mariola is also commonly associated with guayule on the footslopes and hills. This association of guayule and mariola frequently misleads the inexperienced observer in estimating the amount of guayule which may be found in a given area.

Local guayule distribution may be strongly affected by competing species. Table III-1 lists species identified as competitors by Muller (1946) and as possible competitors by Alder and Ostler (1980). All these plants are often associated with guayule.

Little is known of germination requirements in wildstand guayule, but germination is the critical stage in the life of a plant. Seed survival seems to be greatly enhanced by nurse plants, non-competing older plants that provide a cooler, more moist microclimate and physical protection. Guayule grows slowly, especially in its first year, a trait which is disadvantageous to a plant competing for a very limited water supply. Guayule is probably a poor competitor, and this may be the primary factor limiting its local distribution, not abiotic factors such as soil (Alder and Ostler, 1980).

TABLE III-1

POSSIBLE GUAYULE COMPETITORS

Prevalent Species Identified as Competitors (Muller, 1946 in Alder and Ostler, 1980)	Possible Competitors Highly Associated with Guayule
Agave lechuguilla	*Dyssodia setifolia*
Parthenium incanum	*Dyssodia pentachaeta*
Bouteloua curtipendula	*Zinnia acerosa*
Erioneuron pilosum	*Agave lechuguilla*
Bouteloua gracilis	*Dermatocarpon lachneum*
Tiquilla mexicana	*Euphorbia anychioides*
Tridens pulchella	*Mimosa biuncifera*
Aristida purpurea	
Tiquilla greggii	
Stipa eminens	
Jatropha dioica	

Source: Alder and Ostler, 1980

B. Wildstand Distribution

The distribution of native stands of guayule in Mexico is shown in Figure III-1. The northern limit of guayule distribution is in the United States, in the southwestern part of Texas, in Presidio, Brewster, and Pecos Counties (Lloyd, 1911).

Guayule is restricted to the Chihuahuan desert. In Mexico it grows only in the northern portion of the central plateau, in parts of the states of Chihuahua, Durango, Nuevo Leon, Zacatecas, San Luis Potosi, and in scattered locations over the whole state of Coahuila. About 10 percent of this 130,000 square mile (290,000 square kilometer) area supports guayule stands.

In 1942, O.D. Hargis prepared a report for the ERP on Mexican guayule based on data supplied by the Continental Mexican Rubber Company. He divided the area into two categories: states where there are extensive guayule fields, which he designated as the 'Good Zone'; and states where the shrub is found in smaller and varying amounts, or the 'Poor Zone'.

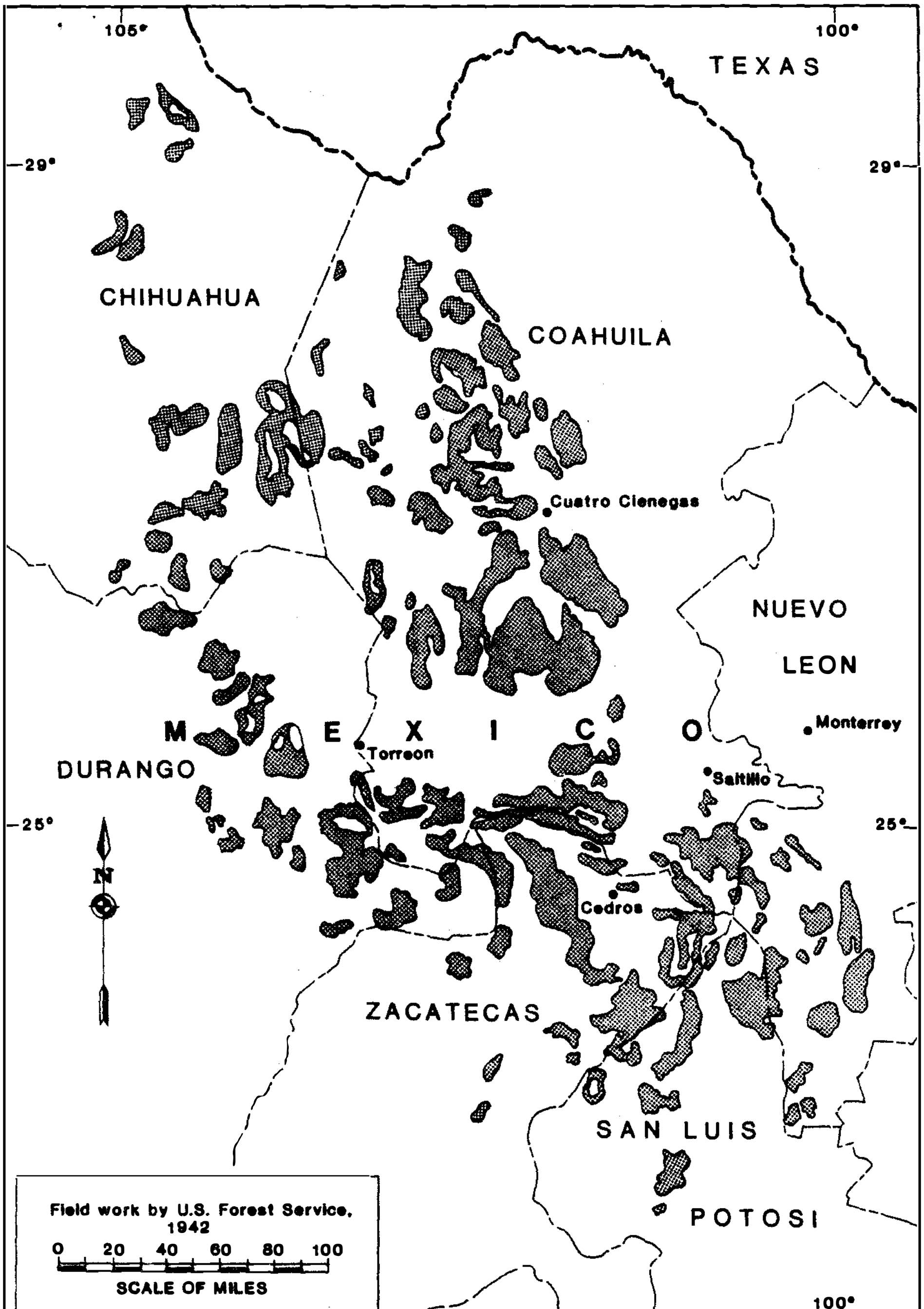
The Good Zone, as described by Hargis, comprises the following areas:

Coahuila. The lower portion of the state, beginning at a point south of the towns of Monclova and Cuatrocienegas.

Nuevo Leon. The southern part of the state, beginning at the border of Coahuila north of San Luis Potosi.

San Luis Potosi. The extreme northern part of the state.

Zacatecas. The northern portion of the state.



After C.K. Cooperrider, 1943

Figure III-1. Guayule Distribution in Mexico

Durango. Approximately the eastern third of the state, the line running just east of the city of Durango. Guayule plants are not found in all of Durango, but usually grow on the slopes and tops of limestone hills, and in some places on the flatter lands. In this area fields are more widely distributed, and plants have a higher density per unit of area.

Guayule exists outside the above delineations, usually in small isolated patches, in some cases far from water, and in areas with poor roads or transportation facilities. Consequently, this guayule is difficult and expensive to exploit. This Poor Zone is located in the northwestern part of Coahuila and the eastern part of Chihuahua, as described below.

Coahuila. The area, north of the Good Zone, usually referred to as the Cuatrocienegas area. The best fields are near the villages of Zaragoza and Playas in the north central part. Guayule also exists in smaller quantities east of this line, toward the Texas border.

Chihuahua. Guayule in Chihuahua is limited, and largely confined to two areas. One of these is south and west of the town of Cjinaga (or Presidio in Texas). The best fields are around the village of Marquez. The rubber yield of shrub in this area is reportedly low. The other guayule area in Chihuahua is in the southeastern part of the state, the general area shown on maps as the Bolson de Mapimi.

Several more recent, localized guayule distribution and inventory studies include a 1974 study by the National Institute for Forestry Research (Instituto de Investigaciones Forestales) (INIF) of a portion of the Cuatrocienegas region in Coahuila and by the National Commission on Arid Zones (Comision Nacional de las Zonas Aridas) (CONAZA) of two other areas in Coahuila: approximately 240,000 hectares in the Cuatrocienegas region in 1976 and 2.3 million hectares in the Agua Nueva region in 1977. In 1979 CIQA and Native Plants Inc. of Salt Lake City, Utah, U.S.A., undertook a joint study of 1.6 million hectares in the Agua Nueva region, encompassing portions of Coahuila, Nuevo Leon and Zacatecas. Their objective was to determine plant community ecology and update previous inventories through the combined use of satellite imagery and field investigation of 65 macroplots in the area. In 1980 Native Plants Inc., cooperating with CIQA and CONAZA, undertook a study to determine the distribution and standing crop of guayule near Saltillo. The 7-million hectare study area centered near Cedros, in the state of Zacatecas, and included portions of Coahuila, Nuevo Leon, Durango, Zacatecas, and San Luis Potosi. Maps from Landsat data were generated for the entire study area except for small portions where Landsat data were not available. Results showed guayule present on approximately 570,000 hectares. A more detailed, quantitative description follows in the next section.

C. Wildstand Biomass and Sustained Yield

1. Shrub estimates: The historical sources of information on standing biomass of guayule include field estimates by various U.S. researchers in Mexico and Mexican rubber company records of quantities of rubber actually produced. Current estimates of standing shrub are based on a recent series of detailed Mexican regional surveys of guayule shrub made by CONAZA, INIF, CIQA, and Native Plants Inc., referred to in the previous section (Table III-2). The shrub estimates are not strictly comparable due to the lack of a standardized surveying and reporting method.

F.E. Lloyd was commissioned by a rubber company in Mexico in 1907 to investigate guayule. He continued his field work in Mexico for several years with support from the United States Rubber Company, and the results of his work were published in 1911. He estimated that there were 250,000 tons of wild guayule shrub in Mexico at that time, or one-half the total shrub growing in Mexico before extensive harvesting began in the early 1900s.

TABLE III-2

ESTIMATED GUAYULE SHRUB BIOMASS

1911-1981

Report Publication Date	Source	Shrub Quantity (Metric Tons)	Comments
1911	Lloyd	250,000	About one-half of original amount present before intensive harvest
1942	Hargis	213,450 + appreciable amount	Includes mature shrub only on private land
1942	McCallum	Not more than 1/8 amount present in 1910	Except for Durango, only a small fraction of shrub present in 1910
1942	Cooperrider & Culley	198,003	Coahuila
		67,215	Nuevo Leon
		83,684	Zacatecas
		1,240	San Luis Potosi
1943	"	259,698	Merchantable shrub in entire guayule region in Mexico
		222,250	Merchantable shrub with reasonable access
1974	INIF	303,808	Cuatrocienegas region
1976	CONAZA	462,087	Cuatrocienegas region (not including area in 1974 estimate)
1977	CONAZA	406,277	Saltillo region
1978	CONAZA	1,527,000	Zacatecas (not including 1977 estimate)
1981	Native Plants Inc.	2,200,000	Parts of Coahuila, Nuevo Leon, Durango, Zacatecas, San Luis Potosi (7 million ha)

W.B. McCallum (1942), long-time botanical scientist with the Intercontinental Rubber Company, spent two months in Mesico revisiting guayule growing areas he had studied earlier. He estimated that in 1942 only an eighth of the shrub tonnage remained that existed there in 1910. In many places where guayule once had been abundant, it was virtually gone. The only exception was in Durango, where he found some good stands.

Hargis (1942) reported to the U.S. Department of Agriculture the Intercontinental Rubber Company claim that the Continental-Mexican Rubber Company and Cia. Hulera de Parras, S.A., had current contracts for 164,950 metric tons of shrub. They estimated that 48,500 metric tons were still available for contract. According to Hargis' report, the available shrub at that time totaled 213,450 metric tons. However, the total biomass of guayule in Mexico was probably considerably underestimated due to three factors: 1) only private land for which guayule contracts could be made was included in the inventory estimates; 2) small isolated patches deemed too small or remote to harvest economically were excluded; and 3) only mature shrubs, those with a ground-level stem diameter greater than 2 centimeters, or the field measure the size of a man's thumb, were counted. Government and communal land accounted for about 5 to 6 percent of the area reported by Hargis to be in the Good Zone for guayule harvest and contained "an appreciable amount of guayule" (Hargis, 1942).

Not satisfied with the Hargis report, as it was based principally on information provided by the Continental-Mexican Rubber Company, the U.S. Forest Service sent C.K. Cooperrider, an ecologist, and Matt J. Culley, an experienced range technician, to obtain information based both on company estimates and field surveys. Their final estimate (Cooperrider, 1943) was 222,250 metric tons of shrub available on areas with fair to good accessibility. This was 8,800 metric tons more than the estimate in the Hargis report. When scattered stands and those with poor accessibility were included, the total they reported was 259,000 metric tons, 44,000 tons more than the Hargis estimate.

TABLE III-3

GUAYULE SHRUB BIOMASS ESTIMATES FOR CUATROCIENEGAS REGION

County	State	Number of Land Units	Total Area of Guayule (Has.)	Total Tons of Guayule
Ocampo	Coahuila	83	157,300	308,000
Fco. I. Madero	Coahuila	4	1,900	3,500
Cuatrocienegas	Coahuila	14	23,500	35,000
Ramos Arizpe	Coahuila	4	6,600	11,000
Parras de la Fuente	Coahuila	3	5,200	12,000
Sierra Mojada	Coahuila	20	20,700	52,000
San Pedro	Coahuila	5	8,500	15,000
General Cepeda	Coahuila	2	3,700	6,000
Jimenez	Chihuahua	3	5,200	10,000
Camargo	Chihuahua	2	6,800	10,000
	Sub-Total	140	239,400	462,000
	INIF	21	154,900	303,800
	TOTAL	161	394,300	765,900

Average: 1,930 kgs./ha.

Source: Adapted from CONAZA, 1976

INIF and CONAZA conducted surveys in the Cuatrocienegas region in the middle 1970s using aerial photographs and field surveys. They reported an estimated 766,000 metric tons of guayule shrub (Tables III-2 and III-3). Using the same methods CONAZA surveyed the Saltillo region and Zacatecas (Table III-4). They reported an estimated 1.93 million metric tons of guayule shrub. Combining these estimates gives a total estimate of 2.7 million metric tons of guayule biomass existing in Mexico.

Native Plants Inc. (1981) estimated shrub biomass in a 7 million hectare (1.7 million acre) circle centered at Cedros, Coahuila, by combining a computer analysis of Landsat satellite imagery with field density and cover estimates. The computer analysis provided a summary of hectares of land with several classes of guayule shrub cover. The total guayule biomass in the study area was estimated by multiplying the estimated shrub weight per hectare of each designated cover class by the number of hectares in each cover class. Shrub weight per hectare for each cover class was determined by field measurements of shrub cover and weight. The estimates depend on the computer-identified areas of guayule distribution and limited field checks on guayule distribution and density. Their estimate of 2.2 million tons of shrub is probably an overestimate.

2. Sustained yield estimates: Although it is important to have good estimates of available guayule shrub, it is perhaps more critical to the long-range prospects of a guayule industry based on wildstand harvest to know how much shrub can be harvested without depleting the population or destroying its ability to replace harvested shrub. Compared to the number of estimates of standing biomass, there have been few attempts to predict the long-term sustainable yield from wildstands. Hargis (1942) estimated sustained shrub yield for five states and two sections of Coahuila (Table III-5). Based on the information in the Hargis report, the total sustainable production for all of Mexico was approximately 27,000 tons per year. Hargis' sustained yield estimate was based on an assumed 4- to 5-year cycle for natural regeneration.

TABLE III-4

GUAYULE SHRUB BIOMASS ESTIMATES FOR SALTILLO REGION

County	State	Number of Land Units	Total Area of Guayule (Has.)	Total Tons of Guayule
Parras	Coahuila	33	77,350	117,000
Ramos Arizpe	Coahuila	5	41,300	73,000
Gral. Cepeda	Coahuila	2	6,400	8,000
Dr. Arroyo	Nuevo Leon	1	740	1,000
Saltillo	Coahuila	50	39,776	56,000
Cedral	San Luis Potosi	1	709	1,000
Galeana	Nuevo Leon	37	39,376	66,000
Mazapil	Zacatecas	8	20,353	29,000
Concepcion del Oro	Zacatecas	12	22,090	55,000
	TOTAL	149	248,094	406,000

Average: 1,638 kgs./has.

Source: Adapted from CONAZA, 1977

TABLE III-5

GUAYULE SHRUB SUSTAINED YIELD ESTIMATES

Source	Location	Hectares	T/Ha	Tons
Hargis (1942)	Chihuahua			800-1,000
	Coahuila			5,500
	Durango			10,000
	San Luis Potosi			5,000
	Zacatecas			5,000
	Nuevo Leon			1,200
	Guayule Region Total			27,700
Polhamus (1941)	Guayule Region			7,000*
		Hectares	T/Ha	
CONAZA (1977)	Saltillo Region	33,674	1.71	57,611
CONAZA (1976)	Cuatrocienegas	37,144	1.56	57,761
INIF (1974)	Cuatrocienegas	19,362	1.44	27,976
	Cuatrocienegas	56,506		85,736
	TOTAL	90,180		143,347
Anderson (1980)	Cedros Mazapil Region			30,000

* Short tons

CONAZA studies in the mid 1970s produced estimates much higher than those in the Hargis report (Tables III-5, III-6, III-7). CONAZA's estimate of annual sustained harvest in the Saltillo area is based on natural regeneration and an annual harvest of one-seventh of the total estimated shrub (Table III-6). This area alone is expected to yield annually more than 57,450 tons of shrub. In the sustained harvest estimates of the Cuatrocienegas region, both CONAZA and INIF studies assume that one-eighth of the total shrub is harvested each year (Table III-7). The total annual sustainable harvest in Mexico is estimated to be about 143,000 tons of shrub (Table III-5).

Anderson (1981) has estimated that the maximum sustainable yield from wildstand harvest in the Cedros region is no more than 30,000 tons per year. This estimate is based on several mathematical models of biomass accumulation. Because Anderson questions the appropriateness of a number of the assumptions on which the model is based, this estimate, like the others, must be considered an approximation until detailed field studies during harvest provide adequate data.

Implicit in sustained yield estimates is the assumption of a predictable growth rate for guayule shrub, a known population age structure, and a sufficiently high replacement rate to maintain reproduction. Field data to support these assumptions are minimal.

Another indicator of guayule population response to harvest can be found in rubber production records. Table III-8 is a 41-year record of rubber production in Mexico. Production varied considerably and appears to have responded strongly to changes in rubber demand and price. Hargis (1942) reported that rubber extraction was very low in the early production years but increased to an average of 14 to 16 percent. Over the entire period the average extraction of rubber was 10 percent of shrub field weight. A rough estimate of the weight of shrub harvested to produce this rubber can be made by multiplying yearly rubber production by 10. Ten tons of shrub would yield 1 ton of rubber. Based on this shrub-to-rubber ratio, the estimated yearly harvest average over the

TABLE III-6

SUSTAINABLE YIELD* ESTIMATES FOR SALTILLO REGION

County	State	Number of Land Units	Total Tons of Guayule Shrub	Total Area of Guayule (Has.)
Parras	Coahuila	33	17,000	11,000
Ramos Arizpe	Coahuila	5	10,000	4,300
Gral. Cepeda	Coahuila	2	1,000	900
Dr. Arroyo	Nuevo Leon	1	150	100
Saltillo	Coahuila	50	7,500	5,900
Cedral	San Luis Potosi	1	200	100
Galeana	Nuevo Leon	37	9,500	5,600
Mazapil	Zacatecas	8	4,100	2,900
Concepcion del Oro	Zacatecas	12	8,000	3,100
	TOTAL	149	57,450	33,700

* Assuming a 7-year harvest cycle.

Source: Adapted from CONAZA, 1977

TABLE III-7

SUSTAINABLE YIELD* ESTIMATES FOR CUATROCIENEGAS REGION

Municipio	State	Number of Land Units	Total Tons of Guayule Shrub	Total Area of Guayule (Has.)
Ocampo	Cohuila	83	38,500	19,700
Fco. I. Madero	Coahuila	4	440	200
Cuatrocienegas	Coahuila	14	4,400	2,900
Ramos Arizpe	Coahuila	4	1,400	800
Parras de la Fuente	Coahuila	3	1,500	700
Sierra Mojada	Coahuila	20	6,500	2,600
San Pedro	Coahuila	5	1,800	1,100
General Cepeda	Coahuila	2	700	500
Jimenez	Chihuahua	3	1,300	600
Camargo	Chihuahua	2	1,300	900
	Sub-Total	140	57,800	30,000
		21	28,000	19,400
	TOTAL	161	85,800	49,400

* Assuming an 8-year harvest cycle.

Source: Adapted from CONAZA, 1976

TABLE III-8

GUAYULE RUBBER PRODUCTION IN MEXICO AND ESTIMATED SHRUB WEIGHT

Year	Rubber* Lbs (Dry Weight)	Estimated Shrub Weight** MT (Dry Weight)	Year	Rubber* Lbs (Dry Weight)	Estimated Shrub Weight** MT (Dry Weight)
1905	750,000	3,400	1926	9,529,257	43,200
1906	3,637,500	16,500	1927	11,975,701	54,300
1907	8,610,000	39,000	1928	6,210,200	28,200
1908	10,863,750	49,300	1929	3,102,800	14,100
1909	16,875,000	76,500	1930	2,263,200	10,300
1910	21,475,000	97,400	1931	No shipments	
1911	16,064,005	72,900	1932	because of low	
1912	13,870,255	62,900	1933		rubber prices
1913	4,409,874	20,000	1934	891,800	4,000
1914	594,334	2,700	1935	1,189,600	5,400
1915	3,104,047	14,100	1936	2,955,500	13,400
1916	633,154	2,900	1937	7,303,100	33,100
1917	2,299,174	10,400	1938	5,378,300	24,400
1918	4,029,412	18,300	1939	6,408,640	29,100
1919	2,427,022	11,000	1940	10,346,560	46,900
1920	2,200,342	10,000	1941	11,898,880	54,000
1921	64,802	300	1942	16,163,840	73,300
1922	615,770	2,800	1943	17,290,560	78,400
1923	2,742,779	12,400	1944	19,864,320	90,100
1924	3,076,200	14,000	1945	11,397,120	51,700
1925	8,313,200	37,700	TOTAL	270,824,998	1,228,450

*Hargis, 1942
**Based on Hargis estimate of 10 percent average rubber content over entire period.

period from 1905 to 1945 is slightly less than 30,000 metric tons of shrub. Hargis reported that there was a marked and continual reduction in guayule populations from 1910 to 1942. At the end of 1945 the Mexican guayule stands were left nearly destroyed (Velazquez et al., 1978). What other factors contributed to population decline is not known, but it seems unlikely that any other factor could have had an effect with a magnitude equal to the impact of harvesting.

There are several factors that must be considered in comparing these shrub harvest figures to current sustainable yield estimates:

- The boundaries of the areas included in the pre-1970s reports are not precisely defined, although it seems likely that the reported rubber production came from shrubs in the southern guayule region where most of the processing plant capacity existed. This may exclude much of the northern Cuatrocienegas region.

- Rubber weights reported by Hargis included substantial amounts of resin and contaminants. Resin may have constituted 20 percent of the total rubber weight. This would inflate the apparent shrub weight calculated from rubber-to-shrub ratio.

- Extraction efficiency of the pebble mills was much lower than current methods. As much as one-quarter of the rubber was discarded in the bagasse, whereas modern methods remove 90 percent of the rubber in the shrub. Fewer shrubs would be needed today to produce a ton of rubber assuming the same percentage of rubber in the shrub.

- Growth and reproductive rates of guayule vary greatly depending on rainfall and temperature. There is little detailed climatic data for the guayule region and most of what is known regarding the regional climate is derived from recent data.

Perhaps only one firm conclusion can be drawn from this review of biomass and sustained yield estimates. There are still no unequivocal estimates of standing shrub biomass or the amount of shrub that can be harvested annually without depleting guayule stocks faster than they can regenerate. Natural stand harvest should be approached with caution until more is known about its effects on guayule populations. It would be prudent, in order to prevent overharvest, to assume that low sustainable yield estimates, about 30,000 metric tons of shrub per year, are closer to the actual amount than are the much higher estimates.

Anderson (1981) made several good recommendations for obtaining more accurate sustained yield estimates:

- attempt to reconcile existing recent biomass and yield estimates,
- perform carefully designed and monitored harvesting experiments,
- monitor regeneration in control plots in harvest areas, and
- continue population and ecological studies.

3. Management techniques: Commercial rubber production using wild guayule would entail considerable organization and coordination of harvesting, shrub handling, and transportation. To ensure a long-term supply of guayule, reforestation and manipulation of the wildstands would probably be necessary.

a. Harvesting: Current thinking assumes that only plants over 25 centimeters high will be harvested. Alder and Ostler (1980) reported that guayule plants reach about 25 centimeters in approximately six to seven years, and that the growth rate of plants over three years old should be slightly less than 6 centimeters per year. Lloyd (1911) believed that plants less than 30 centimeters high could not be harvested economically, but recommended a minimum harvest height of 40 centimeters.

Lloyd (1911) provided a more detailed analysis of growth in wild plants. Growth in the first year averages about 0.8 centimeters. Between two and five years, growth rate is about 3 to 3.8 centimeters per year, but Lloyd believed the long-term growth rate is closer to 3 centimeters per year. At this rate it would take a plant over eight years to grow 25 centimeters, the current minimum recommended height for harvest, and more than ten years to reach 40 centimeters, Lloyd's recommended minimum harvest size. Lloyd also concluded that the increase in shrub weight from the tenth to fifteenth year was as great as in the first ten years. The maximum economic efficiency of the plant growth generally occurs between heights of 30 and 40 centimeters in plants between ten and fifteen years old. Lloyd, therefore, suggests a harvest rotation period of fifteen years. The advantage of this is not only in the growth of the plants already there, but also in the greater seed production of mature plants.

One should use caution in applying these time and growth rate relationships when estimating stand regeneration time. Cooperrider and Cully (1942) noted that during periods of excessive drought guayule stands may lose many plants and individual plants may grow poorly. During favorable years plant growth and regeneration may be rapid.

A potential problem in long-term harvest rotation is the present age distribution of wildstands. Alder and Ostler (1980) reported that only 23 percent of populations sampled were under 25 centimeters in height. Lloyd (1911) sampled nine 100 square meter quadrants and found that the percentage of plants under 25 centimeters varied from 3 percent to 73 percent, but in only two samples was the percentage of small seedlings substantially more than 25 percent. Unless there were considerable germination and good survival of seedlings, or growth from underground lateral roots, new plants would not replace those harvested at the end of the seventh or eighth year cycle, and the supply of young plants would not be sufficient for a seven- or eight-year harvest cycle.

If plants less than 25 centimeters high were left during the first harvest, they would be about 40 to 50 centimeters tall in another seven years, with a weight of about 400 grams. In the samples available, however, Alder and Ostler (1980) reported an insufficient number of this size class to provide enough shrubs for the second harvest. Therefore, it would be necessary to leave some plants over 25 centimeters high during the first harvest to ensure sufficient tonnage for the second harvest under a seven-year harvesting cycle.

Lloyd recommended that guayule be harvested by cutting at ground level. Any portion remaining above the surface will die back and be an economic loss, since these parts represent a substantial proportion of the weight of the plants. Cutting done with a sharp grubbing-hoe is a method that is easy for the workers and contributes to the preservation of the stand of plants. New shoots usually grow from many of the parts left in the ground. These shoots will flower during the first season following the harvest, producing seeds which will help to repopulate the area.

If the shrub is to be pulled, rather than cut, the easiest time to harvest is while the ground is still soft from the rains and when water is relatively plentiful. However, this is the least efficient time to harvest guayule in regard to shrub transport and storage because there is increased shrub bulk and water content without a concurrent increase in rubber content.

Guayule wildstand harvesting will probably be conducted much as it was in the past. Lloyd states that the usual arrangement for harvesting the shrub in a particular region was to contract with local agents.

Working conditions were often severe because of the great distances involved and lack of water. It should be noted, also, that the months of October through January are very cold in the guayule region, a fact that would make guayule harvesting during those months a real hardship for the workers.

Harvesting was done by workers who pulled the shrub, tied it into bundles, and transported the guayule by burro to a neighboring "campo de guayule," a field-center of operations. Typical loads were two to three bundles with total weights of 70 to 80 kilograms (150 to 175 pounds) for pack hauls up to 7 or 8 kilometers (5 miles). For shorter hauls 90 kilograms could be loaded on the burros. The shrub was weighed and dried at the camp to prevent mold before baling in handpresses (Cooperrider and Cully, 1942).

A person could pull 360 to 400 kilograms per hour (800 to 900 pounds) in a good stand, but 130 to 180 kilograms (300 to 400 pounds) was the usual amount. Two men with five to ten burros could pull and deliver 680 to 1,135 kilograms of shrub (1,500 to 2,500 pounds) per day (Cooperrider and Cully, 1942). But it was sometimes difficult to get as much as 100 kilograms per worker per day as the shrub stands were thinned. The work force often consisted of whole families, including the children. Payment was based on field weight of shrub delivered.

b. Handling and transport: Guayule collection centers in the past were located at various points within the guayule harvesting area, with access to large guayule stands and accessible to the processing plant. At these centers the shrub was pressed into 100-kilogram (220-pound) bales. Four workers, using two presses, could make fifty 100-kilogram bales per day. Bales were loaded on trucks for transport to the processing facility (CONAZA, CONACYT, and CIDER, 1979).

The quantity of harvested guayule brought to the collection centers tended to be variable due to distances involved, variations in stand density, and availability of transport. In addition, some of the unpaved roads in the area were, and still are, at times impassable during the rainy season. The time required for transport from field to factory varied from a few days to several weeks. To insure continuous factory operation, large amounts of baled guayule were stored at the factory.

Guayule harvesting operations of the Intercontinental Rubber Company in California from about 1928 to 1940 were somewhat different from the practices followed in Mexico. Usually guayule was harvested by digging and sunned for varying periods of time, usually five days. The shrub was then ground and hauled by truck to the factory where the cut up shrub was stored in large bins. There are problems with this method: the necessity of handling small pieces of cut shrub, and the difficulty of removing the foliage later by parboiling. Also, the chopped shrub must be protected from oxidation. It tends to deteriorate rapidly during storage (Foster et al., 1979).

During the ERP, cultivated shrub was harvested by digging, field cured about five days, then baled and trucked to the factory. Field curing resulted in moisture loss and reduced shrub weight. Curing and storage were considered essential for complete latex coagulation before the plant material was milled. Research at the U.S. Natural Rubber Research Station after World War II found that this method of handling the harvested shrub was not only unnecessary, but undesirable. Coagulation of the latex can be obtained by other means.

Rubber accumulation in guayule is usually greatest in cool weather or under reduced moisture conditions. However, because rubber remains indefinitely and unchanged in the live shrub once the rubber is formed, guayule can be harvested for rubber at any time during the year.

c. Reforestation and manipulation: Lloyd's harvesting recommendations contain a suggestion by Escobar (1910, cited in Lloyd, 1911) that after cutting, a shallow depression be made in the soil around the remaining root to catch runoff, thus increasing the water supply. Further water harvesting operations such as terracing or furrowing along contour lines to hold back runoff are also recommended.

In discussing removal of competing vegetation in the guayule area, Lloyd reports experiments that involved an area of about 75 acres that were cleared of all vegetation except guayule, the fiber-producing "palms", Yucca carnerosana, and a few large species of cacti that occupied little area and did not constitute an aggressive element in the vegetation. The land clearing operation loosened the top layers of soil, and deeper layers in some spots. The purpose was to remove competition from other plants that frequently constitute a real threat to guayule. This competition relates especially to the water content of the soil. Unless the vegetation removal permits greater runoff, it should make more water available to the guayule plants and thus enhance growth. However, a much greater growth is correlated with reduced activity in rubber accumulation, either directly or by reducing the volume of the rubber-bearing tissues.

It is important to know what effect vegetation removal has upon the crop of seedlings. Germination may be adversely affected by reducing the number of "nurse plants" that provide more favorable microclimates for germination and early growth. The evidence reported by Lloyd appears to favor the clearing of the land: the number of seedlings in the cleared area was far greater than elsewhere.

According to Alder and Ostler (1980), guayule is a poor competitor. Hence, its distribution is limited primarily by competition and not abiotic factors. This suggests that the range of guayule can be extended into sites with suitable soils, near its native range, by removing competing vegetation and seeding or transplanting guayule onto these sites. It appears that continual harvest of wild guayule could not be sustained on a long-term basis if there were no reduction of competitive species or replacement of guayule, by seeding or transplants. Alder and

Ostler make the following recommendations to ensure a sustained population.

1. The land should receive some treatment after the harvest. Two types of treatment seem particularly important: removing competition, and seeding or transplanting seedlings. These treatments may be used together, or the same results might be accomplished using only one. Both of these treatments need further investigation.

2. It appears that guayule can be grown outside its current range in soil conditions that are favorable and where competition is removed. Suitable soils should be identified. These soils should have good drainage, fairly low salts, and low clay content (less than 22 percent). Methods of removing competitors and artificial revegetation techniques need to be studied on these sites to determine the most economically feasible method.

3. Methods of both hand and mechanical cultivation to control weeds and competition, particularly during the first and second years after planting, should be investigated. Drill seeding and planting in rows is the recommended procedure for better weed control in experimental seeding and plantings.

4. Competitors other than those identified in native guayule stands should be determined as early as possible in dryland plantings. Management practices can then be undertaken to reduce these competitive species.

The effectiveness of dryland seeding, survival rate, and cost of seedling transplant are unknown. Removal of guayule competitors involves economic and policy considerations as well as ecological considerations. Some guayule competitors may be lechuguilla (*Agave lechuguilla*) and candellia (*Euphorbia antisyphilitica*), species which are also economically important in rural economies.

The climatic and soil factors important in wildstand reforestation are also important in dryland farming. They are discussed in the following section.

D. Dryland Farming

The amount of shrub available for commercial production may be significantly augmented through implementation of a multi-year program to introduce dryland farming of guayule. This would necessitate clearing land and planting guayule as a cultivated crop. There has been only limited experience in growing guayule as a dryland crop, primarily in west Texas and California, in the United States.

1. Climate considerations: Certain climatic conditions and soil characteristics must be considered in both wildstand reforestation and dryland farming for commercial guayule production.

The minimum annual precipitation requirement for good guayule dryland culture is 15 inches; 20 inches is preferable where summers are very hot; and more than 25 inches would be unsatisfactory, especially if more or less equally distributed throughout the year. Rainfall distribution is important in guayule production. For good dryland culture, precipitation at the beginning and during the first half of the growing season is desirable, as is a dry period of at least 2 months' duration prior to the cold season.

A biseasonal precipitation pattern seems to produce good yields of rubber when total precipitation is only enough to produce a gradually developing xeric-type shrub. During the ERP program in the United States guayule grew year-round on non-irrigated farms in the high rainfall belt at the lower end of the Rio Grande Plain in Texas, where no marked drought periods occurred and temperatures were high enough to permit plant growth. The rubber content of guayule grown in this region was usually low, except where moisture competition was increased by closer plant spacing.

In some areas insufficient rainfall may be augmented by other sources of moisture. On agricultural lands along the U.S. California coast, rainfall varies between 10 inches and 15 inches, somewhat low for guayule. Summer fogs and night condensation in the area help maintain soil moisture and suppress daytime temperatures. While guayule did not grow as vigorously under these conditions as in hotter areas, its growth was adequate and rubber production was very good. Guayule apparently has no pronounced seasonal growth adaptations or mechanisms and seems to be well adapted to a moderate environment.

ERP experience demonstrated that precipitation distribution, particularly individual storm frequency, affects plant establishment and survival in new plantations. Where drainage was poor, storm frequency and intensity were correlated with increased plant mortality. Planting was not successful when the soil was either too wet or too dry, and it was most apt to succeed when accomplished between storms. Sufficient rainfall after planting was found to be a necessity (Bullard 1946b).

Guayule grows best when temperatures range between 90°F and 100°F. The most suitable climate for dryland guayule culture would be one with a mean annual temperature range of 56°F to 62°F and extreme minimum temperatures always above 15°F. Warm, dry summers are conducive to growing guayule with a higher rubber content, although maximum rubber production demands relatively low night temperatures. Daytime temperatures from 65°F to 80°F combined with nighttime temperatures of 35°F to 45°F promote satisfactory rubber accumulation in young shrubs.

Rainfall adequacy for dryland farming cannot be completely expressed by mean annual precipitation, even when the seasonal distribution of rain is known. Rainfall variability tends to be inversely correlated with the total amount of annual rainfall. Thus, in semiarid and arid areas where the amount of monthly rainfall is small, rainfall variability tends to be high (Figure III-2 a-c). Drought must be recognized as a frequently occurring phenomenon in Mexico and in desert areas in general (Steila,

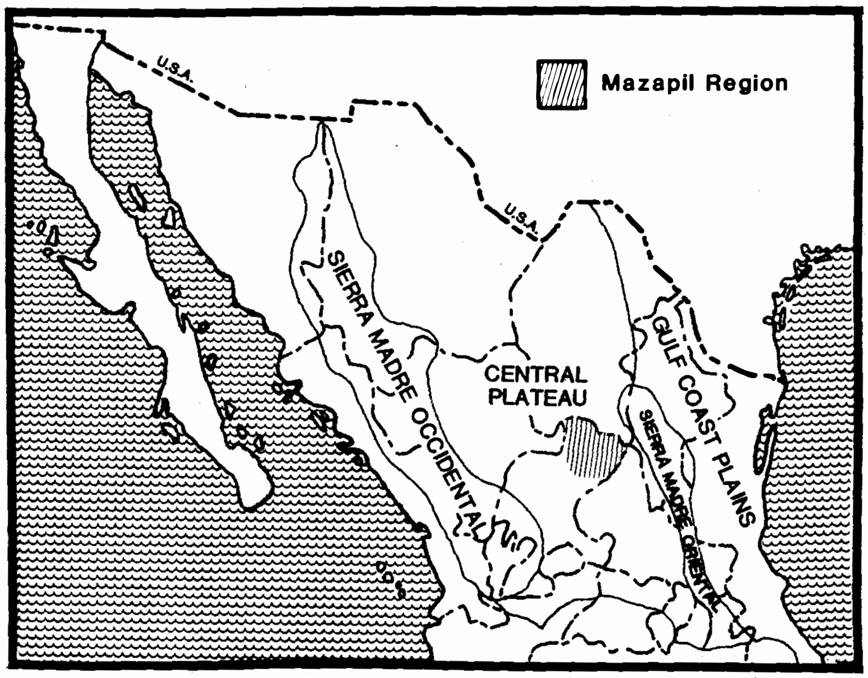


Figure III-2a Physiographic Regions in Mexico.
Adapted from Leopold, 1972

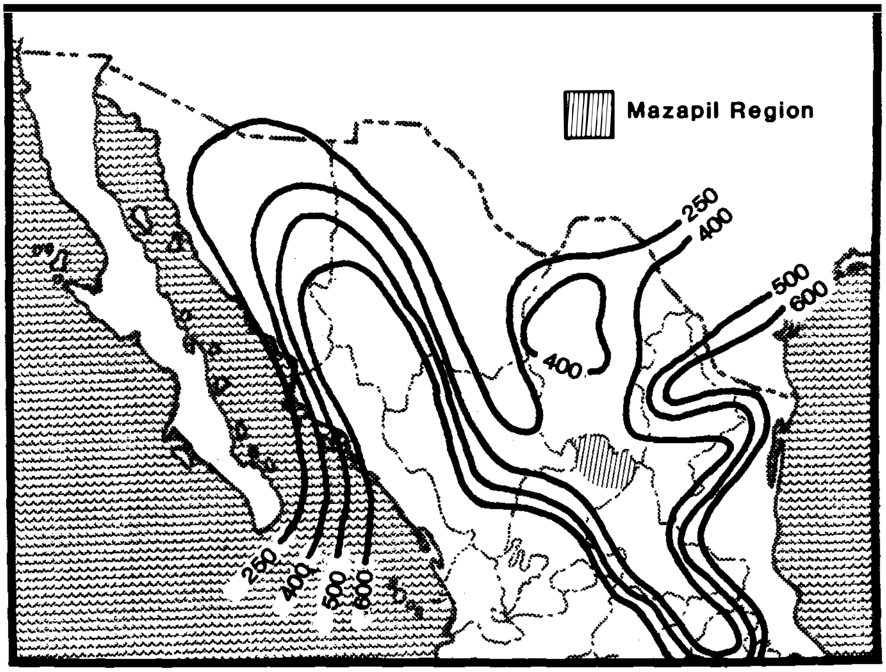


Figure III-2b Mean Annual Precipitation (mm)
Adapted from White, 1960

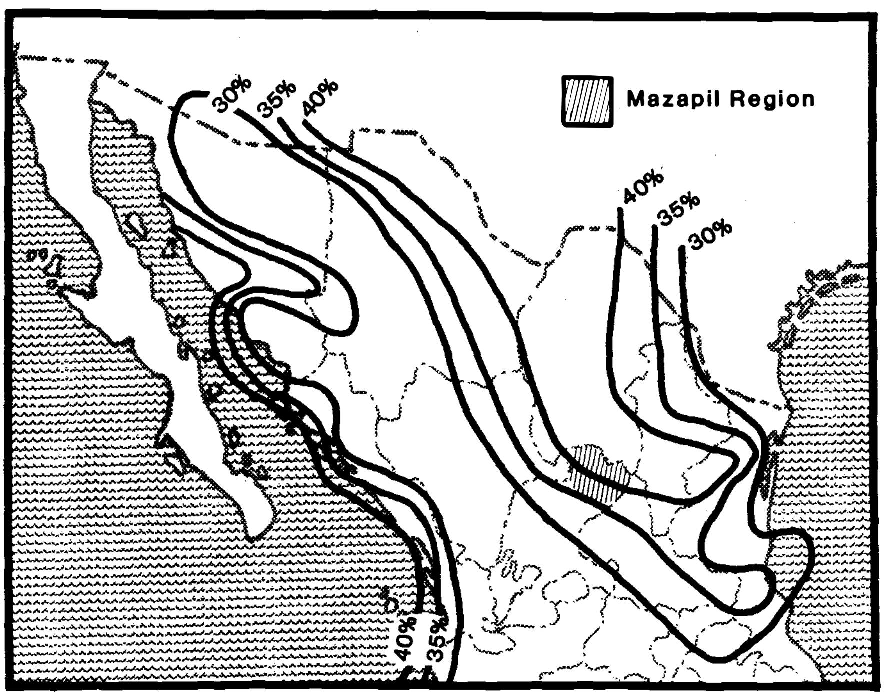


Figure III -2c Interannual Variability of Annual Precipitation
Adapted from White, 1960

Note: Isopleths depict relative variability from year to year over the period 1919 to 1953, expressed as a percentage of the mean annual precipitation for that period.

1972). Years may pass with little more than 3 or 4 inches of rain at a given station, yet a long-term average may show more than 10 inches of rain per year for the station (Dunbier, 1968). This often means that a good growth of native plants will be produced only one year in four or even one year in ten. During a ten-year period in one desert area studied, biomass production in the best year was as much as five times the production in the worst year (Sheridan, 1981).

Disease incidence in guayule is affected by temperature. Experience in ERP plantations showed that cotton root-rot is most severe in hot, humid weather, or after irrigation in hot weather. Verticillium wilt became serious in spring and fall when temperatures were near 70°F and surface soil moisture was relatively high. Crown-rot was worst in wet soils when temperatures were high. Pink root-rot in the ERP nurseries was most common in cooler, foggy weather with high humidity. While insect epidemics were known to be correlated generally with climate, the few local outbreaks could not be tied to specific temperature or moisture conditions (Bullard 1946b).

2. Soil considerations: Soil is the dominant factor in rubber production and a major factor in shrub production because of its relation to moisture control. The shrub varies in size, weight, and rubber content according to minor changes in soil moisture retention and availability (Retzer and Mogen, 1945). Soil moisture also is important in relation to disease. Attacks by various fungi usually coincide with excessive moisture, especially on heavier soils with slow drainage. On the other hand, the extent of cold damage is usually inversely related to the moisture content of the soil and the plant.

Soil moisture availability varies with soil texture. For best growth, guayule requires permeable, well-drained, well-aerated soils with a reasonably good supply of soil moisture most of the year. Optimum vegetative growth, however, usually is not combined with maximum rubber production in the shrub. Those soils that make water available slowly to the plants promote the highest rubber content per unit shrub weight and, if growing conditions otherwise are favorable, give the highest yields of rubber per acre.

In the ERP experience, the best growth of both irrigated and dryland plantings was in light and medium-textured soils. With the same cultural treatment and planting stock on a single plantation, larger shrubs were developed in loam and sandy loam than on other soils. But the highest percent of rubber occurred in smaller plants grown in other soils. Dryland production on problem soils is impractical. On soils of very open, porous structure, a low survival rate occurs because of poor contact between the soil and plant roots.

Unsatisfactory growth and yields result when guayule is grown in soils with very coarse substrata at shallow depths. Under such conditions moisture is easily available for only short periods, and the plant has short intervals of luxuriant growth, during which little rubber accumulates, and then dies back somewhat under the heavy stress of the following dry periods. When available moisture is reduced more slowly and the shrub has time to "prepare" for the dry, dormant period, a xeric-type leaf develops and rubber deposition shows marked increases.

Hardpans and claypans, including plowsole, tend to restrict guayule growth in inverse relation to their depth below the surface. Where pans are shallow and drainage is poor due to heavy soils, guayule is small, lacks vigor, and is susceptible to disease and drowning. In lighter soils the pans restrict growth but have a much less adverse effect on plant survival. Guayule roots penetrate pans with difficulty. If the pans are within 30 inches of the surface, root extension is limited, the feeding area small, and shrub growth is never satisfactory.

Competition between plants is affected strongly by spacing and by moisture availability. Furthermore, moisture relationships change under cultivation, especially with respect to aeration. On newly cleared brushlands with fine sandy loam soil, the soil is loose at first and shows a moisture deficiency similar to that caused by high evaporation. Clays, usually considered too heavy and poorly aerated for guayule, are suitable if they are friable and have good internal drainage; however, rubber content seems to be depressed in plants in clay soils (Alder and Ostler, 1980). On the other hand, in ERP experience, plants grown in clay soils showed a higher concentration of rubber than those in light soils (Bullard, 1946b).

Like other plants, guayule grows best in more fertile soils, but it does not respond noticeably to most fertilizers except in soils with low fertility. Fertilization does promote more rapid seedling growth. While it is native to calcareous soils, guayule grows well on granitic or sedimentary noncalcareous soils. Required fertility levels, like moisture capacities, seem related more to spacing and competition between plants than to general plant needs. Low fertility may limit growth in a few instances, but if so, soil moisture is the dominant factor.

Guayule tolerates iron or manganese deficiencies but is very sensitive to boron deficiency. Potassium and calcium seem to be required for best plant growth, but in wildstands plant density has been found to be inversely related to potassium level. Guayule has shown no marked response to added nitrogen unless the soil is nearly sterile.

Guayule grows well on granitic or sedimentary non-calcareous soils and in a soil pH from 6.0 to 8.5 but is stunted at pH 4.5 or 10.5. Optimum growth occurs from pH 7.2 to 8.3. The soil salt content is important. Guayule tolerates up to 0.3 percent salt anywhere in the soil profile, but soil salt content from 0.3 to 0.6 percent in the top 2 feet of soils greatly retards growth. More than 0.6 percent salt in the surface soil kills the plants (Bullard, 1946c).

The lower leaves of the shrub actually increase in number with soil alkali concentrations up to the limits of tolerance, but shrub weight and survival decreases. The physiological drought brought about by increased soil moisture tensions apparently causes reactions in the plant similar to those caused by natural drought (Bullard, 1946b).

3. Potential dryland farming areas: The survey of the wild guayule situation in Mexico undertaken in June 1942 by Cooperrider and Culley for the U.S. ERP afforded the opportunity for extensive observations of valley lands as possible guayule farm areas, as well as for the more intensive examination of mountain areas where guayule grows naturally.

Cooperrider (1943) submitted a report on the possibilities of guayule cultivation in Mexico. The report is confined to a discussion of lands within the general area where guayule grows wild. He reported that the principal area "to hold promise for dryland farming of guayule is located in the states of Durango and Zacatecas east and northeast of Durango City, and in the general vicinity of Yerbanis, Guadalupe Victoria, and Villa Madera, and south toward Sambrete." This is a high plateau grassland country where large areas are nearly level and physically ideal for farming. It varies from nearly pure grassland of excellent quality to savanna to scrubby growths on the rocky hills. Soils are dark brown loam, in places almost black, and almost free of rock.

"East and northeast of this plateau region, the country breaks off into lower valleys and rough mountains which rise to somewhat higher elevations than the plateau proper. The foot slopes of such mountains are good wild guayule country. They must have about the same elevation and temperature as the grasslands on the plateau. Rainfall on the plateau, judging from vegetation and the records from one place, probably is about 16 inches to 20 inches annually, nearly all of which occurs in summer and early fall .... Large areas of this grassland have been turned under and planted, principally to corn but ... some of this land seems to be submarginal for corn planting."

Undoubtedly, land use in the area delineated by Cooperrider has changed since he wrote his report, but there may be land in the area still suitable and available for dryland farming.

An area where minimum temperatures do not fall below 15°F has been recognized as the potential guayule growing region in the Southwest U.S. (Foster et al., 1980). Using the same criteria, it would seem that guayule plantations could be developed over an extensive region in northern Mexico. Except in the higher elevations in the Sierra Madre Oriental and Sierra Madre Occidental, temperatures in that entire region are normally above the 15°F minimum.

A significant limiting climatic factor is the availability of rainfall. If 15 inches (375 mm) of rain is considered the minimum for plantation success, most of the central plateau must be excluded from the guayule growing region as too dry. However, precipitation is adequate in many areas in the foothills of the two mountain ranges (the southern central plateau and gulf coastal plain) as well as in the foothills of the complex series of mountain ranges in the central plateau.

4. Guayule propagation: Field plantings can be established with transplanted seedlings or by direct seeding. ERP experience involved growing seedlings in nurseries and transplanting at four to twelve months of age. Current practice in the United States is to grow seedlings in greenhouses and transplant at about three to four months of age. Direct seeding experiments have indicated that it is possible to establish guayule by direct seeding, but experience with this method has been extremely limited.

a. Nurseries: Nursery methods used by the ERP to produce guayule seedlings were not greatly different from general nursery techniques used to grow many species of forest tree seedlings. Seeds were sown by mechanical drills in 4-foot beds irrigated by an overhead irrigation system. Plants were weeded, watered, cultivated, and otherwise cared for during a four- to eight-month period. Then plants were lifted, culled, packed, and distributed for field planting. Under optimum conditions seedlings normally attained planting size at about four months of age.

Growing young shrubs in nurseries presents many problems similar to those involved in field culture, although the nursery stands are more dense. Young guayule is very sensitive to soil conditions. The best nursery production is achieved on deep, well-drained, fine sandy loam soils. Climates suitable for growing guayule in the field also are favorable for growing good nursery stock.

b. Greenhouses: New technology in greenhouse management provides another means for producing stock for year-round transplanting. However, initial greenhouse construction costs would be much higher than nursery construction costs.

More than 90 percent germination has been achieved in freshly harvested, treated and coated guayule seeds. The seeds germinate in the greenhouse in two to three days, and healthy plants can be grown with proper irrigation management and regular fertilizer applications. Plants remain in the greenhouse for two to three months, then flats are moved outdoors for two to four weeks to harden the plants before transplanting them to the field. Current research indicates that greenhouse-grown seedlings two- to three-months old can survive transplanting successfully.

Guayule seedlings are now being raised in commercial greenhouse operations at the Golden State Nursery in Bakersfield, California, and the Bud of California Company in Salinas, California, where they are using guayule seed specially coated by a commercial seed company. Use of cleaned, coated seed has made possible a mechanized greenhouse planting procedure. Speedling trays are used, with one to three seeds being planted in each compartment. In their current operation, 80 seedlings are produced per square foot of greenhouse space, but those involved in the operation are confident that production of 144 plants per square foot is feasible (Maniaci, 1981, personal communication).

c. Direct seeding: Establishment of field stands through direct seeding could reduce significantly the cost of guayule crop production. Seedlings produced in nurseries and greenhouses are relatively expensive, and transplant shock can kill a substantial number of transplanted seedlings or reduce growth rate considerably the first year. If labor costs are high, the cost of digging and transplanting nursery stock or moving and planting greenhouse stock can be considerable.

For successful germination and emergence when direct seeding, a number of critical conditions must be met. Minimum daily temperature should not be lower than 50°F (±7°F for pregerminated seed), and maximum daily temperature should not be above 90°F, except briefly. Seed cover must be less than one-eighth inch, with no soil crusting. There must be abundant soil moisture during germination and emergence (Taylor, C., 1946).

Many of the difficulties in direct seeding have been a result of the small percentage of seed with germination potential, even in the best seed lots. However, with the proper seed harvesting, cleaning and treatment available today, seed germination of better than 90 percent should be feasible (Benedict, 1979; Maniaci, 1981, personal communications). Another difficulty in the past has been the handling of each achene as a unit. The seed coating technique developed to coat guayule seeds for ease in handling in the greenhouse production described previously should also facilitate seed handling when direct seeding.

Direct seeding may prove to be feasible only under irrigation, and transplanting seedlings may be the only practical method of establishing field stands under dryland conditions (Benedict, 1979, personal communication). On the other hand, viable seed, properly treated and pregerminated and sown on soil with a fairly high level of soil moisture may make the technique workable (Crowley, 1979). To date there has been very little research on direct seeding and field trials under a variety of conditions are needed to determine whether, and under what circumstances, this method of field establishment has the potential for being commercially feasible.

d. Guayule seeds: Guayule seed germination characteristics differ from those of most other crops. Only a few guayule seeds will germinate if sown immediately after being collected, due to two types of dormancy: an embryo dormancy of short duration, and a seed coat dormancy that makes the inner seed coat impermeable to gas exchange. Seed coat dormancy can be eliminated by chemical treatment. Dormancy can persist for years under dry storage conditions.

Most guayule varieties are prolific seed producers. When soil moisture and air temperature are favorable, plants of all ages bloom and set seed profusely throughout the growing season. Seed yields per acre vary widely according to the number, age, and vigor of surviving plants. In a few instances, under especially favorable conditions, yields of 1,000 pounds per acre were recorded. Usually, the collected seed yield is only 25 percent to 30 percent of all seed produced because of losses from wind and the shattering of seed before harvest. Yield can be expected to increase greatly with variety improvement through genetic selection.

Several types of harvesters that employ revolving brushes or beaters to dislodge the seed into pan or trough receptacles have proved moderately successful and economical. A gasoline-powered vacuum insect net has proven highly efficient in harvesting guayule seeds in trials conducted at Texas A & M University in the United States. The Denholm Seed Company and the University of Arizona have also experimented with a mechanical harvester on guayule in California and Arizona.

Collecting seed by hand cannot compete with mechanical harvesting in speed and cost per pound of seed, but it is practical when seed-picking machines are not available. The number of times seed can be collected from the same plants during one season is influenced by cultural operations, blooming continuity stimulated by irrigation, ripening uniformity, and winds. In some instances six collections were made from plants under irrigation in the same area during a single growing season. Fewer collections can be expected under dry farming conditions.

Cleaning removes foreign material such as stems, leaves, clusters of sterile florets, insects and weed seeds, and also empty guayule seeds. Air-drying collected seed to a moisture content of 6 percent to 10 percent permits temporary storage without danger of molding or heating.

On recently harvested seed the inner seedcoat, a thin, tough membrane enclosing the embryo, is nearly impermeable to oxygen and must be broken or made permeable. Embryo dormancy can be broken, however, by exposing moist seed to light or by treating with giberellin. Guayule seeds also become germinable after treatment with sodium or calcium hypochlorite. Sodium hypochlorite is preferable to calcium hypochlorite because it mixes with water more readily. Treatment duration is immaterial if reduced treatment periods are accompanied by increasing solution strength.

The natural seed dormancy persists in varying degrees for a number of years in untreated and unthreshed seed. Threshing seed, however, can cause a substantial proportion of seed to become viable at once. Dormancy of the remaining seeds disappears in four to six months if the seeds are stored in a well-aerated, dry area.

5. Agronomic practices: For a crop that is not now produced, guayule's agricultural requirements for irrigated cultivation are remarkably well-known. Almost 1,000 scientific papers have been written about the plant, including excellent manuals for germinating seed, caring for seedlings, transplanting, fertilizing, irrigating, and harvesting (National Academy of Sciences, 1977; Foster et al., 1979). This

knowledge is based largely on empirical observations made during 20 to 30 years of commercial production and is supplemented by empirical observations and research by ERP agencies during World War II, by the U.S. Agricultural Research Service Crops Research Branch during the 1950s, and by recent research in Mexico and the states of California, Texas, New Mexico, and Arizona in the United States.

Experience shows that there are no insurmountable difficulties in growing guayule; there are no known fundamental agronomic barriers to be overcome before irrigated production can begin (National Academy of Sciences, 1977). However, experience in guayule dryland farming is limited. The ERP plantations and experimental plantings provide guidelines for producing rubber under a wide variety of soil and climatic conditions. W.A. Bullard reviewed the planting program carried out by ERP and most of the following general statements, unless otherwise credited, are from his report (Bullard, 1946b).

Within reasonable limits, the yield of any crop is related to the number of plants per unit area. This is true for guayule. Stand age, soil fertility, and moisture availability also have considerable effect. In the ERP program it was found that dryland shrubs maintained a plant moisture content of about 44 percent, while moisture content in irrigated shrubs, heavily stressed at times, dropped to about 34 percent. There was more shrub growth and greater efficiency in rubber production per unit of water available with dryland-farmed shrubs than with irrigated shrubs.

Under dryland conditions in California, roots of guayule plants from nursery stock were able to penetrate porous soils (if devoid of thick gravel and coarse sand strata) to depths of 8 feet to 10 feet during the first growing season and to depths of 14 feet to 16 feet during the second season.

ERP guayule nursery transplants started new growth soon after planting, and by the end of the first growing season attained fair size.

In the first season, growth seemed largely related to establishment time. Establishment was delayed one year on a few dryfarmed plantations having soils difficult to prepare prior to planting. Some transplants remained dormant through the hot summer and began growth with the following winter rains; but, survival losses were fairly great.

No known optimum exists for dryland planting density. Using the ERP spacing of 28 by 24 inches would require about 9,500 seedlings per acre (U.S. Forest Service, Emergency Rubber Project, 1943). Ultimate survival in a dryland setting should be at least 80 percent. In the ERP program, the dryland shrubs in cooler climates made the most rapid gains somewhat late in the season. During the winter season, shrub growth is negligible. With respect to shrub age, if the ERP program had continued, the highest gains probably would have been made in the third and fourth growing seasons with irrigated shrubs, and in the fifth and sixth seasons with dryland shrubs, under normal climatic conditions.

ERP researchers found that three phases of growth important to harvesting and milling operations were affected by the kind of culture the plants received. Dryland-farmed plants had relatively higher leaf bulk per unit weight of the entire shrub than did irrigated plants. This increased transportation and other handling job loads per unit of mill capacity (the leaves were non-productive and the shrub usually was defoliated prior to milling). Dryland shrubs had a higher rubber content and could be milled more efficiently. They were also found to have a higher rubber-to-resin ratio. But, irrigated shrub produced more pounds of rubber per acre in almost all instances, because of the larger size of the plants.

There has been much less experience with dryland farming of guayule than with irrigated plots, and the circumstances often involved treatment that was not standardized. Rubber yields in California and Texas varied from under 100 pounds per acre per year to 300 pounds per acre per year of rubber (Table III-9). These figures are not exactly comparable to

TABLE III-9

GUAYULE SHRUB AND RUBBER
DRYLAND PRODUCTION

Region	Age at Harvest (years)	Rainfall (inches)	Rubber (percent)	Short Tons Shrub/Acre	Pounds Rubber/ Acre/year
California[1]	1	--	3-4	0.5-0.6	49-70
--[1]	2	--	6-7	1.7-2.5	130-160
--[1]	3	--	9-10+	2.8-4.2	207-270
--[1]	4	--	11	3.6-5.1	225-308
--[1]	5	--	12	4.3-5.7	224-288
--[2]	--	--	--	3-12	130-308
Lower Salinas Valley[2]	8-9	14	--	--	240
Mid-Salinas Valley[2]	5-6	8	--	--	60
Santa Maria[2]	8	14-16	--	--	110,136,160
Santa Maria[2]	7	11	14-15	1.8-6.3	70-263
San Jacinto[2] Basin	2	14-15	8-9	--	154-168
San Jacinto Basin (Hemet)[2]	2	17-23	8-11	--	112,172,209
San Joaquin Valley[2]	2	8-10 (fallow farmland)	--	--	72-179
Texas[3]	5	--	8	6	192
--[3] (36 plots)	3+	--	7-8	2.8-3.2	122-162

1. Bullard, 1946c
2. Dortignac and Mickelson, 1945
3. Crain, 1946

current yield figures because the percentage of moisture and resins that remained in the crude rubber exceeds that in processed guayule rubber today by an unknown amount. Data from 1944 ERP sampling and 1926-1941 yields from the Intercontinental Rubber Company plantations in the lower Salinas Valley of California (where rainfall varies from the lower acceptable limit to a near optimum of 14 inches to 20 inches per year) indicate that in dryland plantations rubber is formed at an increasing rate over an 8-year period (Figure III-3).

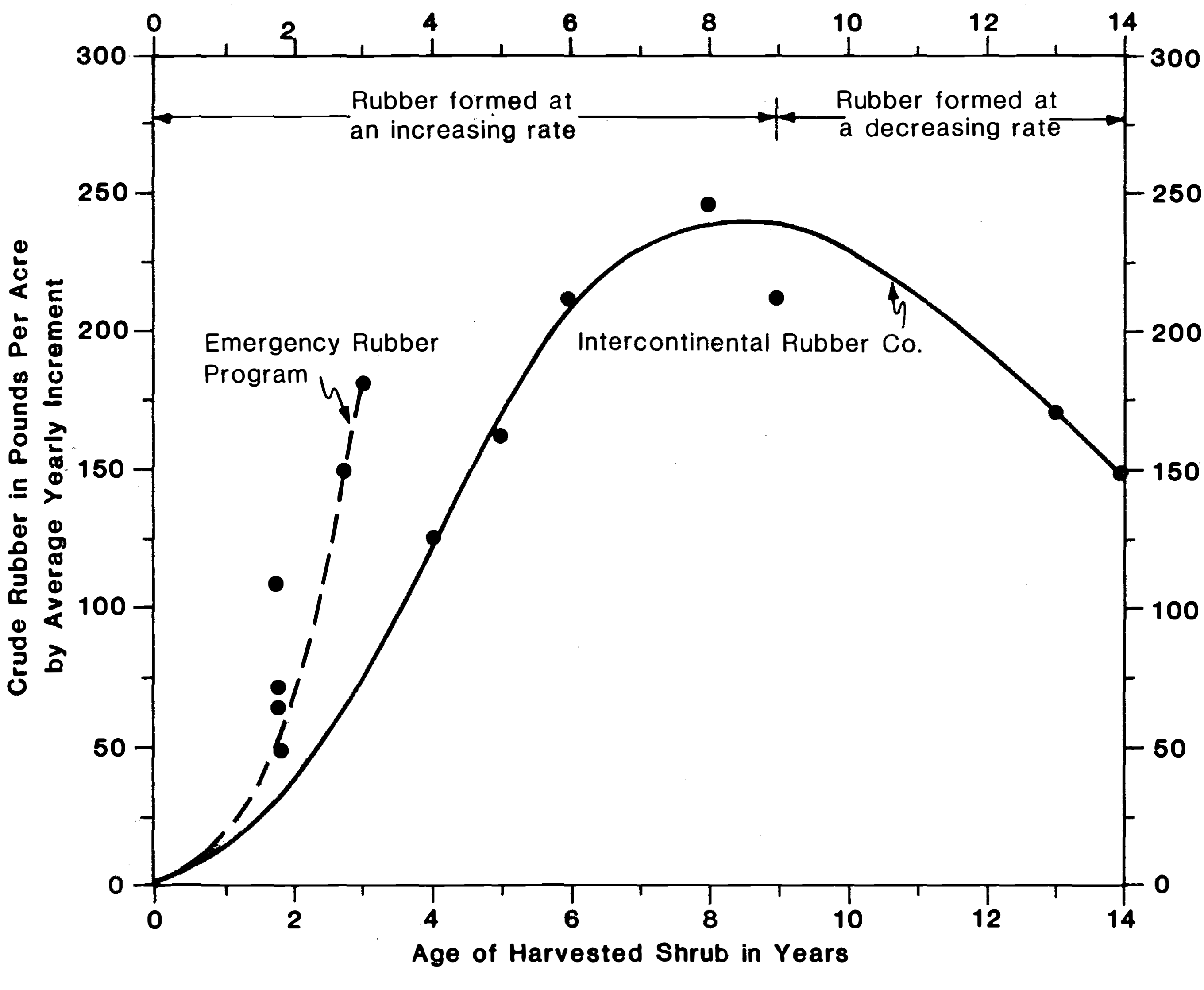
E. Processing

1. Processing methods: Rubber in the growing guayule plant occurs dispersed in liquid in the plant cells. The rubber can be extracted in a dispersion of the latex, by solvent extraction, or agglomorated as a resinous or deresinated rubber (the latter has been the standard practice).

Processing guayule consists of a number of sequential operations carried out to release the rubber from plant tissues: separating the rubber, so far as practical, from other plant constituents; freeing the crude rubber from contaminant materials; applying necessary preservatives; and drying and packaging it for ultimate consumer use. Processing begins with the harvested shrubs and ends with the crude boxed rubber. Processing also includes recovering various byproduct materials having existing or potential use. There are alternative possibilities for accomplishing many of the operational steps. Choice of procedure is based on cost, availability of water and solvents, and byproduct value.

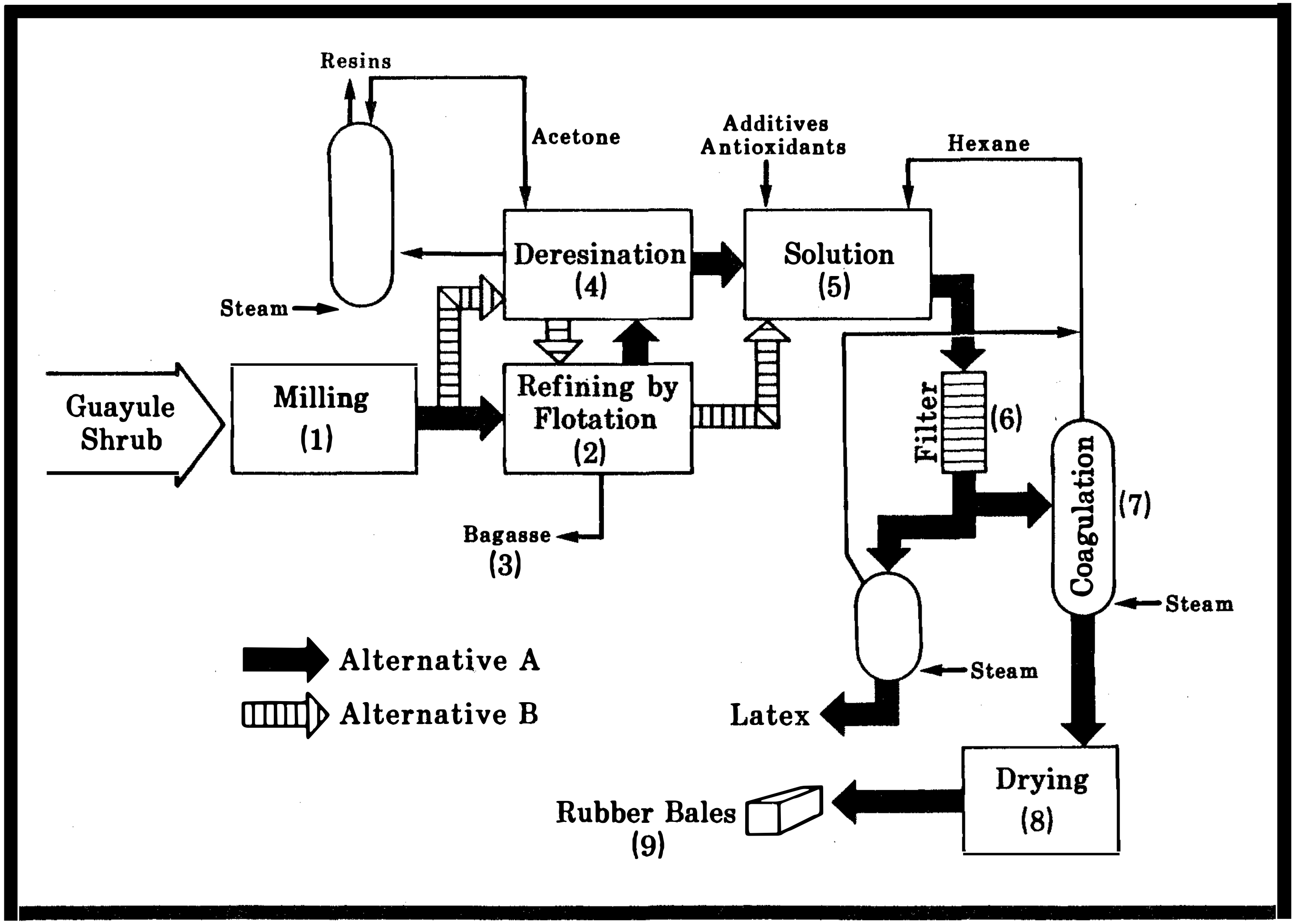
In the ERP experience, because of wartime urgency, there was an attempt to secure the maximum amount of rubber of acceptable quality in the minimum amount of time. The process that evolved was based on the factory operation experience of the Intercontinental Rubber Company.

a. CIQA extraction method: In 1974 the Mexican Project for the Industrialization of Guayule began studying various rubber extraction alternatives (see alternatives A and B in Figure III-4). The industrial



Adapted from E.J. Dortignac and Michelson, 1945

Figure III-3. Average Yearly Increment of Crude Rubber from Dryland Guayule Plantations in Salinas Valley



Source: Campos-Lopez et al, 1978

Figure III-4. Guayule Rubber Extraction Method Developed by CIQA process design that evolved has been used experimentally at pilot plant level since 1976. It allows for the possibility of recovering the various byproducts step-by-step and incorporates considerable innovation into the industrialized use of this shrub.

Baled shrubs are first dipped in hot water for 10 minutes at 167°F to coagulate the rubber and to remove foreign material and leaves. The plants are then passed through a hammer mill and a Bauer mill (a device used in paper making, somewhat similar to the Jordan mill in action on comminuted shrub) which break open the rubber-filled cells. Caustic soda (sodium hydroxide) is added during the pulping process to help break open the rubber-filled cells, separating the rubber from the vegetable matter. The pulping is done in water, which causes rubber and resins to aglomerate into the spongy form known as worms. This material is run through a series of flotation tanks where the waterlogged bagasse sinks to the bottom and is pumped off. The rubber worms float and are skimmed from the surface. This process is repeated twice; further separating occurs in each successive tank. The resinous worms are stirred in hot water with detergent to reduce particle size. Resins (17 to 25 percent of the guayule worm content) are extracted with acetone at about 95 percent efficiency. The acetone is distilled from the resin-water mixture and recycled.

After steam stripping to remove residual acetone, the gray-white guayule rubber contains about two percent resin, as well as a small amount of cork and debris that failed to sink in the slurry tank. In a final purification process, the deresinated rubber is dissolved in hexane and is filtered to remove the residual insolubles (cork, fiber, dirt). This filtered solution is homogeneous and the rubber can be bleached, protected with antioxidants or treated with reagents to give a high-quality, uniform product. While in solution the rubber can be altered by polymerization, chlorination, copolymerization with methacrylates and other chemical reactions producing rubbers with different properties. The end product is a rubber of high quality with very low amounts of ash, copper, and iron (National Academy of Sciences, 1977).

The rubber-hexane solution is mixed with steam and is pumped into a series of two coagulators, where the solvent is vented off and rubber is recovered as crumbs. The wet, purified rubber is carried to an extruder dryer where all but 0.6 percent of the moisture is eliminated. The crumb rubber is then cooled in a long aereated gutter, baled, and packaged as a 75-pound block (Campos-Lopez, 1979).

Alternative B is designed to extract a larger volume of resin by direct shrub deresination (Figure III-4). After deresination by solvent extraction, the ground guayule would be refined by flotation in the same manner as in alternative A. Intermediate steps such as desolventizing and solvent recovery are not shown.

b. Rubber extraction methods developed by Firestone Tire and Rubber Company: The Firestone Tire and Rubber Company is investigating a direct-solvent extraction method to extract both resins and rubber. Direct solvent extraction seems to offer many advantages over wet-processing. Many processing steps would be eliminated including parboiling and/or pressure cooking; wet-milling; addition of alkali, surfactants, etc.; flotation; water washing; and several drying and purification steps. Other advantages are large savings in process water, improved resin yields, lower heavy-metal contamination of the rubber, and the provision for solution-phase purification as an integral component of the operation. Nivert, Glymph, and Snyder (1978) described this process as quoted in the following paragraphs.

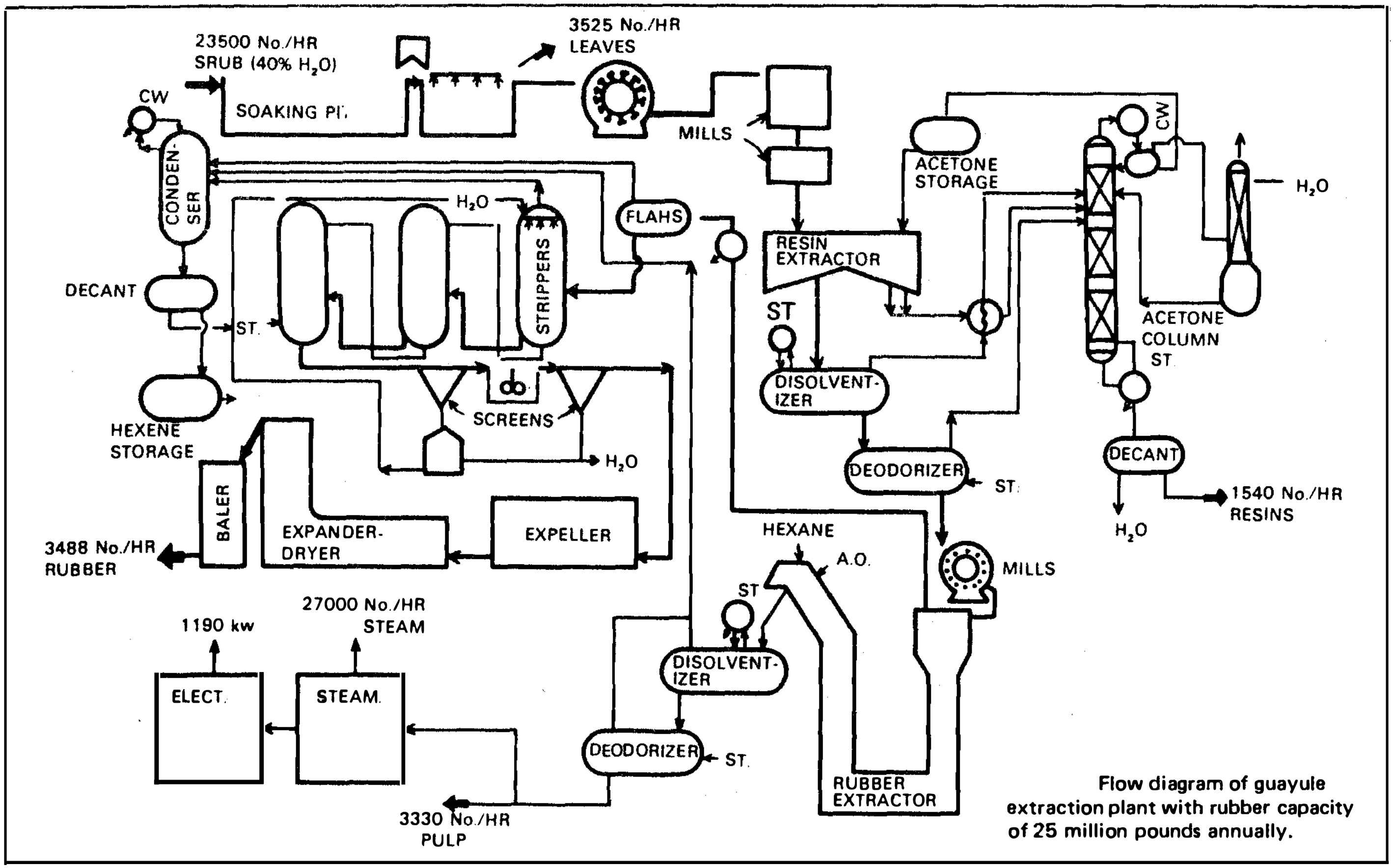
"The wet shrub is chopped and ground in a series of (hammer) mills. The finely pulverized shrub is then conveyed to a countercurrent percolation type extractor where the resins in the shrub are extracted with acetone. Total contact time is one to two hours. Initial contact with acetone dehydrates the shrub. The deresinated shrub is desolventized and deodorized in standard equipment similar to that used in the oil seed extraction industry. Acetone-resin mixture, acetone-water from shrub dehydration and acetone from the desolventizer are combined in an acetone refining column. Resins and water leaving the bottom of the column are decanted giving a crude resin byproduct. Facilities for refining the crude resin are not included.

"The deresinated, desolventized shrub is next conveyed to a countercurrent immersion type extractor where it is contacted with hexane for two to three hours to extract the rubber. Antioxidant is introduced at this point with the hexane. The pulp is desolventized in a similar fashion as in the acetone extraction step and the majority of it is burned for steam generation and in plant generation of electricity. The remainder is by-product.

"The miscella from the extractor (7 percent rubber in hexane) is heated to flash off a portion of the hexane. The remaining rubber solution is sent to a series of stripping columns where the rubber is coagulated with water, and hexane is stripped with steam. Hexane from these stripping columns, the flash vessel, and the desolventizer is condensed. Water is separated from the hexane in a decanter. The hexane is then recycled.

"The coagulated rubber in water is sent to a standard rubber drying section where it is screened, washed, dried and finally baled." A schematic of this process is shown in Figure III-5.

Solvent extraction of rubber from guayule has thus far been impractical on an industrial scale. The fundamental problem in solvent extraction of rubber from plant materials is that rubber, being a high molecular weight polymer, is unable to pass through cell walls and membranous tissue in solution. Thus, in order to accomplish solvent extraction of rubber, the plant structure has to be very thoroughly disrupted. In analytical procedures, this is usually accomplished by fine grinding resulting in fine powders that can be extracted in reasonable lengths of time with sophisticated laboratory equipment in small quantities. However, scale-up difficulties are enormous. They include very low drainage rates and high solvent hold-up resulting in impractically slow extraction and very large solvent losses in pilot-plant or larger scale operations (Buchanan, 1979).



Source: Nivert, Glymph, and Snyder, 1978

Figure III-5. Flow Diagram of Guayule Extraction Process Developed by Firestone Tire and Rubber Company

Nivert, et al. reported in 1978 that this processing method would require considerably more research before it could be considered as an alternative method of processing. However, recent research breakthroughs in the solvent extraction process (perfection of efficient separation column extraction of rubber) and in the CIQA process have greatly improved the economics of guayule processing (Weihe and Nivert, 1980).

Firestone is also experimenting with a process in which the milled shrub is first deresinated with acetone at about 50^{o}C. This process is similar to alternative B considered by CIQA.

c. U.S. Government Patent: R.A. Buchanan, formerly with the Northeast Regional Research Center of the U.S. Department of Agriculture (Peoria, Illinois), developed and patented a nonaqueous process in which the shrubs are converted to a "plastic" mass in a rubber mill or extruder. This is converted to pellets or particles and rubber and resins are extracted with acetone and hexane (Chemical Engineering, 1980).

In this process the fibrous plant material is subjected to the simultaneous action of compressive and shear forces under nonaqueous conditions. This can be accomplished by the use of an ordinary rubber mill, i.e. differential roll mill, or by the use of a single-screw extruder or various other machines designed to produce high shear mastication at high pressure. It may be advantageous to use one or more of these machines in sequence. Polymeric hydrocarbon substances are released and cohere with the comminuted fibrous material. The resultant mass is shaped into particles which, according to Buchanan (1979), can be economically solvent extracted in any of several commercial extractors with complete recovery or rubber, resins, and related hydrocarbons.

The solvent extraction can be conducted in a single- or multi-step operation. "It is generally preferred to extract the shaped particles with a first solvent which will selectively remove resinous components, and then extract the particles with a second solvent for removing the rubber or rubberlike polymeric hydrocarbons. Acetone as the first solvent and cyclohexane as the second solvent is the preferred combination, ... Alternatively, the resin and polymeric hydrocarbon substances may be removed by a single extraction with a universal solvent, such as cyclohexane. In either case, the desired components can then be recovered from the solvent by conventional means" (Buchanan, 1979).

d. Powdered rubber: Although not a new primary processing method, making powdered rubber from either baled rubber or from latex produces a potentially useful product form. Powdered guayule is readily derived from some newer techniques for solvent extraction (Prebluda, 1980). The basic method of making powder from bale rubber is cutting, chopping or smashing rubber into small particles. Latex can be converted to powder by several methods, but the most common is spray drying. Several advantages of powdered rubber are ease of storage and shipping, and potential for computer controlled automatic weighing and metering before mixing in continuous processing equipment. Powdered rubber can be formed with little or no modification of existing plastics machinery and techniques.

2. Facility requirements and logistics: Shrub post-harvest handling, storage, cleaning, and defoliation requirements are presented below.

a. Post-harvest handling and storage: For the most efficient operation, storage facilities at the processing plant should be large enough to provide raw material for continuous factory operation during periods of inclement weather. Baled guayule should be kept dry, and extra precautions should be taken to minimize the danger of fire during storage.

Maintaining a constant shrub supply may involve storage for some period of time. Optimum storage conditions and maximum storage time for successful production are factors that need further investigation.

Postwar U.S. research studies (USDA Bureau of Agricultural and Industrial Chemistry, 1953) to determine the effects of various storage conditions indicated that after six weeks of storage, plants baled with leaves on exhibited decreased yields of rubber hydrocarbon in the crude rubber. There was an apparent decrease of rubber in the shrub; and, there was a slight decrease in the resin in the crude rubber, but not enough to make any appreciable difference in rubber quality. The total amount of crude recovered per ton of harvested shrub decreased as the length of shrub storage time increased.

The crude rubber in shrubs stored after defoliation showed an increase in the percentage of rubber hydrocarbon over a period of six weeks of storage and was accompanied by a decrease in the percentage of resin. The total amount of recovered rubber dropped slughtly as storage time increased.

Two factors appeared to have opposite effects on the physical characteristics of crude rubber recovered from stored defoliated shrub. The physical properties of the crude rubber deteriorated because of the continued degradation of the rubber hydrocarbon in the shrubs during the storage period. On the other hand, the physical properties of the crude rubber were enhanced by a depletion of resins during the storage period. The optimum improvements occurred at about five weeks of storage. Deterioration resulted thereafter.

The rubber recovered from milling freshly harvested shrubs had Mooney (viscosity) values and molecular weight markedly higher than any rubber produced from the stored shrubs. The lowered Mooney values and molecular weights after storage are strongly indicative of rubber deterioration through oxidative processes. The amount of insolubles (material not soluble in water, i.e., benzene and acetone) in crude rubber from freshly harvested shrub were markedly lower than in rubber obtained through other methods.

Storing defoliated shrub, either as whole plants or in comminuted form, and exposing it to a certain microbiological process termed "retting" reduces certain resin constituents. The actual "ret," induced by the mixed microfloral population present in the atmosphere, varies greatly from season to season and from location to location. A pure cultural ret would necessitate a costly installation to sterilize the material and to maintain a pure culture inoculum, and would require apparatus for maintaining the proper environmental conditions throughout the ret period. It is doubtful that this process would be economically feasible as a method of reducing resin, as retting does not result in rubber with the physical properties approximating that obtainable from newly harvested shrub.

ERP investigation of storing shrubs as ensilage under essentially anaerobic conditions indicated that the shrub could be stored as ensilage, but studies were incomplete.

b. Cleaning and defoliation: As an initial step in defoliation, parboiling has been an accepted practice. Leaf materials constitute approximately 25 percent of the dry weight of the plant and obviously constitute an unproductive load on the milling system, since the leaves contain no recoverable rubber. There is some evidence that milling the shrub with leaves only increases the amount of metals in the raw rubber, especially copper, iron and manganese, in the raw rubber. These materials degrade the quality of the rubber. Parboiling induces coagulation of latex within the cells.

The procedure used by guayule researchers at the Firestone Tire and Rubber Company was described by Nivert et al. (1978) as follows: "Fresh guayule shrub is received from the fields in bales, loaded on a conveyor and sent through a soaking pit where the bales are parboiled at 70°C for 10 to 20 minutes to loosen the leaves and any dirt. The bales are cut and shrub is passed under a high pressure water spray to remove the leaves." Weihe and Nivert (1980) report that alternatives to baling, parboiling, and trommeling are now being considered because guayule leaves contain about 8 percent resins "which could be extracted and recovered if the leaves were processed, eliminating the operations prior to grinding. If, however, leaf removal is necessary either from a technical or economic standpoint, an alternative leaf removal process has been demonstrated and is being further developed. This technique consists of removal of the leaves from the branches, followed by air classification to separate the lighter leaves from the heavier wood chips. This technique can be employed at the plant site or in the field, provided the chipped shrub can be protected from oxidation."

Chemical leaf defoliation prior to harvesting has been tried without success (Taylor, K., 1946) but still may be possible. Because of processing difficulties it is doubtful that using the leaves for byproducts will prove to be economically feasible (Bonner, 1979), but use of leaves remains a possibility because of their resin content (Weihe and Nivert, 1980).

c. Water requirements: The major consumptive uses of water in CIQA's guayule processing are as process water and steam, and for cooling. Preliminary estimates of water use (Motomochi, 1980) were based on the processing methods used at the Saltillo pilot plant. They indicate a probable consumptive use of 58.5 cubic meters as process water and 14.35 metric tons of steam per metric ton of rubber (0.05 acre-foot per metric ton).

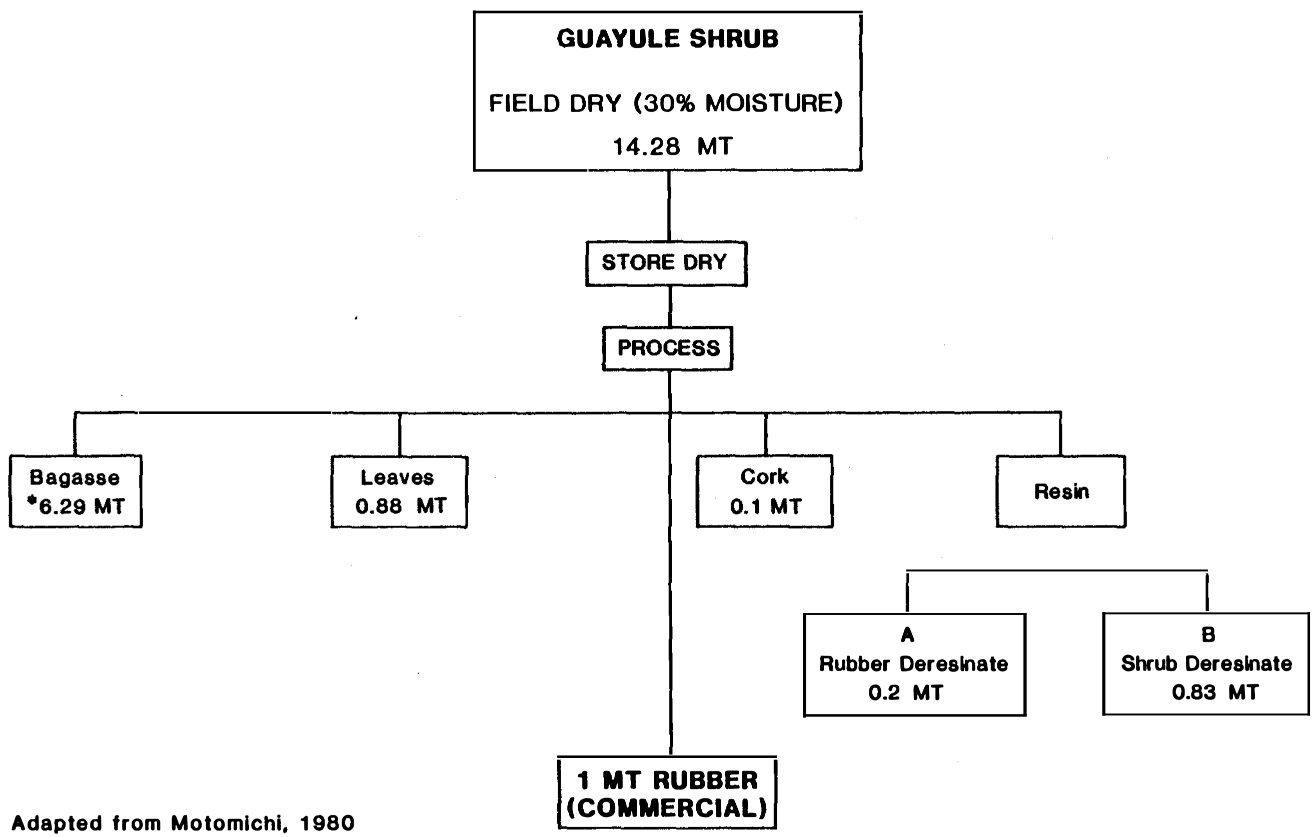
Based on data from laboratory-scale processing using solvent extraction methods, Firestone researchers have concluded that a 50,000 ton processing plant operating at full capacity would use as much as 458 acre-feet per year for chemical processing. An additional 317 acre feet per year would be lost in the conversion to steam. More than 90 percent of the water used in the cooling cycle could be recovered, but Firestone estimates that 14,000 acre-feet per year of water would be lost in the cooling process through evaporation, leakage, and other causes. The total consumptive water use for a 50,000 ton processing facility using solvent extraction methods is estimated as 15,000 acre-feet per year (Donelson, 1980).

Engineers at the Goodyear Tire and Rubber Company disagree with these estimates. They believe that process, steam, and cooling water losses plus water used to convert bagasse into alcohol by fermentation would total only 3,100 acre-feet per year (Donelson, 1980).

d. Cost estimates: Sufficient experience was gained at the Mexican pilot processing plant to develop materials balance sheets and estimates of processing costs and quantities of materials and energy required. The amounts of byproducts and guayule shrub processed to produce one metric ton of rubber are shown in Figure III-6.

Preliminary estimates for processing costs at the Saltillo plant indicate a total materials, labor, and energy cost of $819 US per metric ton of rubber (Table III-10).

Energy content of guayule should also be considered, i.e. the total amount of energy in the raw material plus that used in conversion operations, a concept called energy accounting. In guayule, the main components of energy are in the solvents and process chemicals, the power required to pump any water used and the steam and power required in resin and rubber recovery operations. These energy requirements can be offset by utilization of the bagasse as fuel for steam and power generation. The energy content of guayule grown and processed in the United States is a negative 1,500 BTUs per pound, which means that growing and processing guayule and using bagasse as fuel results in a net gain of energy (Weihe and Nivert, 1980). Shrub harvested from wildstands and processed by the CIQA method in Mexico would produce a net gain of 3,200 BTUs per pound. Energy balance for guayule processing is compared with that for synthetic rubbers and for hevea rubber in Figure III-7.



Adapted from Motomichi, 1980

Figure III-6. Materials Balance to Produce One Metric Ton of Guayule Rubber by the CIQA Process
*Dry Basis

TABLE III-10

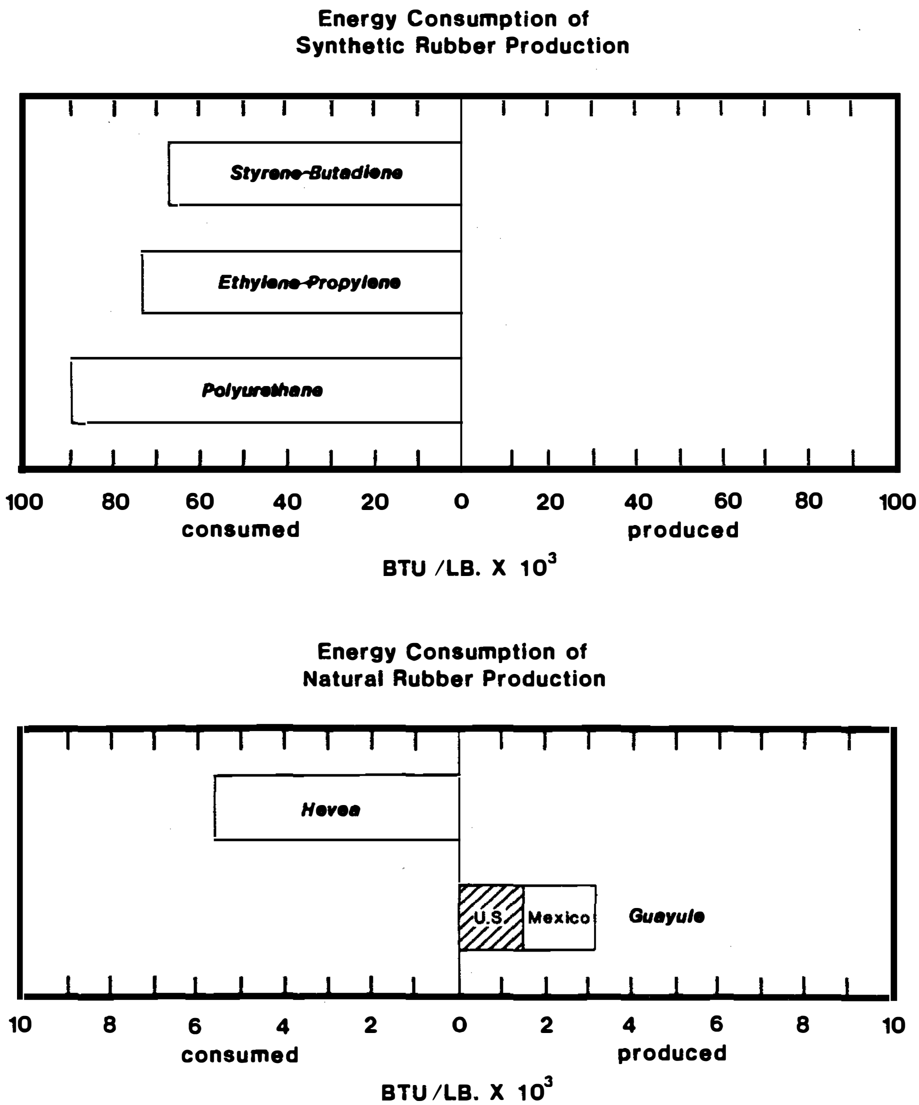
PRELIMINARY ESTIMATES OF GUAYULE PROCESSING DIRECT COSTS IN MEXICO

Material	Unit Cost ($US)	Consumption Per MT/Rubber	Cost Per MT Rubber ($US)	Percent of Total Cost
Process water	0.089/M^3*	58.5 M^3	5.20	0.63
Guayule (30 percent moisture)	31.50 /MT	14.28 MT	450.00	54.92
Sodium Hydroxide	275.56 /MT	0.45 MT	124.33	15.17
Acetone	785.24 /MT	0.025 MT	19.94	2.43
Hexane	276.51 /MT	0.071 MT	19.85	2.42
Antioxidant	3555.56 /MT	0.01 MT	35.55	4.33
Fillers	0.89 /M^2	14.27 M^2	12.70	1.54
Surfactant	5333.33 /MT	0.0094 MT	50.13	6.11
Polyethylene	0.49 /M^2	22.66 M^2	11.10	1.35
Steam	1.78 /MT	14.35 MT	25.54	3.11
Electricity	0.024/Kwh	2142.0 Kwh	51.40	6.27
Direct Labor	0.276/Manhr	49.41 Manhr	13.64	1.66
			819.38	

*M^3 = 264.2 gal.

MT = Metric ton or 1,000 Kg.

Source: Adapted from Motomochi, 1980



NOTE: Processing hevea natural rubber consumes less than 1/10th the energy required to produce synthetic rubber -- AND production of guayule rubber produces energy.

Data from Weihe and Nivert, 1980; Campos-Lopez, 1981

Figure III-7. Energy Consumption to Produce Rubber

3. Product quality and utilization: Three grades of isoprene rubber can be obtained from the guayule shrub: 1) resin-containing rubber; 2) latex; and 3) deresinated rubber obtained by removing resin from the shrub prior to shrub-milling or from milled shrub in either a wet or dry state. These grades of rubber differ in quality. Rubber processed without resin removal has a 20 percent to 25 percent resin content. For general industrial use, the resin-containing rubber is the poorest quality. Only deresinated guayule rubber is now being considered for use.

The resins adversely affect its stress-strain characteristics, decreasing the cure rate and requiring compounding adjustments. Also, the resins contain a pro-oxidant which speeds the degradation of guayule rubber. Since the rubber does not contain a natural antioxidant as does hevea rubber, the guayule rubber tends to degrade and become tacky during storage unless protected by adding antioxidants. Removing the resins reduces degradation and improves the physical properties of guayule rubber vulcanizates. Solvent extraction of resin from the guayule shrub or rubber without adding antioxidants produces little improvement in the rubber's quality until virtually all the resin is removed (Taylor, 1975).

Arguments for removing resin are compelling. Rubber quality is vastly improved, and the resin recovered may have a profitable market. The major argument against removing resin is the added costs of equipment and operation. However, these costs may be offset by the market for the recovered resins and a higher price for the higher quality rubber (Taylor, 1975).

Because guayule rubber is recovered from the whole shrub (including the roots), dirt and rocks as well as cork and bagasse are potential contaminants. Contaminants are largely removed in the solution-phase purification process carried out at the Saltillo pilot plant. Although the ash content is higher than in the best grades of hevea rubber, it is not excessive (National Academy of Sciences, 1977).

a. Chemical structure: It is well known that the microstructure of natural isoprene rubber is one of the determining factors in its mechanical properties (e.g., "green strength")*; and that its capacity to crystallize under stress is due to a highly-regular polyisoprene chain exclusively composed of head-to-tail cis-1,4 structure (within the detecting limits of modern equipment). The synthetic polyisoprenes available on the market scarcely reach 98 percent of this structure. While in the past it has been said that guayule rubber has a microstructure identical to that of hevea rubber, it was claimed later that only 97.8 percent was made up of the head-to-tail cis-1,4 structure; recently, using nuclear magnetic resonance (H-300 Mhz and C^{13}) it has been shown that guayule has a microstructure made up exclusively of head-to-tail, cis-1,4 structure. Although questions about the presence of carbonyl groups in the chain (correlated with gel formation in hevea rubber) still exist, the identical microstructures of guayule and hevea essentially are assured (Campos-Lopez et al., 1978).

Molecular weight is another very important characteristic of the elastomer. During storage and processing of the guayule shrub the rubber will be subjected to different degradation conditions. This can cause fluctuations in the gum properties. In synthetic rubbers the molecular weight can be controlled easily; however, in hevea rubber biosynthesis makes molecular weight hard to control, which could imply that considerable variations exist (Campos-Lopez et al., 1978).

Guayule rubber in its natural state presents important differences compared to hevea rubber. Recent studies by gel permeation chromatography show that the molecular weight (Mn) is in the order of 10^6 and is unimodal with a polydispersity lower than 2.5. In tests showing the characteristics of guayule rubber from four regions of Mexico (Zacatecas, Coahuila, Nuevo Leon, and Durango), it has been found that the variation in macromolecular size in guayule rubber is not materially influenced by geographical locations (Angulo-Sanchez et al., 1978).

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*See Section entitled "Mechanical properties."

However, the rubber content is influenced by geographical locations and shrub variety. On this basis, it is possible to foresee that, unlike hevea, the genetic improvement of guayule will be helped as the characteristics of the rubber are not markedly affected by modest genetic changes (Campos-Lopez et al., 1978).

While molecular weight is a critical property, methods generally used to measure it use the soluble fraction of the rubber, thus eliminating the gel. The gel is an important fraction and noticeably influences the physical properties of the elastomer. It has been found that the gel content (macro and micro) of native guayule rubber is noticeably low (less than four percent) and that it is not increased during storage, as is hevea rubber; nor does it require any chemical treatment to be prevented. This is an important advantage for guayule rubber that will reflect advantages in its rheological properties and processing (Campos-Lopez et al., 1978).

The amount of branching in guayule rubber molecules has not yet been reported. Research is now being done both at the Institute of Polymer Science at Akron University and the Centro de Investigacion en Quimica Aplicada to determine the extent of linearity. Preliminary results show that guayule rubber is predominantly made up of linear chains (Campos-Lopez et al., 1978).

Glass transition temperatures (Tg), crystallization, heat capacities (Cp), etc., are very similar in guayule and hevea rubber. Studies are being carried out to determine the crystallization efficiency of guayule rubber by differential scanning calorimetry (DSC) and electron microscopy. Preliminary results indicate that the crystallization rate of these pure rubbers is similar, but slightly faster in guayule. This could be additional evidence of a greater linearity in the guayule rubber macromolecules. Thermal and thermo-oxidative stability also have been studied. Activation energies of chain scission in both rubbers are very similar (20 Kcal/mole), irrespective of the model used (Campos-Lopez et al., 1978).

The amount of branching and crosslinking among guayule rubber molecules has not been determined although the ease with which the rubber dissolves in solvent suggests that it is low. Little gel is produced during rubber formation and little forms after extraction. The Saltillo pilot plant relies on dissolving the rubber in aliphatic solvent as a step in the purification process (National Academy of Sciences, 1977). Dissolution would be very troublesome in the presence of moderate amounts of gel (Gregg, 1979).

The rheological properties of non-vulcanized guayule rubbers are just beginning to receive attention. Flow properties of this material, because of its macrostructure (low gel and high linearity), should present important behavioral advantages compared to hevea rubber (Campos-Lopez et al., 1978).

On a commercial scale, hevea rubber is produced with a series of impurities (proteins, sugars, etc.); some are of great importance, as they assist further processing steps (milling, vulcanization, etc.). In the same way, guayule rubber now produced on a pilot scale contains impurities, but the chemical composition of its components is different from those present in hevea rubber. This is one of the biggest differences between the two rubbers and will be reflected both in the processing characteristics (milling, vulcanization, extrusion, etc.) and the mechanical properties (tensile, modulus, etc.) if identical curing formulations are used (Campos-Lopez et al., 1978).

b. Mechanical properties: Green strength is a measure of the strength of raw rubber during extension. Imperfections in the microstructure are believed to be a major factor contributing to reductions in the green strength of a polyisoprene rubber. The similarity of microstructure might be expected to result in similar green strengths between guayule and hevea rubbers, but measurements show that guayule's green strength is intermediate between that of synthetic polyisoprene and hevea rubber. If this proves to be a general feature of guayule rubber (and not just that of early samples from a new pilot facility), it might limit the percentage of guayule that would be added to the blend of rubbers used for tire making by large manufacturers. Green strength is important only during fabrication, i.e., before vulcanization. It does not affect the quality of the final manufactured product, and it is important primarily to large factories manufacturing tires (National Academy of Sciences, 1977). Also, preliminary studies indicate that if guayule rubber has an apparent green strength less than that of hevea rubber, this could be increased by using chemical promoters (Campos-Lopez et al., 1978).

"Building tack" measures how well layers of raw rubber stick together before they are vulcanized. It is a very important property in fabricating certain types of tires. Synthetic elastomers have less building tack than hevea rubber. Because hevea and guayule rubber have good building tack, adding ingredients to increase tack is not necessary. The excellent flow and tack characteristics of guayule rubber should make it suitable for tire manufacture (National Academy of Sciences, 1977).

The Mooney viscosity, which tests the flow of a rubber under applied force, has been measured at 95 to 105 in modern guayule samples. This is in the same range as hevea rubber and means that guayule rubber should not exceed hevea rubber in the amount of softening needed for extrusion. But guayule rubber, like hevea rubber, probably will be more difficult to process than synthetic isoprene rubbers (National Academy of Sciences, 1977).

The plasticity-retention index measures a rubber rheological stability. Although the guayule sample tested fell short of the standards of the highest quality hevea rubber, it is in the range of the hevea rubber used in tires (National Academy of Sciences, 1977).

Systems for handling elastomers in solution, modern technology for extracting oils using solvents, "ad hoc" drying systems, etc., are recent technological achievements which make possible recovering guayule rubber and byproducts with the necessary economic and technical quality requirements (Campos-Lopez et al., 1978).

In the past, little or no effort was made to standardize the individual processes to a point where the products had specifications similar to the Technically Specified Rubbers (hevea). This lack of specifications left potential users with no consistent opinion of guayule's capabilities (Campos-Lopez et al., 1978). Evaluation studies of Mexican guayule rubber produced at Saltillo have been conducted using American Society for Testing and Materials (ASTM) and Efficient Vulcanization recipes for determining the vulcanization characteristics and physical properties of guayule rubber produced by modern techniques. Neglecting recipe modifications, guayule rubber does have physical properties similar to those obtained with hevea rubber vulcanizates. If a "technically specified" type of guayule is commercially feasible, it can become a direct substitute for hevea rubber. In order to obtain the optimum physical properties available with guayule rubber, additional work attempting to find vulcanization recipes is needed (Winkler et al., 1978).

On aging, the percent changes in tensile properties of hevea and guayule rubbers were equivalent, thus indicating that the guayule was sufficiently stabilized to age at the same rate as hevea (Winkler et al., 1978).

c. Processing characteristics: The presence of resins in guayule rubber could be beneficial to processing by facilitating milling and extrusion and even by reducing energy consumption during these operations. These aspects are being studied. Some preliminary experimental results on hevea and guayule energy consumption during milling show guayule rubber requirements two percent lower than those necessary for hevea rubber (pale crepe No. 1 NBS and smoked sheet RSS No. 1). As the resin content of guayule rubber increases, energy consumption falls considerably. With respect to flow during extrusion, important results have recently been obtained regarding advantages of the resin in guayule rubber and its possible use as a plasticizer in hevea rubber and styrene-butadiene rubbers (Campos-Lopez et al., 1978).

Because of its structural similarity to hevea rubber, no difficulties are expected in processing guayule rubber with standard equipment. It softens readily and is expected to extrude readily and to flow properly in molds. Guayule rubber differs slightly from hevea rubber in the ratio of chemicals needed to compound it for adequate cure rates because of the slightly different non-rubber impurities in commercial hevea rubber. Both contain small amounts of moisture, dirt, terpenes, and triglycerides; but, guayule lacks the protein and amine "impurity" that is beneficial to the curing properties of hevea rubber. Guayule's lack of vulcanizing activators causes it to vulcanize more slowly than hevea rubber. However, by adding accelerators to the formulation this can be readily overcome (National Academy of Sciences, 1977). Recent experiences in rubber compounding by Goodyear Tire and Rubber Company, Goodyear Oxo Mexicana, and others have not revealed significant problems.

d. <u>Performance</u>: Almost nothing is known of guayule's performance under full operating conditions. Virtually all the 120,000 tons of resin-containing rubber purchased by rubber companies between 1903 and 1946 were blended with hevea rubber and may have been used as much for its tackiness as for its rubbery nature (National Academy of Sciences, 1977).

While the federal guayule project was winding down in the early 1950s, several tons of deresinated guayule rubber were distributed to industry for performance testing. Results were erratic (not always attributable to the rubber); but, in a federally supervised test, Firestone Tire and Rubber Company placed one guayule tire and one hevea tire on the back wheels of three gravel-laden trucks. To ensure equal wear, the tires were switched regularly. The guayule tires performed as well as the hevea tires. One guayule tire survived 50,900 miles without showing a body break (National Academy of Sciences, 1977).

Various Mexican, U.S., and European rubber companies have been testing guayule rubber for both tire and non-tire use (Campos-Lopez et al, 1978). Based on laboratory and field trials, CIQA, the University of Akron, and the Goodyear Tire and Rubber Company have recently confirmed that guayule is capable of yielding high quality natural rubber. Automobile and truck tires containing 35 percent to 40 percent guayule rubber have passed vigorous U.S. Department of Transportation high speed and endurance tests and a number of the diagnostic tests (Dyckman, 1978). Goodyear has recently developed a 10-foot-high, 5,000-pound earthmover tire containing 1,900 pounds of guayule rubber. Tires retreaded with guayule rubber showed normal wear and performance on the main landing gear of a United States Navy jet fighter. Guayule rubber is considered an acceptable substitute for hevea rubber on rebuilt A-7 aircraft main landing gear tires (Fontanoz, 1980).

Results of previous tests have led Goodyear to conclude that the technical qualities of purified guayule rubber make it acceptable for use as a replacement of hevea rubber and synthetic "natural" rubber (cis-polyisoprene) in many tire formulations. It is believed that the variability found in testing pilot plant batches of guayule rubber would be improved greatly by large volume commercial production; and, if guayule were available today at a competitive price, it would find its place in the rubber market. Based on its evaluation of guayule rubber, Goodyear is optimistic that additional research will make guayule a viable product, competitive with hevea prices of the 1980s (Riedl and Creasey, 1978).

If guayule rubber production were resumed, it would likely be used, initially at least, in blends with hevea and synthetic polyisoprene rubbers and with the more widely used styrene-butadiene synthetic rubbers. Under such circumstances, slight differences from hevea rubber in processing or properties are less noticeable, a factor which could greatly facilitate commercial guayule introduction (National Academy of Sciences, 1977).

4. Byproduct characterization and utilization: Perhaps more than any other factor, commercial use of guayule byproducts could affect guayule rubber production economics. Each ton of rubber extracted produces about eight tons of wood fiber (bagasse), half a ton of resins, and about one ton of leaves.

The components of harvested guayule shrubs are shown in this table from the National Academy of Sciences (1977) report on guayule (Table III-11).

TABLE III-11

COMPONENTS OF HARVESTED GUAYULE SHRUBS

	Percent
Moisture	45 - 60
Rubber	8 - 26*
Resins	5 - 15
Bagasse	50 - 55*
Leaves	15 - 20*
Cork	1 - 3
Water Solubles	10 - 12*
Dirt and Rocks	Variable

*Dry weight basis.

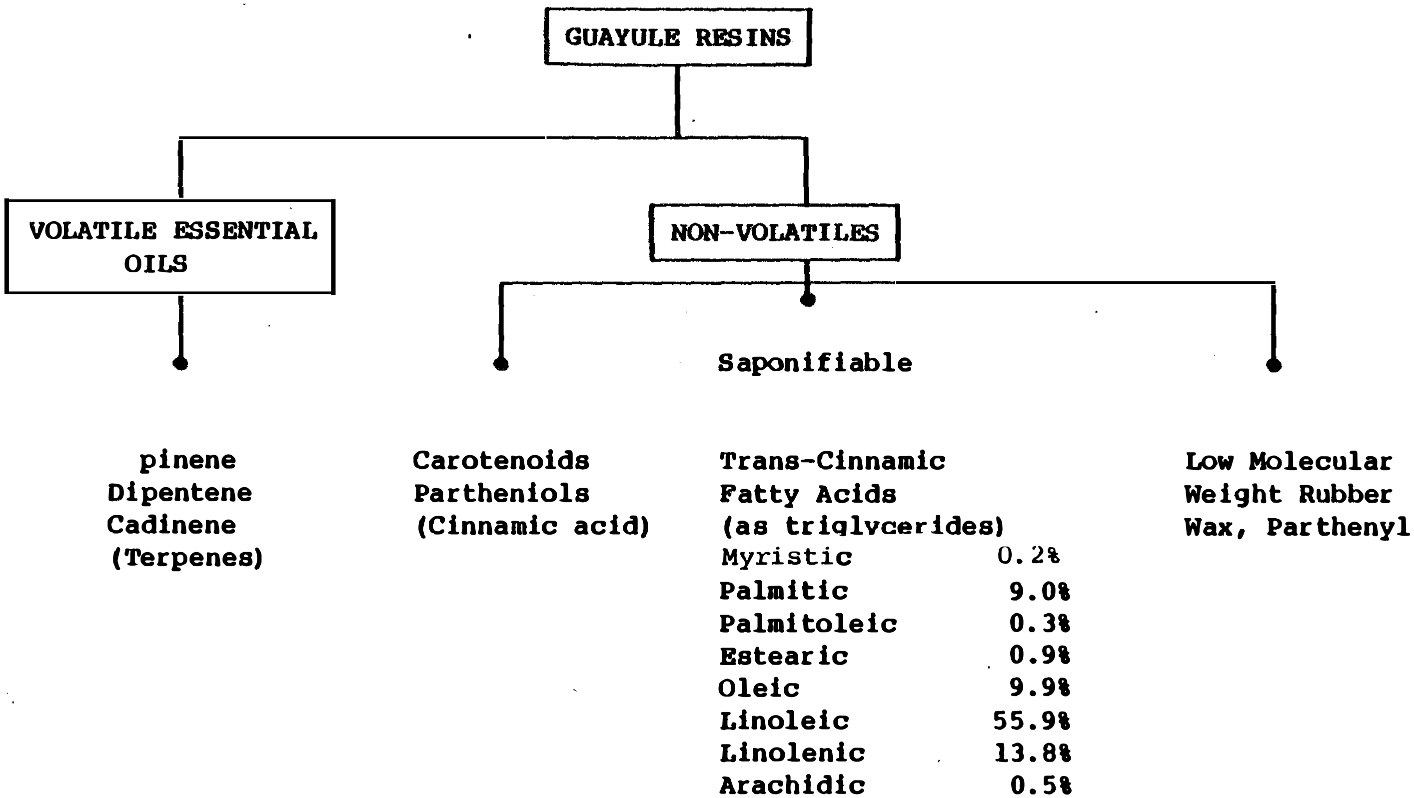
Source: National Academy of Sciences, 1977.

a. <u>Resins</u>: Identifying and characterizing guayule's acetone-soluble constituents received major attention during guayule research efforts in the 1940s. The resins seemed to offer the most economic value. In shrub deresination of variety 593, approximately one-half pound of resin could be obtained from each pound of rubber produced. Deresinating rubber extracted in the form of worms resulted in about half that yield. Resin availability varies with varying resin contents of different strains of guayule. The resin differs with respect to percentage composition of principal components depending on whether it is essentially a total extractive as with "shrub resin" or a partial extractive as with "worm resin." Essentially all the resin could be obtained by solvent extraction of the shrub before extracting the rubber (Hammond and Polhamous, 1965). Small-scale pilot tests to explore the feasibility of removing resin and coagulating the rubber in the cells by extraction with water-miscable solvents such as acetone and alcohol indicated that milling the residual shrub resulted in high recovery of excellent rubber (Byrne, 1979).

Figure III-8 shows the major resin constituents in whole shrub extracts. Resin components as described by Hammond and Polhamus (1965) are as follows. Some 37 percent of the resins obtained from the rubber worms consists of unsaturated long-chain fatty acids, notably linoleic acid, along with traces of linolenic and oleic acids. Linoleic acid has an established position in the paint and varnish industry.

Cinnamic acid is present in resin as the ester of partheniol and can be released by saponification. It has an established value in the cosmetics and pharmaceutical industries. The sesquiterpene cinnamic acid ester, guayule A, has been identified as a potent elicitor of allergic contact dermatitis, comparable to poison ivy allergens, in laboratory animals (Rodriguez et al., 1981).

A "drying resin" fraction readily obtainable from shrub resin is a hexane-insoluble, alcohol-soluble shellaclike gum resin easily polymerized to a heat-resistant clear coating of good solvent resistance. This fraction constitutes 35 to 50 percent of the shrub resin but constitutes a much smaller proportion of the worm resin.



Source: Campos Lopez et al, 1978

Figure III-8. Guayule Resins

Guayule terpenes constitute a potentially valuable "naval stores" type of byproduct. Three percent to five percent of the worm resin, a much higher proportion of leaf resin, is comprised of volatile terpenes including alpha-pinene, dipentene, cadinene, partheniol and others. Sesqui-, di-, and higher terpenes also are readily obtainable in significant quantities from the nonvolatile, unsaponifiable fraction.

The "drying resin" fraction is of the greatest interest and probably is of most economic value. Apparently all rubber-making plants make larger or smaller amounts of cyclic tri-terpene alcohols, such as lupeol and -amyrin which are combined as esters. In some cases these same cyclic tri-terpenes are present as oxidized carboxyl group-containing derivatives. The drying resin fraction may be of a tri-terpene nature and possibly may contain diterpenes such as abietic and pinaric acids. If this is true, the drying resin fraction could compete in the "naval stores" industry. This would be of economic importance as this industry needs a new source of the higher cyclic di- and tri-terpenes for paint, paper sizing and so on (Bonner, 1979).

Betaine, a constituent of guayule resins, is found in water extracts of guayule shrub. This substance commonly is obtained as a byproduct of the sugar beet industry. It has a limited market as a pharmaceutical and as an intermediate in producing surface-active agents, disinfectants and other chemicals (Hammond and Polhamus, 1965).

In research at the Institute of Polymer Science, University of Akron, studies have been made of possible guayule resin applications as a peptizing agent for natural rubber, helping to break down gel of high molecular weight fractions in the rubber which now are broken down by mechanical shear.

Studies of guayule resin to develop varnishes and adhesives have been underway at the Centro de Investigacion en Quimica Aplicada. Possible other uses such as pigment dispersors for rubber and tackifiers are being evaluated.

Recent studies by Firestone have shown that through chemical modification of the whole resin, a tackifying resin can be prepared giving similar properties to materials currently being used in tire compounding. Commercial tackifying resins are priced from $.30 to $.40 per pound (Weihe and Nivert, 1980).

Research is needed to devise commercially feasible techniques for separating the resins into their saleable products. It is conceivable that the resins could prove to be more valuable than the rubber (National Academy of Sciences, 1977). If a use is found for guayule resin, that fact would influence profoundly production methods and the quality of the rubber recovered (Taylor, K., 1946). Ongoing studies at the University of Akron and Goodyear Tire and Rubber Company on byproducts and resins may answer questions about net value of non-rubber constituents of guayule.

b. Bagasse: Based on weight, the bagasse constitutes the largest amount of byproduct. Its importance as a source of fuel for guayule processing is indisputable. ERP work showed that properly dried bagasse can be made to supply all heat requirements needed for large processing operations. For this purpose bagasse must be dried down to less than 35 percent moisture content. This can be accomplished in two stages: first, a reduction to 63 percent to 65 percent moisture in a centrifugal filter; followed by further drying by means of stack gases. The entire operation, including the stoking, can be handled mechnically (USDA Bureau of Agricultural and Industrial Chemistry, 1953). Bagasse from a direct solvent extraction process is essentially anhydrous and would require no drying. Production of guayule rubber results in a net gain in energy of about 1,500 BTUs per pound rubber due to the high caloric value of the bagasse.

Some of the first work by the ERP contemplated using bagasse for covering guayule seed in the nurseries and as a soil amendment. Using bagasse in this manner did not introduce any pathogens, although under certain conditions it adversely affected young seedling growth. The effect, which did not persist, was ascribed to the fact that the soil microorganisms tied up the nitrogen, normally available for plant growth when bagasse was added to the soil (Taylor, K., 1946). Studies of bagasse used as a soil amendment and fertilizer indicated, as a general rule, that guayule bagasse should not be added to the soil as an organic material unless nitrogen is added with it. It would appear then that bagasse could be used as an amendment to the heavier soils for its lightening effect, but its value as a fertilizer is questionable (Taylor, K., 1946).

CIQA reported a potential use of guayule bagasse as an animal feed supplement (CIQA, 1980). The basic process is a microbial fermentation of cellulose residues to produce large amounts of protein in the microorganisms feeding on the bagasse substrate. Table III-12 shows the chemical composition of guayule bagasse. Cellulose and hemicellulose, polymers of simple sugars, generally are the largest fraction of cell wall material in plants and are the major constituents of guayule bagasse. They also are the main substrate used by bacteria. Since bagasse will be produced in large amounts and the process water from rubber extraction might supply the water needed for fermentation, a combined rubber extraction/fermentation facility has been proposed. The process is still in the experimental stage and fermentation has only been carried out at the laboratory level. Large-scale tests of palatability and effectiveness as an animal feed have not been conducted.

c. Water solubles: The water solubles of guayule can be classified as three types: polysaccharides, amino acids, and inorganic salts. The polysaccharides comprise levulins (fructose polymers) and pentosans, including possibly xylan. The amino acids include betaine, discussed above. Inulin-derived levulins are present in the defoliated shrub to the extent of 8 percent to 12 percent, and are extracted readily by hot water. They are of interest as a possible source of low-cost alcohol (Hammond and Polhamus, 1965). Levulins are readily extracted by hot water (80°C). Thus, they will concentrate in the milling and other

TABLE III-12

CHEMICAL COMPOSITION OF GUAYULE BAGASSE

Composition	Percent
Cellulose	23 - 24%
Hemicellulose	
Xylose	20 - 22%
Arabinos	4 - 5%
Galactose	2 - 3%
Manose	0.5 - 1%
Rubber[1]	1%
Resin[1]	5%
Protein[2]	4.7%
Ash	1 - 2%

[1] Varies according to extraction efficiency.

[2] % N X 6.25

Source: CIQA, 1980.

processing waters to the extent of 3 percent to 5 percent. Further concentration might result from greater reuse of process waters. The direct conversion of the high polymeric inulin to alcohol in 90 percent yield can result from fermentation with the proper strain of Saccharomyces fragilis (NRRL). Despite the high concentration of pentosans (xylan) in the guayule tissue (12 percent to 15 percent), its low solubility in hot water precludes the presence of much of this material in procesing waters. If readily obtainable in significant quantity, it could be used as source material in the production of furfural (USDA Bureau of Agricultural and Industrial Chemistry, 1953).

d. Effluent: Large quantities of water are used in the flotation method of guayule rubber extraction (CIQA process). The water from the flotation tanks contains caustic soda, organic and inorganic material from dirt clinging to the shrubs, and water solubles described earlier. Caustic soda and water must be almost entirely recycled for the process to be economical (Glass, 1979), and incomplete recovery will result in effluent containing caustic soda and other organic and inorganic chemicals. Waste water from the ERP process and from hevea rubber mills was safe for plant irrigation (Bonner, 1979), but caustic soda in the effluent would make this hazardous. The Firestone method of rubber extraction would not produce any effluent.

e. Leaves: Large amounts of leaves accumulate at a guayule mill and must be disposed of in one way or another. In early attempts they were dried for use as boiler fuel, as was bagasse. The practice was not practical because of the large amounts of heat required to dry them sufficiently (Taylor, K., 1946). Recent work in the United States suggests that it may be practical to grind the whole shrub prior to direct solvent extraction. This would produce an anhydrous whole plant bagasse comprised of cork, leaves, and fiber.

Investigations of the use of leaves as fertilizer showed favorable growth responses when leaves were applied at rates comparable to those commonly used for farm manure. Soil applications of dry guayule leaves, which were removed from the plants without boiling, retarded crop growth as they tied up the nitrogen available for plant growth. Parboiled leaves did not have this effect. It may be concluded that leaves removed by parboiling may be used as fertilizer (Taylor, K., 1946).

The leaves represent an important untapped source of guayule resins, especially volatile terpenes, wax and plant pigments. However, much of the leaf value for resins would be dissipated in the parboiling process. Leaves constitute an excellent soil amendment, especially when composted. After parboiling, they can be compressed into a building board which, due to the structure of the leaves, possesses a pleasing pattern. As a source of livestock feed, leaves appear to have no value because of their unpalatability (USDA Bureau of Agricultural and Industrial Engineering, 1953).

f. Wax: Cuticle wax constitutes 2.5 percent of guayule leaves on a dry weight basis. This is a hard wax with one of the highest melting points (169^{o}F) ever recorded for a natural wax, particularly important today because hard waxes are in universal demand (National Academy of Sciences, 1977). Its relative hardness, molecular weight, and melting point justify its consideration as a substitute or extender for carnauba wax (USDA Bureau of Agricultural and Industrial Engineering, 1953).

It may be that none of the suggested uses for the leaves will be useful in the long run unless the whole shrub is ground for direct solvent extraction. It would appear that extracting the cuticle wax may be most promising. However, in view of the small quantity involved and the fact that the wax would have to be removed by solvent extraction, this process may not be economically viable (Bonner, 1979).

g. Oil: A volatile oil with a distinctive lingering, spicy odor can be separated from the resins and leaves by steam distillation. The oil contains mono- and sequiterpenes (including α and βpinene, limonene, cadinene and partheniols 3 and 4), and may be valuable to industry (National Academy of Sciences, 1977).

h. Cork: The cork is conveniently obtained in a waterlogged condition from the last flotation tank discharge. It has been suggested as a possible linoleum filler; but no tests have been conducted (Hammond and Polhamus, 1965).

i. Seeds: Guayule seed contains oil and has a protein content of 11 percent to 14 percent. Its potential use as human and animal food is unknown, therefore research is needed to test guayule as an oilseed crop. It produces many seeds. During the 1940s, seed collecting and processing equipment was designed but the seed was used for propagation (National Academy of Sciences, 1977).

CHAPTER IV. PROSPECTS FOR GUAYULE COMMERCIALIZATION

Commercial production of guayule in Mexico will depend on government support, which in turn depends on numerous political and economic factors. The overall program direction will lie with the agency designated to create an integrated approach to dealing with rural poverty in the marginal and arid zones. Political factors will interact with the technical, agronomic, social, and economic aspects of harvesting, growing, and processing to determine the course of commercialization. This chapter presents a review of the forces that could promote or constrain guayule commercialization.

A. Driving Forces

Forces that are operating to promote the commercialization of guayule can be grouped into three categories:

1. Federal goals and plans;
2. Regional development programs; and
3. Governmental and academic research and development programs.

1. Federal goals and plans: Mexico's reported reserves of petroleum and natural gas are the third largest in the world. Projected petroleum export revenues for 1981 exceed $15 billion US (Latin American Weekly Report, 1981). The efforts and programs of some government agencies have been redirected to utilize federal revenues from the state-owned petroleum industry, Petroleos Mexicanos (Pemex), to develop industries based on renewable resources. All development plans are outlined in the Global Development Plan. Specific objectives are defined in a variety of plans, including the National Agroindustrial Development Plan; the National Industrial Development Plan; the Mexican Food System; and the Desertification Plan. Guayule development appears to be a promising means of supporting some national plan goals.

Mexican imports considerably exceed exports, consumer prices are rising rapidly, and foreign credit is becoming tighter and more expensive. The 1982 peso devaluations will affect dramatically, both positively and negatively, any guayule development programs.

The government now requires permits for 90 percent of the total value of Mexican imports in an effort to stem the ever widening trade deficit. Mexico currently fills its rapidly expanding demand for natural rubber with imports. This contributes to the flow of cash out of the country without generating any potential exports to help achieve a more favorable balance of trade. Domestic production of substantial amounts of rubber could be of some help in reducing Mexico's trade deficit.

Mexico's economy has been expanding rapidly, and a serious shortage of rubber could adversely affect this expansion. A long-term international shortfall of natural rubber would decrease the availability of adequate quantities of rubber and drive up rubber prices. Political instability in the major hevea rubber exporting countries or the use of rubber as a political weapon could drastically reduce available supplies. It is conceivable that disease in Hevea plantations might diminish supplies, or that conversion of rubber plantations to a more profitable palm oil production could create shortages. All of these concerns regarding potential shortages strengthen the argument for using guayule as a means for developing the northern arid region and they demonstrate the need for a national program for polyisoprene rubbers (synthetic and natural) as has been pointed out recently (MacGregor, 1980).

National prestige and the desire for self sufficiency in important commodities is a less tangible concern, but should be considered a significant force.

2. Regional development programs: Guayule commercialization is one of the development programs targeted for the largely rural northern arid region. The region, a substantial part of Mexico's total land surface,

is sparsely populated and its resources are unexploited or only partially developed, while there are other areas in Mexico that have very high population densities and overused resources.

The most direct regional benefit from guayule commercialization would be economic. The entire region is characterized by underemployment and a shortage of jobs in which a person can earn an adequate wage. Harvest of several kinds of economically useful wild plants is commonly practiced. Guayule is not harvested for commercial use now, but many residents remember when the shrub was an important source of income, and they would like to see a return of the industry to provide more jobs and a greater diversity of economic activities.

In addition to the new jobs and increased income resulting from the development process itself, the guayule program will help stimulate the development of needed community services such as better roads - giving improved access to outside markets - improved and extended water and power distribution networks, and sewage disposal systems. Government health and education services can be expected to extend into the areas being developed in conjunction with the guayule collection centers. Service sector jobs, supported by the increased money flow and concentration of populations at regional centers, would bring more consumer goods, services, and additional jobs.

3. Governmental and university research programs: Research and development is ongoing in the fields of guayule biochemistry, rubber and byproduct analysis, engineering for processing facilities, and product development. Guayule-related socio-economic, agronomic, ecological, and feasibility studies are also being conducted. Guayule research was initiated in 1972 under the sponsorship of the National Commission of Arid Zones (CONAZA) and the National Council on Science and Technology (CONACYT). CONAZA is in charge of arid lands development. Guayule is one of its most important projects. In 1976 the Mexican government, through CIQA, completed a pilot plant to process wild guayule at

Saltillo, Coahuila, Mexico. The plant has a processing capacity of one metric ton of guayule shrub per day. Analysis and testing of the rubber produced at the pilot plant show guayule to be an acceptable substitute for hevea in most applications. Improved processing methods were developed and have been included in the engineering design for a larger commercial facility.

An international guayule conference was held in Tucson, Arizona, in 1975. Technical papers were presented by scientists and the proceedings of the conference were subsequently published. A second international conference was held in Saltillo, in 1977, to discuss the new Mexican processing procedures, the chemistry of guayule rubber, and the agronomic and ecological implications of recent developments. The proceedings of this conference were published in 1978 by CONACYT. A third international guayule conference was held in the United States in 1980, in Pasadena, California.

Germ plasm has been collected from natural guayule stands, and plantings have been established for yield tests and seed increases; some plant breeding studies are underway. Significant research also is being conducted to increase guayule rubber yield by treating the entire plant with chemical or bioregulatory agents. Surveys were undertaken to determine guayule distribution and density. The great amount of time, effort and financing that have already gone into guayule research, and the high level of interest in guayule that has been evidenced on an international level all add a weight of their own to drive the guayule development process forward.

B. Constraints

Some national, regional, and, to a small degree, local concerns may inhibit guayule commercialization. These include the economic uncertainties of the program and the funding for it; the incomplete and changing definition of development agencies and potential conflicts between them; land use and land tenure conflicts; incomplete planning at the national and regional level; and environmental concerns.

1. Economic uncertainty: Funding for all aspects of the guayule agroindustrial program comes or would come from federal revenues generated largely by petroleum exports. The unstable oil market and varying profit predictions create uncertainty in budgets of agencies channeling oil revenue into development projects. This uncertainty increases the risk of relying on the federal government as the sole source of funding.

Costs and benefits of the guayule program also are uncertain. It would be developing in a rapidly changing scene. Other regional improvement programs will in part accomplish the socio-economic aims of the guayule program, and some may actually compete with it for the limited resources of the region such as manpower, land, and water. Benefits resulting directly from guayule commercialization are difficult to calculate. Major uncertainties exist regarding the long-term supply and cost of guayule shrub and the price of imported hevea rubber. Current natural rubber prices are well below those predicted a year ago. If hevea prices remain below the cost of producing guayule rubber, every pound produced increases the actual cost to Mexican consumers of the guayule rubber. That is, the industry would have to be subsidized at a time when there is increasing pressure to make all government programs self-supporting, if not profitable.

If the intent of the guayule program is to produce a significant quantity of rubber and reduce the flow of money out of the country, the large amount of machinery and equipment that would probably be necessary for large-scale farming and processing of the shrub should come from domestic sources. If the equipment is not available internally, the cost in terms of the balance of payments of importing substantial amounts of machinery could offset savings from reduced rubber imports.

Economic uncertainty is also a concern at the regional level. The guayule industry has already experienced one boom-bust cycle within the memory of some residents of the northern arid region. Concern over a repeated boom-bust cycle might affect local and regional support for the reintroduction of a program with the inherent uncertainties of shrub supply and rubber market prices. This fear of failure of the program may also affect the individuals and agencies promoting the program. Directing or working in a program that ultimately fails could be career-damaging.

2. Agency interactions: With the change of national presidents, at six year intervals, there is often a major change in personnel and program emphasis, including the creation and dissolution of agencies. The uncertainty of program support by new administrations may decrease support for long range programs. The force of such a constraint would probably depend on the extent to which the program is self-supporting.

Mexico lacks a clearly articulated federal rubber policy, although the country is unique in its large number of potential rubber sources: domestic hevea production; domestic synthetic rubber production based on supplies from a large federally owned petroleum industry; domestic guayule production; and hevea and synthetic rubber imports. Even if guayule is viewed as an important component of the national elastomer supply, the absence of a government directive to integrate guayule rubber development programs into a broader policy may constrain large-scale development.

The complexity of potential agency interactions, even when largely directed by the federal government, presents many opportunities for conflicts between agencies. Competition may arise for program leadership and recognition, and involved agencies may be directing other programs with conflicting needs for limited resources, skills, and funds. The parties-at-interest in guayule development are identified in Chapter VII, the policy analysis section of this report. Agencies' areas of responsibilities, potential overlapping of interests, and possible conflicts are discussed there.

Poor cooperation and lack of confidence between private industry and federal agencies may inhibit guayule commercialization. There is a nearly universal perception of federal inefficiency in operating an industry. Whether other forms of ownership and control are more efficient is debatable, but the perception often creates an adversarial position between government and involved industries. Government and industry are potentially in conflict over processing and marketing policies. Even though the amounts of rubber involved are small, Mexican rubber companies have not been enthusiastic about federal directives to purchase domestically produced hevea rubber because of its highly variable quality. Similar reluctance could be expected if industry does not actively participate in the guayule development program.

3. Environmental concerns: Some uncertainties regarding possible environmental effects of guayule industry operations may constrain its development. The concerns fall into three categories: environmental pollution, resource depletion and trade-offs, and environmental damage (desertification).

The major concerns that have been expressed about potential environment pollution involve the release of process water wastes containing caustic soda (NaOH). If recycling procedures are not implemented until several years after processing starts, as seems likely from current technology, it will be necessary to dispose of large quantities of waste water. Released water could contaminate local surface waters or seep into wells and aquifers.

The solvents used in the extraction process, are both flammable and toxic. Standard recycling procedures should prevent release of significant amounts into the air and into effluent water, and adherance to standard safety procedures should prevent serious accidents. However, concern over undefined methods and potential danger could create resistance to development.

Water supplies in the region are limited. Possible conflicts over its use for processing and in nurseries and irrigated farms could constrain the guayule program.

There is also some concern that a strong drive to increase wildstand harvesting might deplete those populations and lead to destruction of other competing but economically valuable native plants. Displacement to non-guayule land of activities such as grazing might cause over-use of this land, as well, resulting in a decrease in plant biomass and diversity. Dependence on the land and many of its products, rather than reliance on a single source, adds to rural economic stability. Failure of any one income source can bring economic hardship but failure or destruction of an industry on which many had become highly dependent could be disastrous.

V. SCENARIOS FOR THE FUTURE

Two development scenarios are proposed to represent feasible alternatives for developing a Mexican guayule industry: one, Scenario A, is based on harvesting wildstands of guayule and is motivated by social needs; the other, Scenario B, assumes cultivation of guayule in extensive dryland farming operations in order to meet one-third of Mexico's natural rubber demand by 1995. The scenarios are not predictions about development or suggestions about how commercialization should occur. They are designed to give a structure from which to generalize possible impacts, policy conflicts, and policy needs. Inherent in the scenarios is a common set of state-of-society and rubber market assumptions as partially outlined in Tables V-1 and V-2. World and Mexican rubber supply and demand are projected in Table V-3. The sociopolitical, guayule technology, and regional sector assumptions upon which each scenario is based are different for each scenario and are discussed separately in each forecast section.

The two scenarios are intentionally restrictive. Guayule could be harvested or grown in a much larger area throughout its natural distribution. The small Mazapil region was chosen for scenario analysis because impacts resulting from development there, one of the most marginal and economically depressed areas in northern arid Mexico, should be representative of impacts from developing guayule in nearly any part of the guayule zone, although the impacts may be magnified in the Mazapil region. Mazapil is a suitable location already selected for government programs of limited guayule commercialization.

Although many scenarios could be created, examining small-scale and large-scale development possibilities provides reasonable bounds to the study. The range of other possibilities should lie somewhere between the two scenarios that have been developed here in detail. Impacts and policy options relevant to new conditions can be inferred from this technology assessment.

TABLE V-1

SCENARIOS A AND B STATE-OF-SOCIETY ASSUMPTIONS*

- No natural disasters or wars of worldwide dimensions will occur.

- International tensions between major powers and big-small and small-small country conflicts will increase. Political instability in rubber-producing regions in Southeast Asia will continue.

- World population will continue to increase, but the rate of increase will be slower.

- The pressures of population growth and dwindling natural resources will continue to challenge capabilities. Self-sufficiency in basic foodstuffs is a long-term goal. Mexico will remain a net-energy exporter.

- Mexico works toward a more favorable balance of trade.

- OPEC will continue to be a dominant factor in the world economic situation and the price of crude oil will continue to escalate, but at a reduced rate. There will continue to be fears of a worldwide recession.

- The price of Mexican crude oil and products will be pegged to world oil prices.

- Cost of labor will increase and unemployment and underemployment rates will remain high.

- Mexican government and societal institutions will not change dramatically.

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* These assumptions are not intended as predictions, but as a reasonable framework within which to construct the scenarios and provide bounds for the study.

- Growth of the Gross Domestic Product (PBI) in Mexico will be about 8 percent and inflation will continue at or below the current rate.

- The costs of minerals, materials, chemicals, equipment, and all products derived from petrochemicals will increase.

- The annual growth rate of population in Mexico will be about 2.7 percent.

- Shifts to urban centers will continue and rural to urban shifts will become exaggerated.

Scenarios A and B are partially based on the rubber market assumptions outlined below (Table V-2). World elastomer production and future world and Mexican demands are presented in Table V-3.

TABLE V-2

SCENARIOS A AND B
RUBBER MARKET ASSUMPTIONS

- World elastomer demand will increase at an average annual rate of 3.6 percent during the 1980-2000 period.

- Mexican elastomer demand will increase at an average annual rate of 7 percent during the 1980-2000 period.

- Natural rubber consumption constituted 29 percent of the world elastomer market in 1980. The absolute amount of natural rubber consumed will increase, but if no alternative to hevea rubber is available, the natural rubber market share will decrease to 27 percent by 2000. It will constitute 32 percent of Mexican elastomer demand in 1980, declining to 28 percent by 1990.

- World hevea rubber supply will increase at an average annual rate of 3.2 percent during the 1980-2000 period.

- The world natural rubber shortfall, based on a 30 percent market share, is expected to be approximately 0.2 million metric tons (mmt) by 1985; 0.3 mmt by 1990; and 0.8 mmt by 2000.

- Mexico's percentage of world natural rubber consumption will be 1.5 percent in 1980, but will increase to 2.8 percent by 2000.

- Any potential world shortfall of natural rubber which Mexico must share will be made up by a shift to synthetic rubber, produced domestically.

- Mexican natural rubber demand in 1995 will be 140,000 to 160,000 metric tons.

- Natural rubber prices will continue to escalate over the long-term and roughly parallel world oil prices.

- Price and quality of guayule rubber will be competitive with hevea rubber.

TABLE V-3

WORLD AND MEXICAN RUBBER SUPPLY-DEMAND PROJECTIONS

	1980	1985	1990	1995	2000
WORLD					
Natural Rubber Production -- 3.2% per annum growth (x 10^6 MT)	3.8	4.4	5.1	6.0	7.0
Total Elastomer Demand -- 3.6% per annum growth (x 10^6 MT)	12.8	15.3	18.2	21.8	26.0
Potential NR Market Share Percent	29.0	28.7	28.2	27.6	27.1
MEXICAN					
Potential Mexican NR Demand -- 7% per annum growth (MT)	58,000	81,000	114,000	160,000	224,000
Mexican Percentage of World NR Demand	1.5	1.8	2.1	2.5	2.9

A. Scenario A: Wildstand Harvest

The sociopolitical, guayule technology, and regional sector assumptions inherent in Scenario A, harvesting and processing wild guayule, are outlined below. The scenario is developed within the framework of a relatively "surprise-free" set of state-of-society and rubber market assumptions (Tables V-1 and V-2) over a 10-year time period that will allow program planning, implementation, and full-scale operation. It represents a course of events that assumes low technological inputs, no increase in natural stand productivity, no reforestation, no byproduct credit initially, and use of the CIQA aqueous rubber extraction method as described in Chapter III.

SOCIOPOLITICAL ASSUMPTIONS

- Federal research and development funding for guayule will remain at a moderate level.
- The Mexican government provided funds in 1981 through CONAZA to begin an engineering design of a processing facility using the CIQA rubber extraction process to provide 5,000 tons of rubber per year by 1985.
- A guayule agency will be formed to plan, initiate, and manage commercial wildstand guayule production. It will purchase guayule from local ejidos (peasant collectives) at regional collection sites, arrange transportation to the processing facility, process the rubber, and arrange for product sale.
- Guayule development will be consistent with the Global Development Plan, which stresses employment and government and private industry cooperation in development.
- The guayule program is oriented toward increased general productivity and employment and thereby improved health and welfare in the Mazapil region.

- Article 32 of the <u>Ley de Fomento Agropecuario</u> (LFA), a law promoting agricultural development, relaxes restrictions concerning use of ejido land. <u>Ejidatarios</u> (members of ejidos) and communal landholders are allowed to rent to or join in association with "small landholders" to develop their lands.

GUAYULE TECHNOLOGY ASSUMPTIONS

- Seventy-five thousand tons of green shrub (30 percent moisture) will be harvested annually in the Mazapil region, yielding 1 metric ton of rubber per 14.28 metric tons of shrub (30 percent moisture).

- Only plants more than 25 centimeters high will be harvested.

- Shrub harvest will follow a 10-year plant regeneration cycle.

- Relative consumption will be evaluated at the end of five years to determine sustainable levels for the remainder of the program.

- The harvesting system will be similar to procedures established during the mid-1900s. Two people will be able to pull or cut and deliver 580 to 1,135 kilograms of shrub per day. Burros will transport the shrub to the regional collection centers. An average burro load is 70 to 80 kilograms.

- Shrub will be collected daily at 5 to 10 regional collection centers (Figure V-1).

- To provide a daily supply to the processing plant of 275 tons of shrub, a minimum of 450 harvesters and 200 to 500 burros will be required.

- The guayule processing plant will be located in the Mazapil region in or near Cedros, Zacatecas.

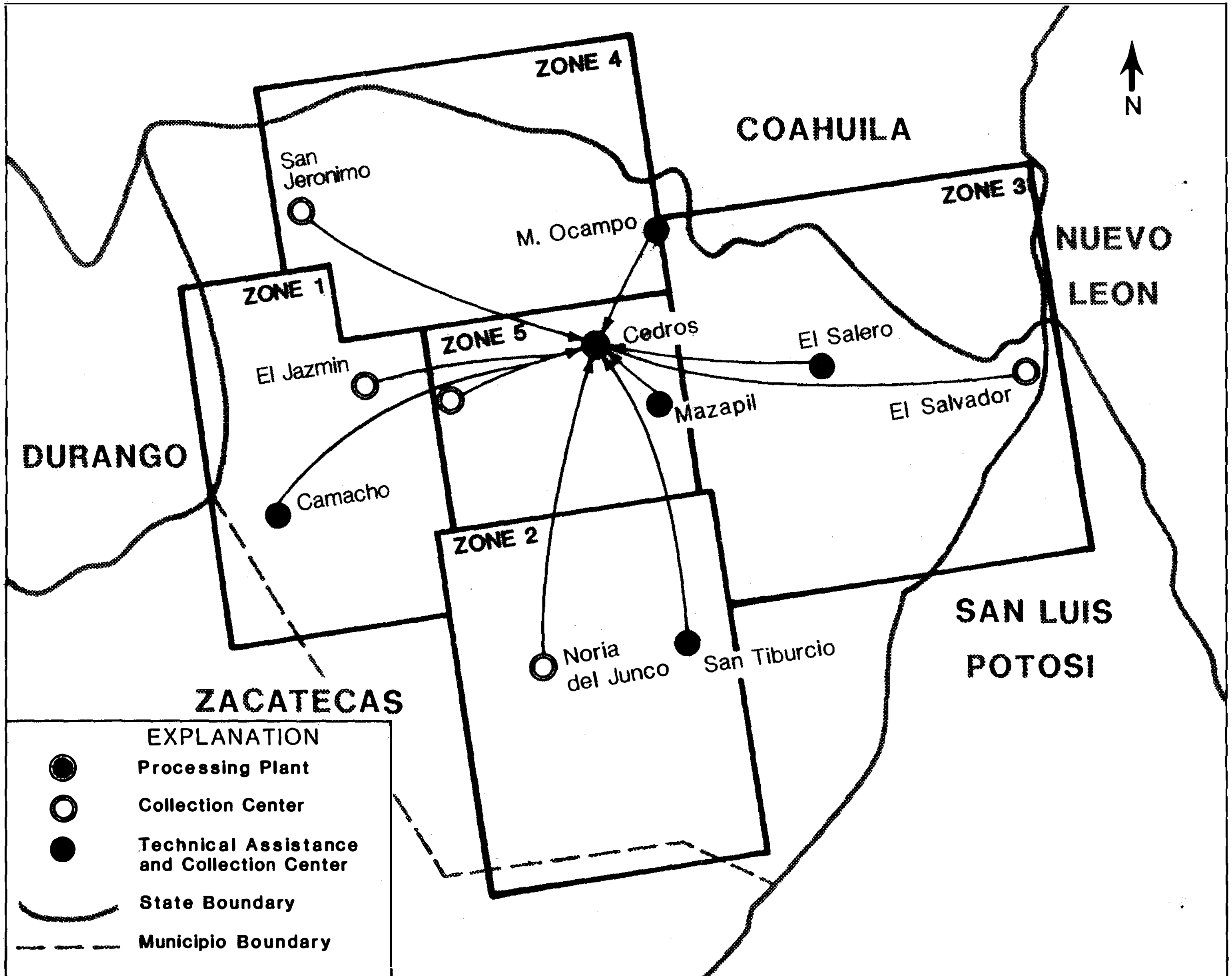


Figure V-1. Wildstand Harvest Zones, Collection Centers and Processing Plant in the Mazapil Region, Northern Zacatecas

- The daily processing capacity of the plant is 237 metric tons of shrub (30 percent moisture) in a 24-hour day, 300-day per year operation, producing 0.69 metric tons of rubber per hour.

- Byproducts will not be used initially, but by 1985 bagasse will be processed to make animal feeds, and purifed resins will be marketed.

- The processing facility will use approximately 58.5 cubic meters of process water and 14.4 cubic meters of steam per ton of processed rubber (0.06 acre-feet water per ton of rubber).

- Improvements in processing will reduce water and caustic soda (NaOH) use and decrease processing cost significantly by the end of this decade.

REGIONAL SECTOR ASSUMPTIONS

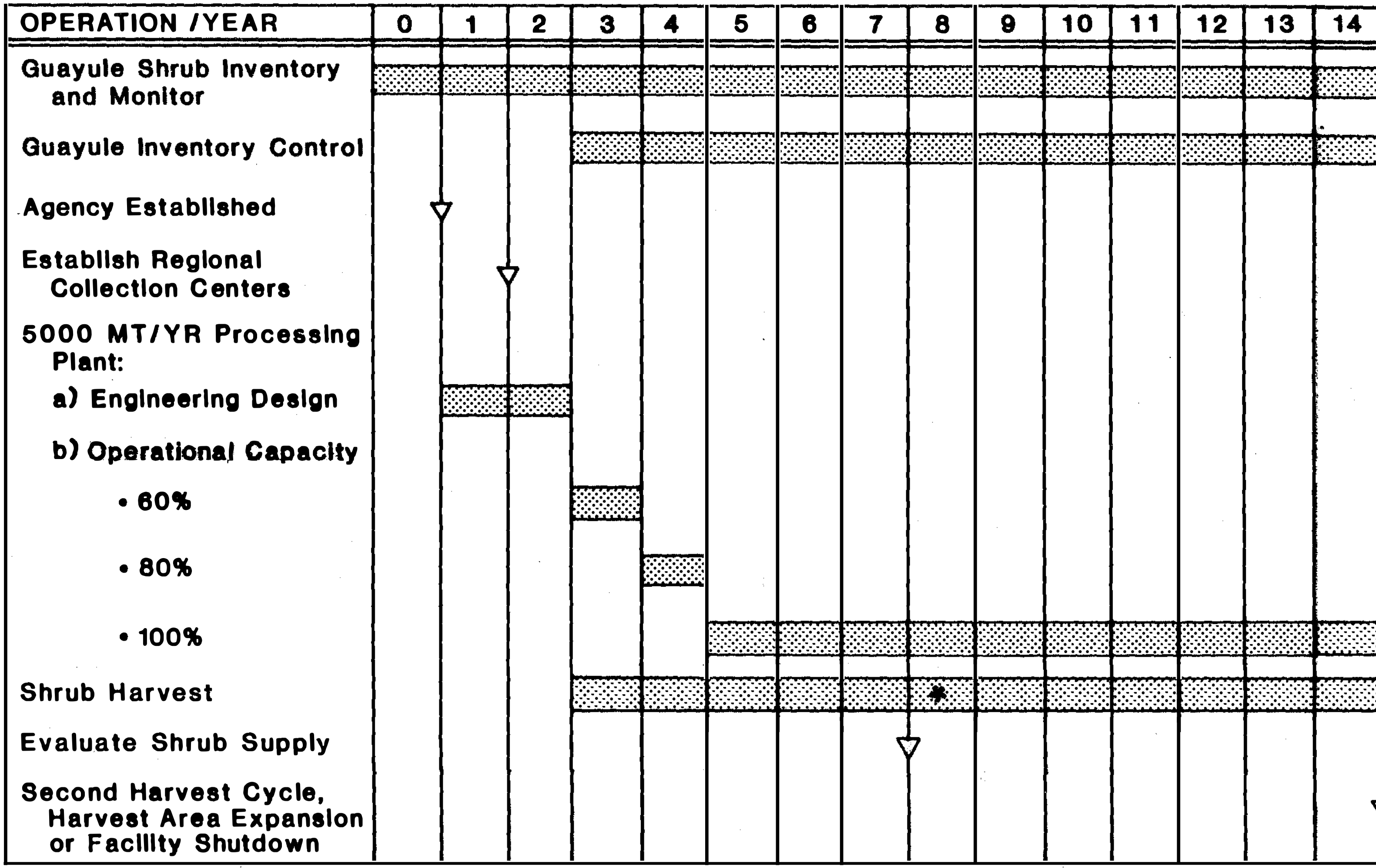
- Ejidatarios will wish to harvest guayule and there will be a sufficient number of workers to harvest the needed quantities of shrub for delivery when it is needed at the processing plant.

- Conflicts between institutions will be solved through political decisions to integrate into one body renewable resources planning and management.

- Wages for unskilled and semi-skilled laborers in Saltillo and Monterrey will not rise faster than the average inflation rate.

- The Mexican Food System (SAM) will begin to develop dryland basic foodstuff production in the region.

1. Timing of the program: Figure V-2 shows the timing for planning and implementing Scenario A. Once the guayule agency is established, it will manage major aspects of the harvest operation. An official guayule shrub inventory will be initiated at the beginning of the program and will be closely monitored through a 10-year harvest cycle. Regional



* Rubber production level may be reduced

Figure V-2. Timing of Program for Scenario A collection centers will be established in years 2 and 3. Construction of the processing facility will begin in year 1 and be completed in the second year after start up. Operation at up to 60 percent capacity will begin by year 3. The plant will be fully operational by year 5. Approximately 75,000 metric tons of shrub will be processed annually for up to ten years. By year 13, 10 years after initiation of harvesting operations, a decision will be made to initiate a second harvest cycle or terminate the program. This decision will be based on the ability of guayule to regenerate for a second harvest within the 10-year period.

2. Jobs and income created: The analysis that follows forecasts the approximate number of jobs and income generated by the guayule industry under Scenario A.

Approximately 75,000 to 80,000 metric tons of guayule shrub (30 percent moisture) are needed per year to produce 5,000 tons of rubber. The amount varies according to the rubber content of the shrub in the field. Table V-4, below, shows the range of person-days of work required to supply the processing facility with shrub to produce 5,000 metric tons of rubber per year. It is based on 300 work days per year. The number of days per year when guayule actually will be harvested will vary according to weather conditions and other factors, and the number of working days may be much fewer than the figure used. In such a case, for the total supply to remain constant, the rate of harvest, the number of harvesters, or the number of hours of harvesting would have to increase. The number of workers employed as guayule harvesters would vary in relation to the number of harvest days; the harvest rate would depend primarily on the density of the guayule stands being harvested.

Approximately 49 man-hours will be required at the processing plant to produce one ton of dry guayule rubber (Motomochi, 1980). On this basis, 102 people, working 300 days, will be required in order to produce 5,000 tons of guayule rubber per year. It is estimated that a total of approximately 700 workers will be employed in guayule wildstand harvesting and processing: 500 in harvesting and 200 in processing and associated work.

TABLE V-4

PERSON-DAYS OF GUAYULE HARVEST PER YEAR
TO SUPPLY 5,000 METRIC TON PROCESSING PLANT

Annual processing plant need of 75,000 MT of shrub
requires 250 MT/day harvested
Annual processing plant need of 80,000 MT of shrub
requires 267 MT/day harvested

Harvest Rate	250 MT/day*	267 MT/day*
100 kg/day	2,500 person-days/day	2,670 person-days/day
180 kg/day	1,389 person-days/day	1,483 person-days/day
500 kg/day	500 person-days/day	534 person-days/day

* Based on 300 workdays per year.

The wage rate for harvesting guayule will be set to equal the minimum wage. Workers at the processing facility will receive, on the average, wages at 30 percent over the minimum wage figure.

3. Costs: A major cost incurred by the guayule agency will be the wages paid guayule harvesters. In addition, processing direct costs for materials, labor, and energy will be approximately $820 (US) per metric ton of rubber. The agency will contract with local truckers to transport shrub between the collection sites and the processing facility. Transportation costs will be based on one cent per pound of rubber, or 2.3 million pesos ($100,000, US) annually.

It is assumed that costs associated with the construction of the processing facility ($13 million, US) will be financed by the Mexican federal government.

4. Infrastructure alternatives: One of the major obstacles confronting an agroindustry dependent upon a wild resource is assurance of timely delivery of specific amounts of raw material. This requires coordination of harvest, materials transportation, and processing. The coordinating group must know the location, the quantity and rubber content of the shrub, and the amount harvested in an area in order to coordinate transportation, establish payment schedules for the shrub, and optimize processing procedures. The coordination and direction of these activities could be divided between the ejido community representatives and the guayule agency, or they could be handled entirely by the agency or entirely by the ejidatarios.

a. ALTERNATIVE 1: This approach allows the ejido community and the guayule agency to work together in developing and carrying out a guayule industry. The agency contracts with ejidos for guayule shrub and assists with some coordination of harvesting activities, while the ejido organization is responsible for the details of the harvest. The agency manages processing and marketing aspects of the industry, and alone has the following responsibilities:

- Scheduling a delivery time-table for a contracted volume of shrub.
- Determining a price for shrub based on rubber content.
- Determining payment of wages and salaries.
- Surveying wildstands to determine average rubber content of shrubs within a specified area and the volume of harvestable shrub.
- Coordinating activities with other involved governmental agencies in the region.
- Transporting shrub from collection centers to processing plant or arranging for transportation by private companies.

- Processing guayule shrub and marketing rubber.

- Contracting for the harvest and establishing quotas with private landowners.

The ejido organization arranges details of harvesting and transporting shrub to collection centers, and has the following responsibilities:

- Organizing and supervising work units.

- Arranging to transport workers to production zones.

The guayule agency and the ejido organization cooperate in:

- Setting quotas of shrub to be cut and scheduling harvest in accordance with area potential.

- Determining location of collection centers.

b. ALTERNATIVE 2: The agency recruits salaried workers and organizes all aspects of harvest, transport, and processing. This alternative seems improbable because of the difficulty of recruiting and organizing workers without the cooperation of the local ejidatario organizations, but offers advantages in harvest control and planning, wage control, and negotiations with private landowners.

c. ALTERNATIVE 3: Organization and supervision of workers and all harvest, transport, and processing activities are carried on via an inter-ejido cooperative mechanism. It seems unlikely that the degree of cooperation necessary for conducting and managing all aspects of the harvest-transport-processing chain of activities could be achieved at the ejido level alone, particularly the processing aspects, which would be an entirely new ejido activity. Also ejido control of processing activities could create conflicts with private landowners.

5. Summary of Scenario A: Scenario A is motivated by social needs. It is designed around a modest set of social and economic improvement targets that require only low level improvement in existing regional organization and management. No extensive research and development is needed, and the existing infrastructure used in current native plant harvesting and marketing requires only modest expansion to accomodate the needs of commercial wildstand guayule harvesting. Current practices in the commercial utilization of wild plants are organized on the individual level in the harvest, processing, and marketing sectors; guayule commercialization requires more organized and coordinated harvesting, transportation, and processing systems than do the candelilla and ixtle industries. The greatest changes in existing patterns would be the use of a machinery and capital intensive processing facility for guayule and greater coordination of harvesting with processing. The amount of rubber to be produced under Scenario A is a small fraction of the national rubber demand (Figure V-3).

Guayule commercialization in this scenario is considered from the perspective of a sustained yield from wildstands, the facility needed to process the rubber, and the employment opportunities associated with this development. The organizational structure defined in Alternative 1 is presumed to be the most likely method. The timetable for developing Scenario A was presented in Figure V-2. Based on the assumed number of jobs created and costs (Table III-10), the increased community income would be as follows (peso value in 1979):

Shrub cost to supply 5,000 MT/yr plant (75,000 MT at $13.50 US/MT)	$54.3 million pesos/yr ($2.36 million US)
Wages for processing plant personnel ($13.64 US/MT rubber)	$1.6 million pesos/yr ($68,000 US)
Total	$55.9 million pesos/yr ($2.4 million US)

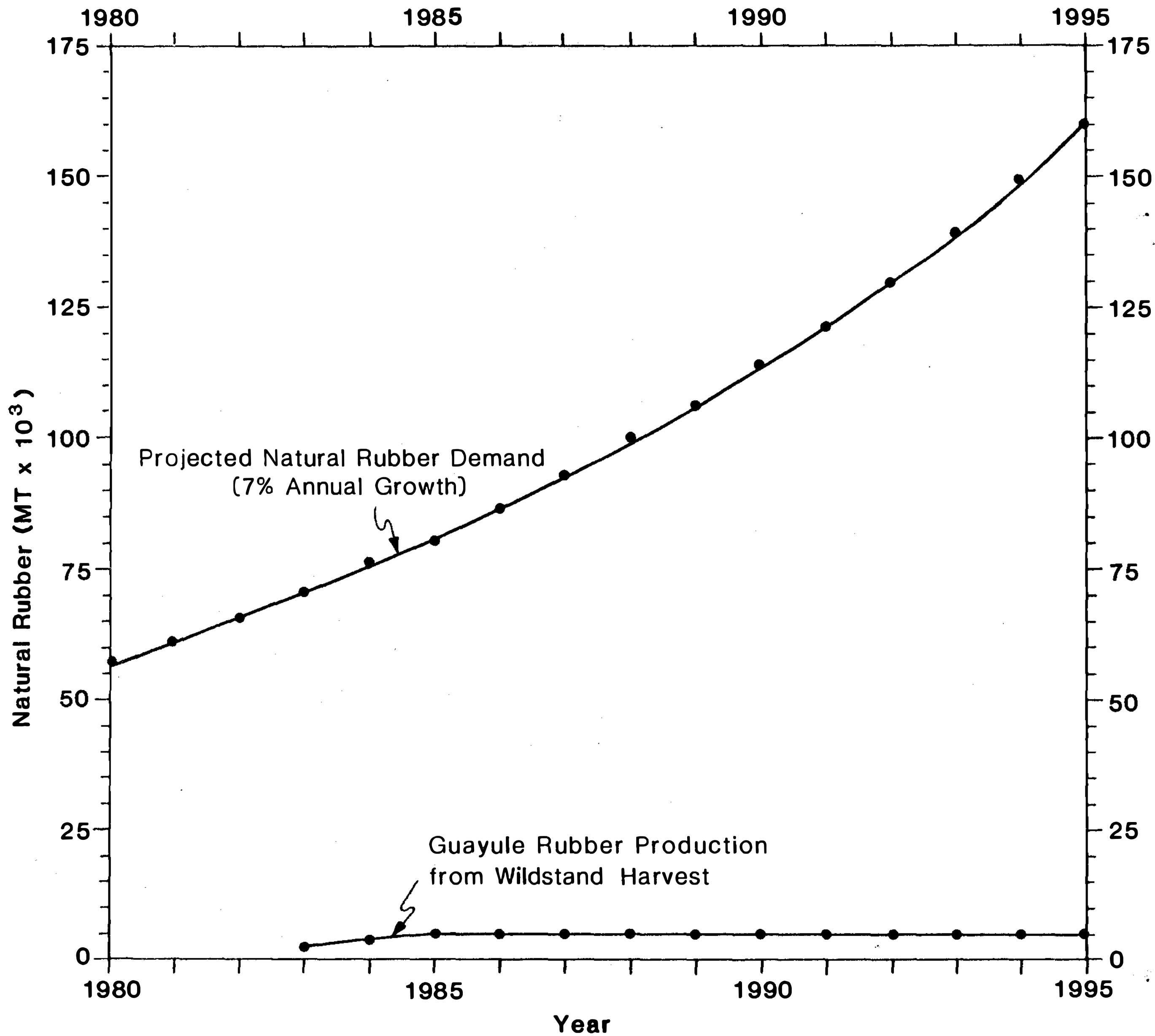


Figure V-3. Guayule Rubber Production in Scenario A Compared to Projected Mexican Natural Rubber Demand

The $55.9 million pesos per year in wages is a minimum figure for increased community income generated by guayule commercialization, because it does not include secondary income derived from support services and the cascade effect of money spent in the region. Also, not all of the income is "new" income because jobs in the guayule industry represent to an unknown degree displacement of part-time work in farming, native plant harvesting, and non-paying maintenance jobs such as road and fence repair in the community. All the activities that the workers forego to participate in the guayule industry represent lost income to the community or community service jobs that must be completed later.

Current estimates of processing costs indicate that guayule rubber will cost $.91 per kilogram (or $.41 per pound) to produce. Of that total, guayule shrub cost is $.27 to $.36 per kilogram (30-40 percent) (Motomochi, 1980). The remainder is processing cost. If the rubber sells for $1.43 US per kilogram ($.65 US per pound), a 5,000 MT per year facility will generate $7.2 million (US) gross income and $3.1 million (US) net profit ($71.4 million pesos). This does not include processing facility cost. Figure V-4a shows the relationship between rubber prices and processing plant production capacity needed to break even with a production cost of $.91 US per kilogram ($.41 per pound). Capital costs and profit are considered in Figure V-4b which shows the rate of return and time required to pay off plant capital costs in relation to various prices harvested for guayule shrub. Cost is figured as price per pound of rubber (30 - 40 percent of total production cost).

B. Scenario B: Stimulated Development of Guayule Farming

State-of-society assumptions and rubber market assumptions common to both scenarios were listed previously in Tables V-1 and V-2. In addition, Scenario B assumes that guayule rubber plays an important role in the Mexican rubber plan to produce domestically a significant fraction of Mexico's total natural rubber demand and thereby bring about a more favorable balance of payments. Guayule is considered to be important in

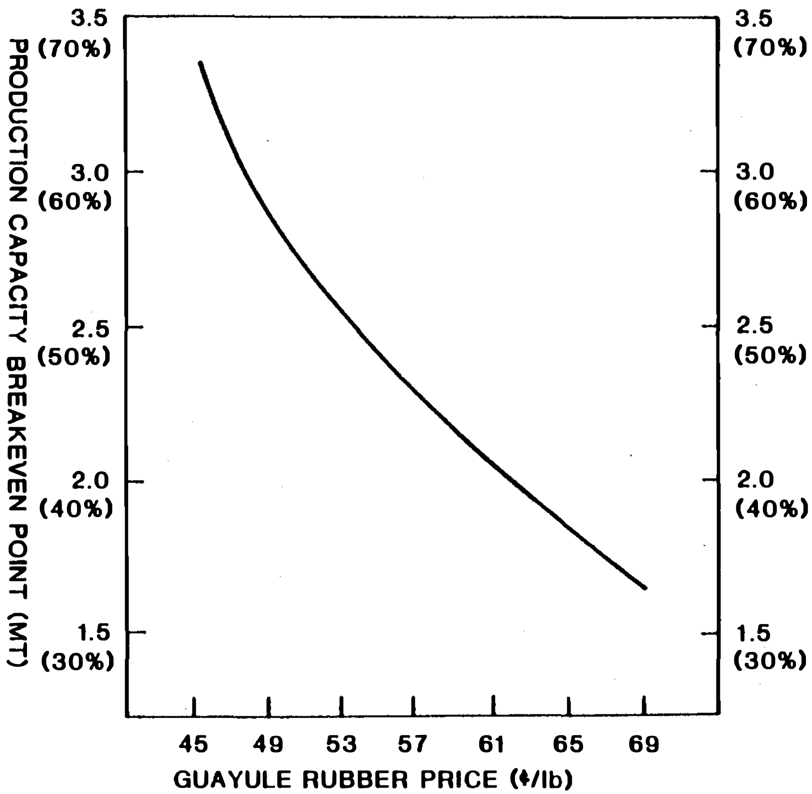


Figure V-4a. Sensitivity of Production Capacity Breakeven Point to Guayule Rubber Price

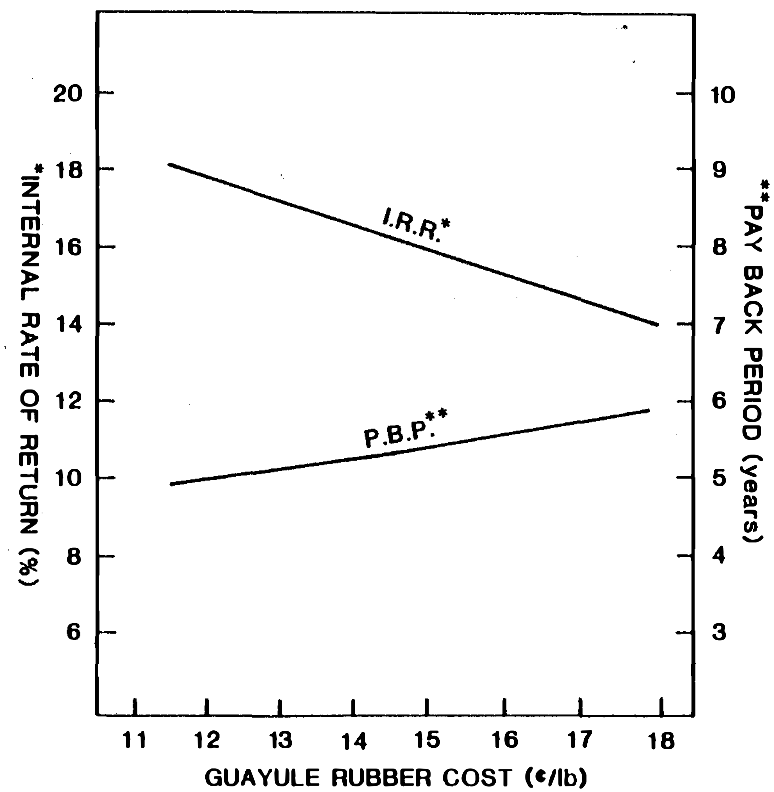


Figure V-4b. Sensitivity of Internal Rate of Return and Payback Period to Guayule Rubber Cost

Source: Motomochi, 1980

Mexican economic development over the next 20 years. Oil revenue is expected to continue to spur rapid growth of the Mexican economy and to stimulate expansion of the national rubber market at an annual rate of between 7 percent and 10 percent, corresponding to the current growth rate and projections following the National Industrial Development Plan and growth of the PBI.

Scenario B, the rapid development of commercial dryland guayule farming and sustained wildstand harvest, is based on the following set of sociopolitical, guayule technology, and regional sector assumptions:

SOCIOPOLITICAL ASSUMPTIONS

- Government and private research and development activities and funding will increase substantially.

- Guayule rubber will provide about one-third of Mexican demand for guayule rubber by the mid-1990s. Many of the following assumptions are designed to achieve this production goal.

- The guayule project is oriented toward relatively high volume rubber production and increased regional employment and productivity.

- The guayule project is part of a program to reduce imports of material that can be produced internally, thereby decreasing the flow of money out of Mexico.

- A guayule agency will be formed to plan, initiate, and manage wildstand guayule production monitoring and reforestation, and dryland farming. The guayule agency will purchase guayule from organizations of landholders at regional collection sites and arrange transportation to the processing facility.

- Production of guayule rubber will be supported by limited wildstand harvest in the Mazapil region (Figure V-1) and by new dryland farms in five zones in northern Zacatecas (Figure V-5).

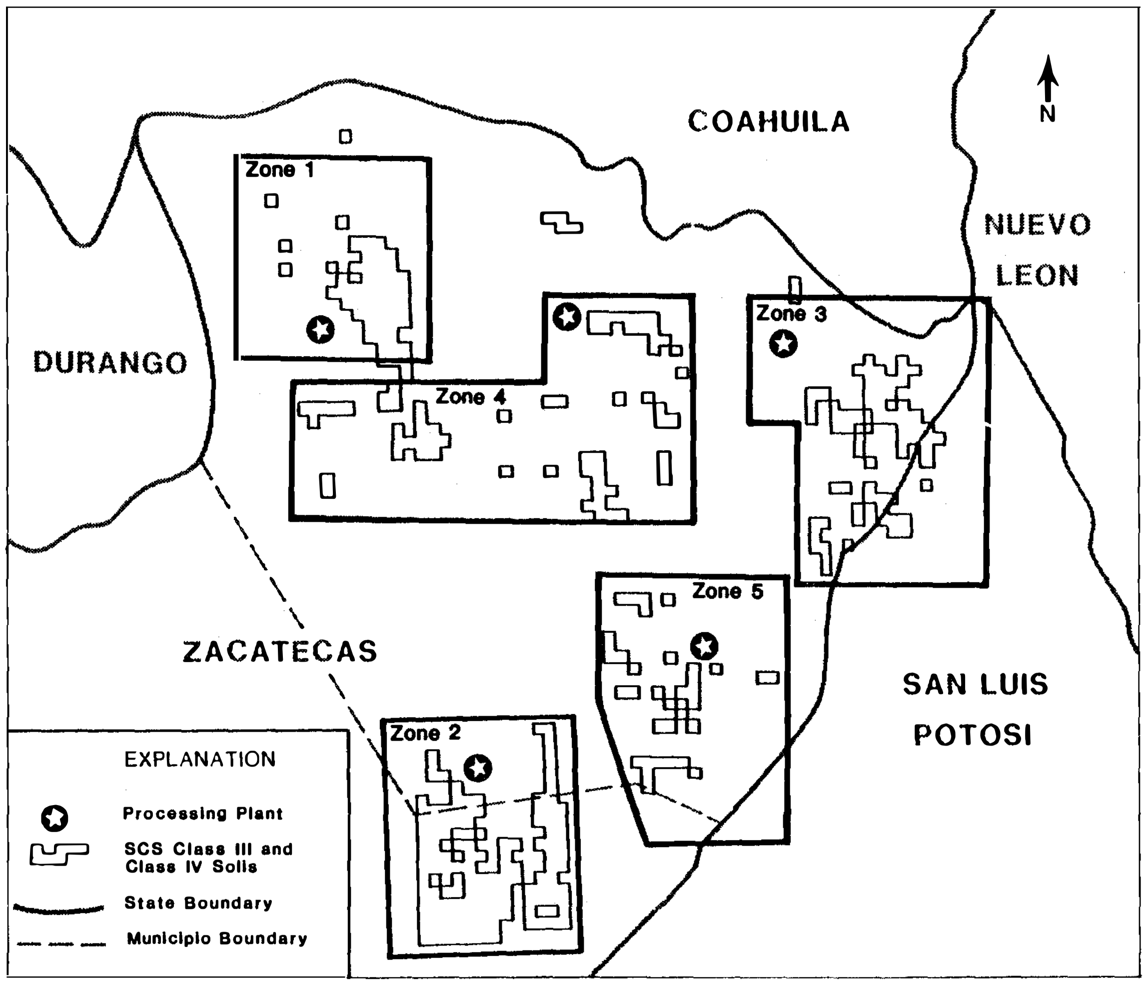


Figure V-5. Possible Guayule Dryland Farm Zones and Processing Plants

- Wildstand utilization will include reforestation and management to sustain continuous production to supply a 5,000 MT/year processing plant.

- Harvesting, transporting, and processing wildstand shrub will be carried on in the same manner as in Scenario A.

- Article 32 of the Ley de Fomento Agropecuario relaxes restrictions concerning use of ejido land. Communal landholders are allowed to rent to or join in association with "small landholders" to develop their lands. Large unified production blocks of land may be formed by combining, under agreement, scattered private and ejido lands.

- New dryland guayule farming will compete for land and materials with existing and proposed SAM food crop farming and will compete minimally for irrigation water to supply nurseries or greenhouses. The new farms will be developed on marginal lands.

- Dryland farming of guayule will occur on up to 200,000 hectares in the Mazapil region in any or all of five production zones (Figure V-5).

- The Mexican government will supply the initial capitalization for farm and nursery development.

- The Mexican government will fund the engineering design and construction of the processing plants. The CIQA extraction process will be used, with improvements and refinements adopted as they are developed.

GUAYULE TECHNOLOGY ASSUMPTIONS

- Guayule will be harvested on a five-year cycle with an assumed average rubber accumulation of 0.22 metric tons per hectare per year (200 pounds per acre per year) or 1.1 metric tons per hectare per harvest (1,000 pounds per acre per harvest).

- Average rubber production is 10 percent of dry shrub weight.

- Seedlings will be planted at a density of 24,000 per hectare (9,700 per acre).

- Seed initially will be collected from wildstands, but starting in the third planting year, seeds from plantations and developed varieties will be used.

- Five processing plants will be required to transform the shrub into rubber: one at Cedros, with a capacity of 5,000 metric tons of rubber per year for wildstand harvest; and four with an individual capacity of 10,000 metric tons of rubber per year, each located in one of the four remaining growing zones in the Mazapil region (Figure V-5).

- Byproducts of guayule procesing will include purified resins, animal feeds manufactured from the bagasse, and bagasse biofuels.

- Processing methods will improve to allow: 1) recycling the process water and caustic soda, reducing water use 55 percent and NaOH use 50 percent; 2) improved purification, deresination, and latex coagulation, reducing water use by 10 percent; 3) processing shrub by compression-decompression, enhancing recovery of resins and rubber; 4) chemical conversion of bagasse for biofuels; and 5) production of new, modified rubber at the plant site.

REGIONAL SECTOR ASSUMPTIONS

- Ejidatarios will wish to harvest guayule and there will be a sufficient number of workers to harvest the needed quantities of shrub for delivery when it is needed at the processing plant.

- Conflicts between organizations will be solved by government, political, and institutional arrangements.

- Wages for unskilled and semi-skilled laborers in Saltillo and Monterrey will not rise faster than the average inflation rate.

- The Mexican Food System (SAM) will begin to develop dryland basic foodstuff production in the region.

- Zacatecas, and the Mazapil region in particular, are targeted for widespread public sector assistance from arid and marginal zone development agencies. COPLAMAR, in conjunction with other federal agencies (SARH, SEP, SAHOP, CONASUPO, and IMSS), will direct extensive infrastructure development in the area. Improvements in the transportation, energy distribution, health systems, and other basic areas will stimulate more expansion and create more jobs in mining, farming, and the service sector.

- The guayule program (SAIG), as part of a much larger regional development plan, is intended to be the catalyst for greater rural economic infrastructure development.

1. Timing of the program: The processing plants will be developed according to the schedule in Figure V-6. Development of processing plant products and technology will be targeted on the following schedule: year 1, production technology for guayule rubber and research into use of byproducts; 1985, production of guayule rubber, resins, and animal feeds from bagasse; recycling process water and caustic soda; improved purification, deresination, and latex coagulation; 1989, improved shrub processing by compression-decompression; bagasse conversion to biofuels; production of new, modified rubbers.

Development of product distribution systems after processing plant start-up will follow the schedule below:

Year 3 - Establishment of guayule rubber distribution channels
Year 5 - Establishment of distribution channels for resins and bagasse protein derivatives
Year 9 - Establishment of distribution channels for modified rubber products and bagasse biofuels

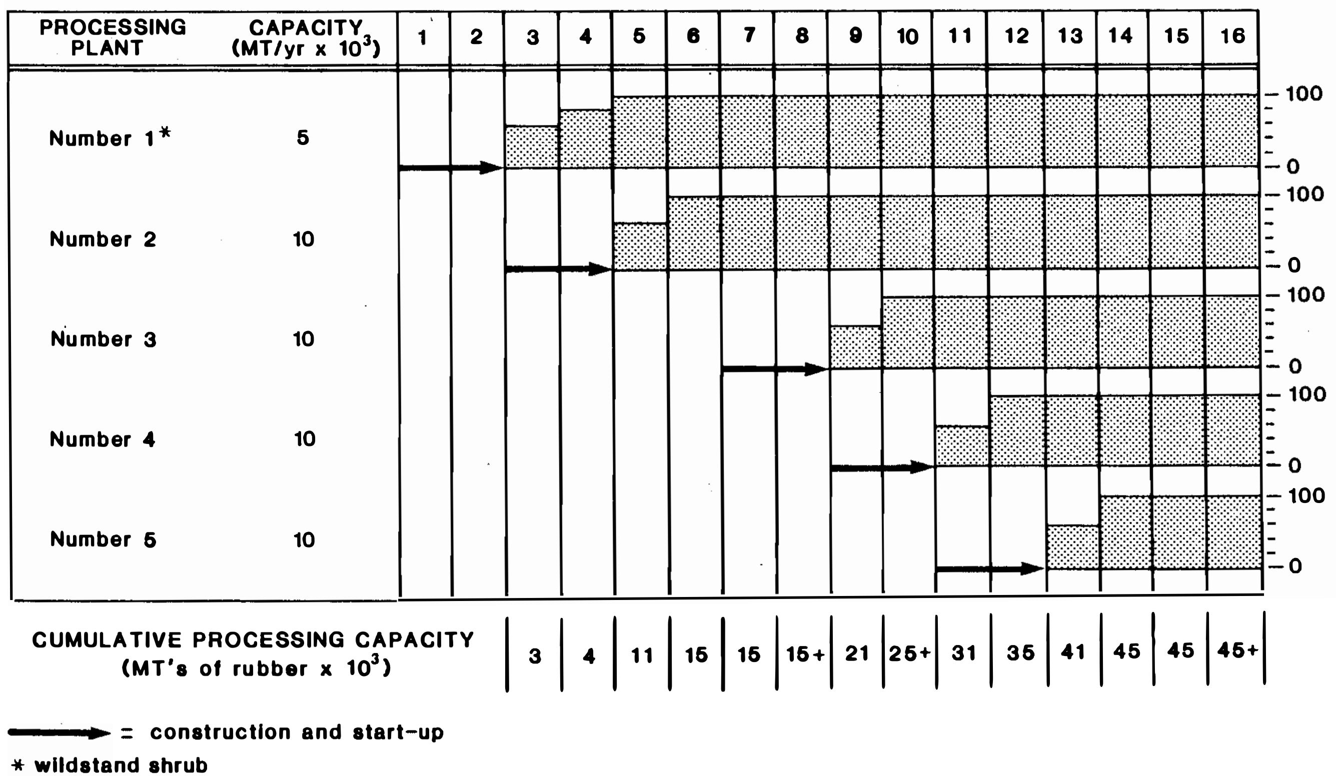


Figure V-6. Schedule for processing plant development and cumulative processing capacity

Cumulative processing capacity is shown in Figure V-6. This plan is designed to complete a processing capacity of 45,000 to 50,000 metric tons of rubber per year by the mid-1990s. Assuming an average yearly rubber accumulation in the shrubs of 224 kilograms per hectare (200 pounds per acre) over a period of five years in dryland cultivation, a schedule (Table V-5) was devised to coordinate planting and harvesting with the development of the processing capacity. Implicit in this coordinated scheduling is the initial and continuing harvest of wildstand guayule to produce 5,000 metric tons of rubber per year. It is assumed that continuity of the wildstand harvest is assured through a reforestation program.

TABLE V-5

DRYLAND PLANTING AND PRODUCTION SCHEDULE

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Hectares Planted (Replanted) X 10^3	5	9	9	9	14	18 (5)	23 (9)	27 (9)	32 (9)	36 (14)	36 (18)	36 (23)	36 (27)	36 (33)	(36)	(36)	(36)
Hectares Harvested X 10^3						5	9	9	9	14	18	23	27	32	36	36	36
Cumulative Hectares Planted X 10^3	5	14	23	32	46	59	73	91	114	136	154	167	176	179	200		

Assumptions: Production 224 kg/ha/yr (1.12 MT/ha/harvest) (200 lb/ac/yr) dryland farms
Production 5,000 MT/yr rubber from wildstand harvest in reforestation system.
Assume 98% extraction efficiency -- numbers are rounded off.

2. <u>Materials requirement for seedling production</u>: Seedling production will be required in order to plant the guayule farms as proposed in Table V-5. Most seedlings for guayule production will be grown in nurseries in the production zone. A typical nursery, as laid out by ERP researchers (U.S. Forest Service, 1946), has beds 4 feet by 400 feet, with 2-foot aisles. There are 18 beds per acre and in each bed 40,000 seedlings are germinated. The number of seedlings per bed is

later reduced to 32,000 seedlings by culling weak plants. On this basis, one hectare of nursery would germinate 1.8 million seedlings. After culling, the number of seedlings per hectare would be reduced to 1.42 million seedlings. Assuming a planting density of 24,000 shrubs per hectare (9,700 per acre) on guayule farms, one hectare of nursery will supply 59.4 hectares of production shrub. However, field survival is expected to be less than 80 percent. If a 100 percent stand is desired, some replanting would be necessary. The farming area that could be supplied per hectare of nursery depends on the number of seedlings that survive the initial planting and decreases as shown in Table V-6.

Using the production schedule in Table V-5, nursery space needed for seedling production to meet the schedule is calculated and shown in Table V-6 and V-7. Seed production can be met by harvesting seed in nurseries. Until sufficient experience is gained in seed and seedling production, the actual production may be somewhat lower than these figures show.

There are no available figures on nursery production of guayule seedlings, but it is safe to assume that the unit cost would be lower than for greenhouses since both capital and labor costs would be lower. Because of the low capital requirements of nurseries and the large number of jobs created to service them, it is assumed in this scenario that a number of small nurseries will be built near production areas.

3. Jobs and income created: Commercial guayule rubber production will be directly responsible for the creation of new jobs in six sectors:

- Wildstand production
- Seedling production
- Dryland farm production
- Processing
- Administration and monitoring
- Research, development and agricultural extension.

TABLE V-6

NURSERY AND SEEDLING REQUIREMENTS PER HECTARE OF GUAYULE FARM

Survival of Initial Planting (Percent)	Hectares Planted / Hectare Nursery (100 percent final stand)	Seedlings/Hectare to Achieve 100 Percent Stand
100	59.4	24,000
95	56.4	25,200
90	53.5	26,400
85	50.5	27,600
80	47.5	28,800
75	44.6	30,000

TABLE V-7

LAND REQUIRED FOR GUAYULE SEEDLING PRODUCTION

Year	Required Farm Production (Hectares X 10^3)	Seedling Production Nurseries* (Hectares)
1	5	105
2	9	190
3	9	190
4	9	190
5	14	295
6	18	379
7	23	484
8	27	569
9	32	674
10	36	758
11	36	841

* Assuming 80 percent transplant survival rate.

The nature of the jobs and a qualitative assessment of manpower needs are shown in Table V-8. The rate of increase in jobs will parallel the development schedules shown in Figure V-6 and Table V-5. There will be a regular employment increase as production and processing capacity grow to their maximum in the 1990s. Most jobs in farm production and processing will be permanent and full-time. Processing will continue all year and because of the limited storage period for harvested shrub, harvesting will have to be conducted throughout the year as weather permits. Transplanting of nursery stock will be seasonal, because the seedlings will have to be planted in the field at the beginning of the rainy season when the soil will be moist long enough to allow seedling establishment without irrigation. Many of the jobs that require a large temporary labor force could be filled by transferring people between different sectors in the program. The one major task that will require a large amount of temporary labor is construction of the processing plants. Many of these jobs will require specially skilled workers that would probably be brought in from a large city outside the area.

TABLE V-8

QUALITATIVE ASSESSMENT OF MANPOWER NEEDS

Job Area	Seasonal	Full-Time	Temporary	Labor	Foreman/Supervisor	Technical	Administrative
Wildstand Production							
Harvest	x			x	x		x
Reforest	x			x	x		
Seedling Production Nursery							
Establish & Maintain		x			x		
Harvest	x		x	x	x		
Dryland Farm Production							
Production	x			x	x	x	
Harvest	x					x	
Industrial Processing							
Construction			x	x	x	x	
Operation	x				x	x	x
Administer & Monitor	x						
Agricultural Extension		x				x	

Estimating the number of jobs created in each sector is difficult due to the lack of previous experience with guayule farming and the numerous alternative methods of achieving the same results in the program, especially considering the possible mixes of labor-intensive and machine-intensive agricultural procedures. The following tentative estimates were based largely on recent experimental work and past ERP experience. At the start of production the number of jobs created is estimated to be 570 for farming and 500 for wildstand harvest. At the highest level of production, with all processing plants operating at maximum capacity, the total number of jobs is estimated to be 4,665. Jobs created at the start and at maximum production fall into six categories:

	Start-up	Maximum
Nursery establishment and maintenance of seedlings	168	1,346
Seedling transplant and field establishment	210	1,683
Farm production	50	360
Farm harvest (machinery intensive)	18	130
Processing	125	575
Wildstand harvest	500*	-
Agricultural extension	?	?
Processing plant construction	?	?

* approximate

If seedling production pays the minimum wage (in 1981) of 150 pesos per day and farm work and processing pay 195 pesos per day (minimum wage + 30 percent), annual wages total $640,000 US to $6.1 million US in production and $224,000 US to $1 million US in processing.

4. Costs: Guayule dryland farm development and maintenance, processing development, and operation are capitalization costs to be paid by the Mexican government. These costs suggest several policy options for repayment and subsidy and for targeting income and jobs.

5. Infrastructure alternatives: Rapid development of the guayule industry as presented in Scenario B requires considerable mechanization to meet seedling harvest and planting schedules; intricate and highly interdependent seedling production, shrub production, and processing sectors; and highly mechanized and complicated processing. This necessitates strong government involvement in organizing, operating, and coordinating the project. To what extent industry and local citizens are involved in operation and ownership is the major variable. Several alternatives are possible:

a. ALTERNATIVE 1. Several government agencies coordinate their activities to operate all aspects of farming, processing, and seedling production. The operating level of wildstand harvest and reforestation would be controlled by local peasant organizations and coordinated with the government agencies' activities. Transportation of shrub, rubber, and byproducts would be arranged by government agencies. Numerous government agencies are already engaged in developing some aspects of the infrastructure needed for the guayule program, and they would likely continue on an expanded scale to meet the needs of the guayule project. Ownership would lie entirely with the government, and all workers would be paid a salary or wages.

b. ALTERNATIVE 2. In this approach, industry would share in the ownership of the project and would operate the processing plants and market the products and byproducts. Such an arrangement already exists with Hules Mexicano, in which private interests own most of the stock in the company, and Petroleos Mexicanos (Pemex), a federally owned company, owns the remaining portion. Such an arrangement ties government concerns for national and social benefits to industrial efficiency. Wages and salaries would be paid to workers, but revenues would be divided between the government and the private company. The guayule agency would have a director independent of government and industry who would report to a board of directors representing involved government agencies and industry.

c. ALTERNATIVE 3. This approach is similar to Alternative 2 but would add partial ownership of the agency by ejido communities involved in wildstand harvest, reforestation, and farming. The ejido representative would sit on the board of directors. Workers would be paid salary and wages, but in addition there would be a share of the profit paid to the participating ejidos.

6. Summary of Scenario B: The stimulated commercialization scenario assumes substantial government assistance that initiates, supports, and coordinates sustained wildstand harvest, dryland crop production, and processing. Intensive research and development leads to technological advances in primary and secondary product processing.

Guayule production is targeted at supplying one-third of the Mexican natural rubber demand by the mid-1990s (Figure V-7). In order to meet this goal, up to 200,000 hectares in the Mazapil region are allocated to dryland guayule farming. In addition, a program of wildstand harvest and reforestation is initiated. To meet the production goal of 45,000 to 50,000 metric tons of guayule rubber per year, five processing plants are constructed over a 14-year period: one 5,000 metric tons per year facility at Cedros to process the wildstand harvest; and four 10,000 metric tons per year facilities in four other production zones (Figure V-5). Product distribution systems are also developed.

An estimated total of 700 hectares in the guayule dry farming zones will be used for nurseries. One hectare of nursery is expected to produce 1.42 million seedlings and thus will supply shrubs for 59.4 hectares of farmland planted at a density of 24,000 shrubs per hectare (assuming 100 percent survival).

Dryland farm harvest will be on a five-year cycle, but dryland and wildstand harvesting will be conducted throughout the year, as weather permits, to maintain a continuous supply for the processing plants. Transplanting nursery stock to the farms will be done seasonally.

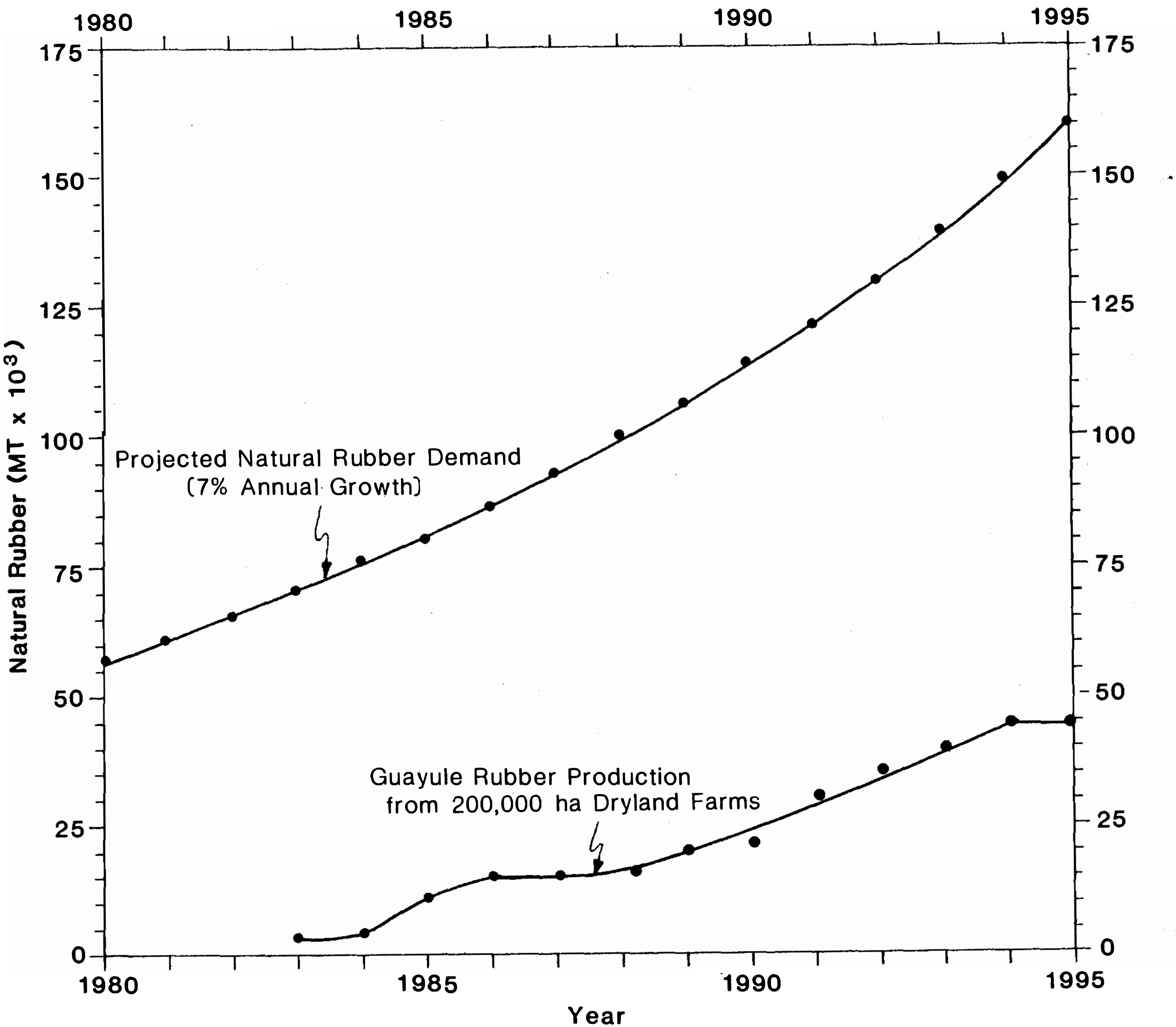


Figure V-7. Guayule Rubber Production in Scenario B and Projected Mexican Natural Rubber Demand

The total number of jobs directly created by guayule commercial production in Scenario B is estimated to be 571 in farming, 450 to 500 in wildstand harvest, plus an undetermined number of construction jobs at the start of the project, increasing to 4,665 in farming, 450 to 500 in wildstand harvest, plus construction jobs at the time of maximum production.

Since guayule farm production and shrub processing costs in Mexico are not known, net direct value from the project cannot be calculated. However, total gross value of the rubber and direct wages can be estimated. If rubber sells at $1.43 US per kilogram ($.65 per pound), annual rubber sales of 50,000 metric tons will gross $64.4 million US. Some predictions place rubber prices in the 1990s between $1 to $2 US per pound. In that case, total direct wages could exceed $7 million US.

CHAPTER VI. IMPACT FORECAST OF GUAYULE COMMERCIALIZATION

An important objective of a technology assessment is to enhance decision-making by determining a range of impacts of alternative courses of action. Two scenarios for future development in the guayule growing regions of Mexico were presented in Chapter V. These scenarios, based on guayule rubber technology as discussed in Chapter III, described two pathways for commercial guayule development. This chapter discusses the potential impacts of development under each scenario.

Efforts were concentrated on determining the impacts on the Mazapil region of northern Mexico. The area is typical of the Northern Arid Region (NAR) where guayule grows wild, so that development impacts in the Mazapil should be representative of those that might occur anywhere in the NAR. However, the Mazapil region is one of the most economically deprived areas, so impacts there will probably be magnified. The Mazapil has a history of commercial use of guayule, and it is a region where future guayule development could occur. Guayule exploitation may become an important component of development programs to meet the social needs of that area.

Present social, economic, and environmental conditions in the Mazapil region were reviewed. Regional data examined include:

- Demographic information including current population characteristics, age, and sex distribution;
- Economic characteristics including the size, general composition, and characteristics of the labor force;
- Community services including health, education, and other services and facilities within the community; and
- Environmental characteristics.

The focus of the study was on the nature and size of current economic activities in the region. The levels of employment, unemployment, and underemployment were examined and external factors influencing the economy of the region were explored. These include forces which draw people out of the area on a temporary or permanent basis.

The information that was gathered was used as a basis for examining the potential impacts of guayule production under the two scenarios. The forecasts for alternative futures in the guayule region were based on socioeconomic studies completed by CIQA, CONAZA, and CIDER (Martinez and Bolanos, 1979; CONAZA, CONACYT, and CIDER, 1979; and Camau, 1979), other information from Mexican government agencies, and projections based on this data. In addition, results of an impact evaluation meeting, the second of three workshops held with Mexican federal and local agencies representing the various involved parties, was devoted to impact evaluation (see Appendix A).

Much of the information in the following profile is drawn from a comprehensive summary compiled from many federal sources (CONAZA, CONACYT, AND CIQA, 1981). The impacts of current trends described in the regional profile are analyzed, then compared with projected impacts under Scenarios A and B. By using this approach, "net impacts" of commercialization can be examined as illustrated in Figure VI-1.

A. Regional Profile: Mazapil Region

The Mazapil region, in the southern portion of the NAR (Figure VI-2), encompasses an area of about 20,000 square kilometers. It is divided into five municipios*, four in Zacatecas and one in Durango. The NAR is located within the area usually defined as the Chihuahuan Desert. The region is mostly rural, but is surrounded by a number of large cities such as Monterrey, with a population of 2 million, and Saltillo, Torreon, and San Luis Potosi, each with a population over 200,000.

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* A municipio is similar to a county in the United States.

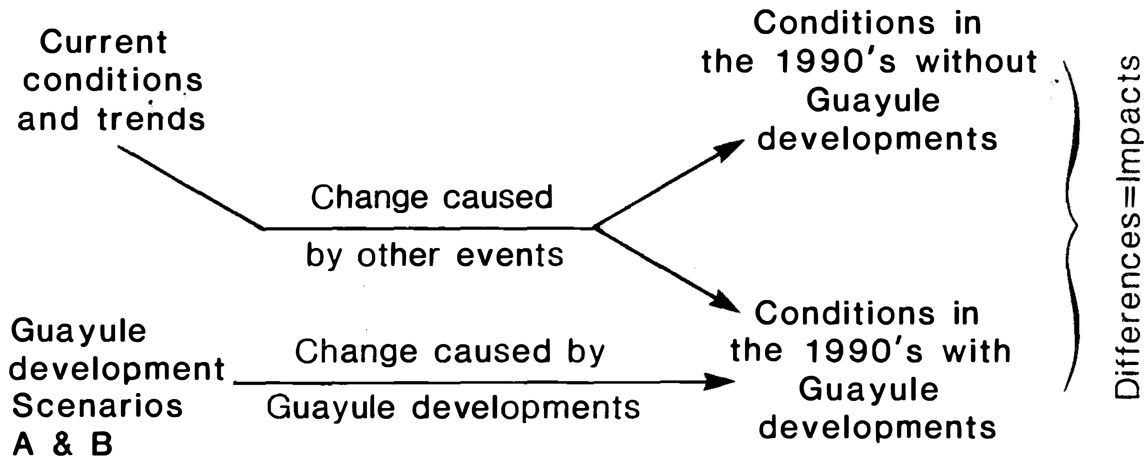


Figure VI-1. Projecting Net Impacts of Guayule Development

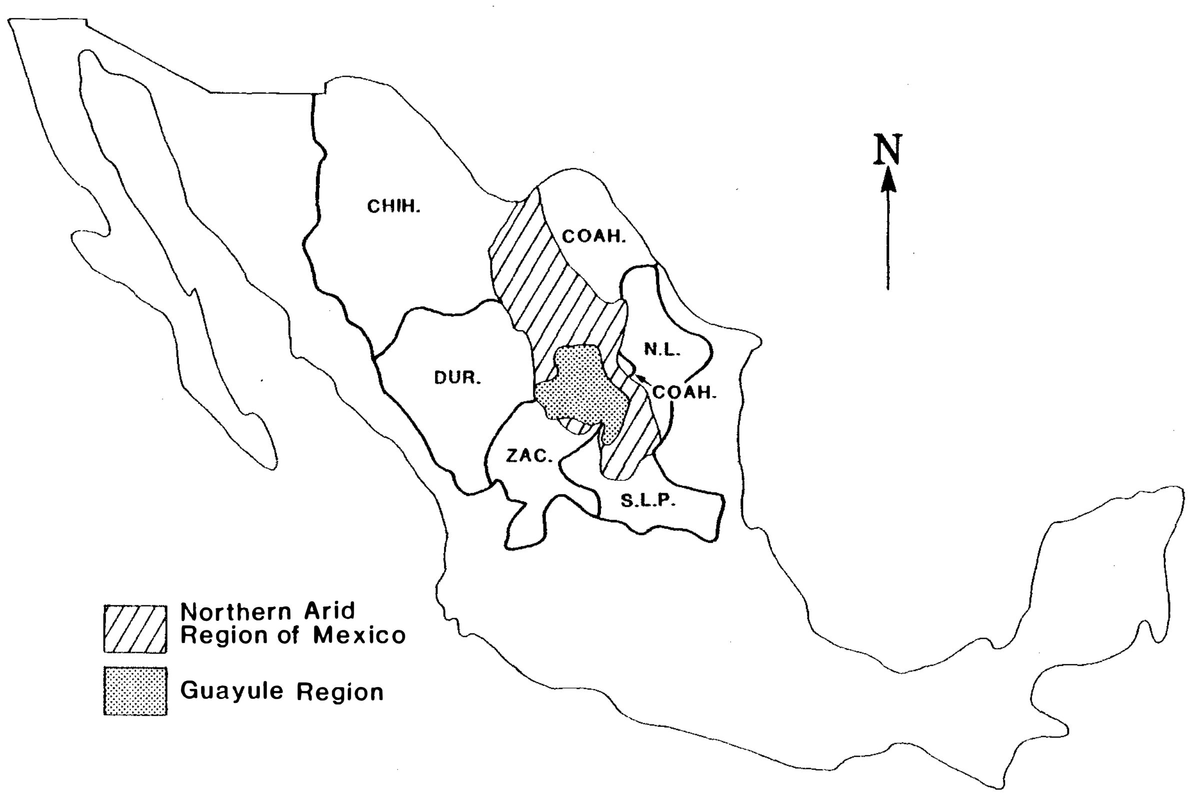


Figure VI-2 Location of the NAR and Guayule Region in Mexico

The population of the Mazapil region is small, dispersed, and declining. The 1970 population of 61,000 had decreased 0.1 percent by 1977. The area is characterized by low income, few economically rewarding opportunities, substandard housing, few basic community services in education and health care, and high rates of outmigration. In general, the Mazapil region can best be characterized as a marginal zone in which the majority of its residents live at the subsistence level.

According to the recent CIQA, CONAZA, and CONACYT studies cited earlier, residents in the region can be categorized into four socioeconomic groups:

- Families whose members are usually permanent residents and who own capital items such as grazing animals (sheep, goats, cattle), land, a truck or tractor, a store or shop.

- Families with some members who migrate seasonally to work outside the immediate area. These families usually own a few grazing animals, engage in small-scale agriculture for home use, and collect native plants for sale.

- Families with members who often must migrate, at least temporarily, to work in a city. These families usually have land, but no grazing animals, and depend greatly on subsistence agriculture and native plant harvest for cash.

- Families with no land or grazing animals, who depend on subsistence agriculture and native plant harvest, maintain themselves only marginally, and attempt to save money to allow a family member to migrate to a city to work.

1. Land tenure: Ejido communities in the Northern Arid Region hold more than 50 percent of the land and represent 90 percent of the

population. There are also a few private farms and ranches, with a higher investment in equipment and technology. In the Mazapil region, there are 102 ejidos, totaling 1.1 million hectares, and 1,263 private landholdings totaling 342,000 hectares.

The term "ejido" refers to a collective of peasants that has received lands under terms specified by Mexican agrarian law, and to the lands which are given to them under this procedure. The lands belong to the federal government but are controlled in most matters by the collective, which can parcel lands out to individuals or work them as a community. Until 1981, the lands could not legally be sold, rented, or mortgaged (Markiewicz, 1980; DeWalt, 1979; and Simpson, 1937). The Agricultural Promotion Law, (Ley de Fomento Agropecuario LFA), now permits land rental, but the law has not yet been utilized because enabling legislation has not been presented (Latin American Weekly Report, 1981).

2. Population: By 1970 the population of the NAR had changed from predominantly rural (about two-thirds) to being nearly evenly divided between urban and rural. Urban is defined as a community with more than 2,500 inhabitants. It is projected that by 1990 the NAR population will be one-third rural and two-thirds urban. Because of the low level of economic activities in the region, the outmigration from rural areas has consisted mainly of males between the ages of 15 and 34 years (Howard, 1981).

Population density is related to economic activity and climate. In the Northern Arid Region as a whole, 1,300 population centers are scattered within 125,000 square kilometers. Population density in the Mazapil region ranges from 3 to 14 inhabitants per square kilometer. There is an average of 94 square kilometers per community. Of the 61,000 inhabitants of the region, about 13,000 live in urban areas with populations exceeding 2,500; the remaining population of about 47,000 lives in smaller rural communities. A high birth rate is indicated by the large proportion of young in the population. Estimates indicate that over 50 percent of the population is below 15 years of age.

3. <u>Employment</u>: It is difficult to define accurately the employment situation since many of the residents engage in several seasonal, part-time economic activities throughout the year. Thus, the terms "employment," "unemployment," and "underemployment" are not always accurate. Important sources of income in the region, or activities in which large numbers of people are employed, are desert plant collecting, mining, and herding. Substantial income is sent or brought back by workers who have migrated outside the region.

It is necessary to look at employment in the region in terms of family production units. A typical family might be engaged in small-scale agriculture, goat herding, and the collection of desert plants with children working in all three activities. The family might also take in laundry and have one or more members working temporarily in a Mexican city, or in the United States, and sending home part of their income. It is only through a combination of these activities that the family can maintain itself and try to accumulate capital.

Many activities produce food and materials, but no cash. Labor jobs often pay well below the minimum wage. Peasants acquire cash largely by selling surplus animal products or vegetables and harvested native plants, and through their labor, especially in larger cities in Mexico and in the United States. Families who own a vehicle can charge for its use. Precise figures are not available, but few members of the potential guayule region work force engage in only one income-generating activity. Most of these are miners near Concepcion del Oro, Zacatecas.

The general employment pattern is shown in Table VI-1. The statistics cited may significantly underestimate employment because they represent only official census data based on workers eligible for coverage under the social security laws. Exact figures are not known, but it is commonly assumed that there are two unreported jobs for every one officially listed. Specific employment patterns are discussed in the following sections on migration, agriculture, the native plant industry, herding, and mining.

TABLE VI-1

PERSONS ECONOMICALLY ACTIVE IN THE MAZAPIL REGION
1970

Municipio	Agriculture, Herding, Plant Harvesting	Industry (Mining)	Business	Other	
C. del Oro	1,704	1,078	573	125	
El Salvador	671	72	121	62	
Mazapil	3,941	1,745	741	246	
M. Ocampo	321	355	63	23	
S. Juan de Gpe.	1,230	603	253	92	
TOTAL	7,867	3,853	1,751	548 =	14,048
Percent of Total	56%	28%	13%	4%	

Source: CONAZA, CONACYT, and CIQA, 1981

a. <u>Migration</u>: The lack of secure economic opportunities, coupled with the demand for an expanding industrial and agricultural work force and the promise of higher wages in cities such as Monterrey, Saltillo, Torreon, and Monclova, has caused seasonal and permanent out-migration. There is also temporary and permanent migration from the region to the United States.

The state of Zacatecas is one of the principle sources of migrants in Mexico (Bustamante and Martinez, 1979; Garcia, 1980; Diez-Canedo, 1980; Howard, 1981). This is a tradition built over almost 100 years. From the times when Mexicans were recruited to build the mines and railroads in the United States, through the bracero program, to the more recent era of undocumented immigration, several generations of residents of Zacatecas have travelled to the United States to work. In some cases, migrants from Zacatecas have established satellite communities in Tijuana as a base for work in California. The vast majority of these migrants return to Zacatecas, while only a few remain permanently in the United States. This is important to note, since immigration from Mexico to the United States is often perceived as being almost entirely permanent. There are few reliable estimates of the amount of money flowing into the region from relatives working in Mexican cities and in the United States, but in 1975 the Nacional Financiera reported that an average of $50 (US) was sent back to each resident of Zacatecas by undocumented Mexican workers in the United States. This was by far the highest recorded per capita payment to any Mexican state (Diez-Canedo, 1980). In actuality, the amount sent back was probably considerably higher, since this figure represents only the amount reported.

Rather than viewing migration as a one-way flow in which the Mazapil region is a "staging area," it is more useful to see migration as a mechanism whereby family units in the Mazapil region generate the necessary income in order to sustain themselves in the region. Without the money that is returned by migrants, some family units might not be able to persist. The Mazapil region can also be viewed as an area that furnishes a labor supply for the rapidly growing industrial areas of Mexico and the rural and urban areas of the United States.

b. Agriculture: Poor soil and the arid climate make intensive agriculture difficult in the NAR without considerable use of irrigation water and fertilizer. In the Mazapil region there is almost no irrigated farming. Only 300 hectares in the Zacatecas municipios and 800 hectares in San Juan de Guadalupe, Durango are surface irrigated. Most agriculture is on a subsistence level. Corn is the main crop and is a major element in the rural diet. The area planted in the Mazapil region decreased from 29,000 hectares in 1970 to 20,000 hectares in 1976, yielding 7,000 metric tons in 1976, a yield of 0.35 metric tons per hectare.

The other major crop is beans. These are totally dryland farmed, need no fertilizer, and adapt well to the climate and soil of the region.

Approximately 9,500 hectares were planted in beans in 1976, yielding more than 3,500 metric tons. The number of hectares planted in beans remained relatively stable between 1970 and 1976.

c. Native plant industry: Commercial exploitation of native plant resources -- candelilla, guayule, and the fiber-producing plants such as lechuguilla and palma -- has been an important activity and one of the main sources of income for the rural population in the region since the early 1900s. Many of the ejidos have been involved in the production of industrial raw materials from candelilla, lechuguilla, and yucca, and also the direct market for wood, "tunas" (cactus fruit), and medicinal plants. In the NAR about 60 percent of the rural population is involved in varying degrees with candelilla wax and ixtle fiber production. These activities, from harvest to extraction, are accomplished on an individual basis. The native plant industry has been characterized by dependence on a highly fluctuating external market and a low level of technology. There have been no surveys of the resource or establishment of resource management practices, but COPLAMAR has recently established a program with ejidos in the Mazapil region to begin reforestation of economically important native plant species.

The native plant industry has also been an important cohesive element. The agency representing candelilla harvesters, Fideicomiso para el Fondo Candelillero (FONCAN), coordinates wax collection and payments as well as other community services and recently became part of the group of agencies coordinated by COPLAMAR. Ejidos active in ixtle production have also formed associations with similar structures. The area of southern Coahuila and northern Zacatecas, which includes the Mazapil region, produces more than 70 percent of the national production of ixtle de palma, more than 35 percent of the ixtle de lechuguilla, and more than 25 percent of the candelilla wax. Approximately 22,000 people in the southern Coahuila/northern Zacatecas area are engaged in this activity, producing an average of $1,500 pesos (about $70 US) per month per family (Martinez and Bolaños, 1979). Annual reported wax and ixtle production and revenue in the Mazapil region are shown in Table VI-2. These figures probably greatly underestimate actual production. FONCAN restricts the amount of wax it will purchase, and it is the only legal buyer and distributor. Production above the quota is sold on the black market and there is no accurate estimate of the quantity sold in this way.

Since 1950 the economic importance of the native plant industry has declined due, in part, to increased use of synthetic materials, especially fibers and plastics. Guayule production was abandoned. The ixtle and candelilla markets diminished precipitously and organized purchasing at the village levels ceased, but the industries still existed at a very low level of production. In 1975 the candelilla market began to improve and the demand for candelilla wax is still increasing. The government-backed candelilla program may be revived (Campos-Lopez et al., 1979). Only the ejidos have access to much of the land on which these native plants grow. For many ejido groups this is the only activity from which they earn cash and receive services such as health care and food distribution.

TABLE VI-2

ANNUAL WAX AND IXTLE PRODUCTION AND REVENUE
IN THE MAZAPIL REGION

Year	Production (MT)		Revenue (Pesos)	
	Wax	Ixtle	Wax	Ixtle
1979	67,900	ND	1.7 mil.	ND
1978	133,700	ND	2.7 mil.	ND
1977	160,500	9,500	3.4 mil.	68,000
1976	273,800	10,900	3.7 mil.	83,000
1975	201,200	15,900	4.2 mil.	122,000
1974	132,900	18,400	2.4 mil.	104,000

ND = No data.

Source: FONCAN in CONAZA, CONACYT and CIQA, 1981

d. Herding: Subsistence and small-scale herding, mainly goats, is carried on in the Mazapil region and is the most important economic activity. There is large-scale ranching in northern Coahuila.

e. Mining: Silver, gold, lead, copper, and zinc are mined in northern Zacatecas. Most of the mining is concentrated in Concepcion del Oro, where about 2,000 workers are employed (Martinez and Bolaños, 1979; Campos-Lopez et al., 1979). Unlike most economic activities in the region, work in the mines is a full-time job. Workers in this sector are less likely to be involved in other economic activities.

Although mining activities in the region have declined in recent years, there may be a revival. Mining interests near Concepcion del Oro are planning an expansion of 1,000 jobs (statement by the mayor of Concepcion del Oro, Zacatecas at the guayule technology assessment workshop in Saltillo, Coahuila, April 3, 1981). Miners are permanent employees, and the industry provides few opportunities for migrant workers.

4. Standard of living: According to reports by the Ministry of Progamming and Budget (SPP), more than half the rural population of Zacatecas consumes no meat, eggs, milk, or fish. In an analysis undertaken by COPLAMAR regarding the standard of living -- including food, education, health, and housing -- most areas in the the NAR are well below the national average (COPLAMAR in CONAZA, CONACYT and CIQA, 1981). A series of improvements in the region have been planned by COPLAMAR, and the first stages have been initiated. Improvements are planned in housing, education, health care, food supply, communication, and transportation. Additional improvements in dryland agriculture are planned by the Mexican Food System (SAM).

a. Housing and services: Federal housing programs until recently have been directed toward urban rather than rural areas. In many of the rural communities, services such as water, sewage, and electricity are unavailable, at least partly because of high costs due to the scattered nature of the rural population.

b. Water: In the Mazapil region, the number of homes with water service available ranges from 23 percent to 89 percent, according to the municipio. Of these, less than half have service inside the house. The availability of potable water is a major health problem for the rural population. To alleviate the problem, COPLAMAR and CONAZA have initiated programs to provide some networks and distribution systems and to transport potable water to communities with the greatest need.

c. Sewage systems: In the NAR fewer than 40 percent of the people have sewage service. In the Mazapil region, the percentage ranges from 3 percent to 21 percent. Fecal contamination of water supplies is largely responsible for the high incidence of disease and infant mortality from infectious and parasitic diseases. Sewage systems are mainly the responsibility of the state and municipio. There seems to be little local planning in the rural areas for dealing with these problems. Federal offices dealing with different aspects of the problem are scattered.

d. Electricity: Electrical services in the rural areas of Mexico are the responsibility of the Federal Electrical Power Commission. Energy consumption patterns depend largely on income level. Low income groups depend heavily on the use of wood and charcoal and other non-commercial sources of energy. In 1977, in the Mazapil region, between 64 to 88 percent of the homes did not have electricity. Rural electrical consumption is estimated to be only 9 percent of total energy use. Wood provides about 86 percent of the energy. High voltage lines extend to only eight communities, the larger urban areas.

e. Health: Respiratory problems, infectious diseases, and parasites are the most common health problems. The political organizations of candelilla and ixtle harvesters have been instrumental in obtaining health services for the rural population. Government health services are offered through the Mexican Institute for Social Security (IMSS). The candelilla harvesters have been incorporated into the service since 1974. New agreements between IMSS and COPLAMAR promise to deliver more health services to marginal areas, such as the Mazapil region. These programs are independent of guayule development.

f. Education: Indicators of literacy and the number and level of schools reveal that the Mazapil region is well below the national standard. The illiteracy rate in municipios varies between 20 percent and 35 percent. There are 32 primary schools and only 8 secondary level schools in the region and a general lack of education infrastructure. School attendance varies considerably, ranging from 80 percent to 7 percent of school-age children.

g. Transportation: Major paved highway systems into the region are adequate and connect the area to the major industrial areas of Mexico (Figure VI-3). However, secondary, unpaved road networks into the areas where guayule is concentrated, or might be grown, are few. In addition, those that do exist are often impassible in the rainy season. COPLAMAR plans to build feeder roads in marginal areas; some may be in the Mazapil region.

5. Summary of current trends: Some changes in socio-economic conditions in the region can be expected, given the present trends, without guayule commercialization. Programs, such as those initiated by COPLAMAR, will begin to increase the standard of living in the Mazapil region, but, because of the uncertainty of their continuation after the change of administration in 1982, the long-range impacts of those federal and state programs cannot be evaluated. Many changes are tied to an influx of capital. The LFA may change land use and land tenure patterns, but the way in which they will change is still a much debated topic.

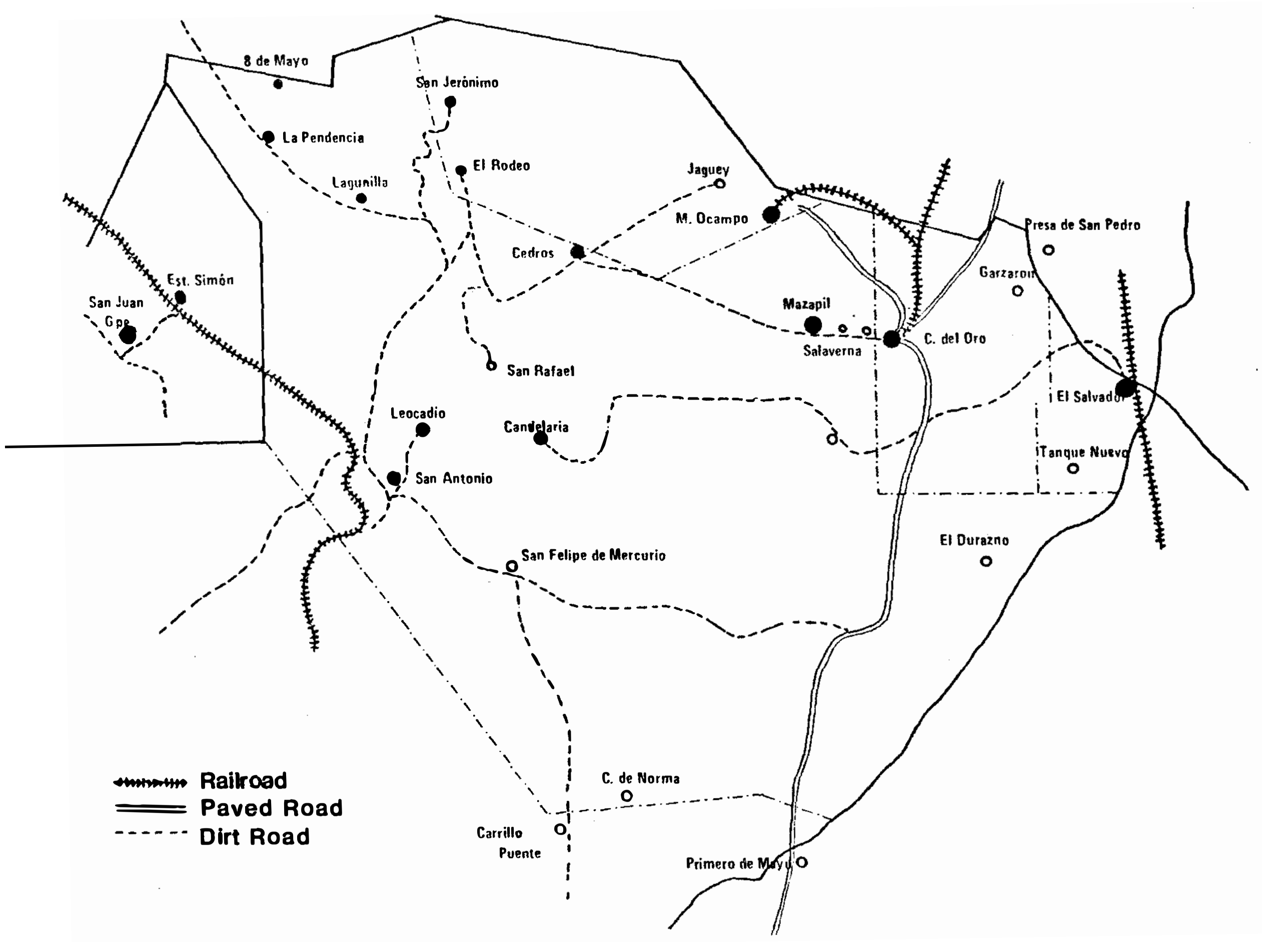


Figure VI-3. Roads in the Mazapil Region.

The population of the region will probably continue to diminish slowly. Migration from rural areas to Mexican cities and the United States may increase due to the opening of the automobile factories in Saltillo and the general industrial expansion occurring in Mexico.

Much of the temporary migration might become more long-term or permanent, especially if migration becomes more costly or difficult. Increased activity and investment by SAM and COPLAMAR may augment or at least maintain farming and small-scale livestock herding to improve the general welfare. Commercial harvest of native plants may continue to be a major source of income, but depleted plant populations and weak markets for most products will limit these industries' economic benefits. Employment opportunities in mining in the Concepcion del Oro region will increase if the planned expansion does occur.

In sum, the level of development that is likely to take place within the region, either in the agrarian and ranching sectors or with the limited expansion of the mining sector, will leave the Mazapil on the margin of Mexican society, although community services will improve somewhat as the COPLAMAR community development plans are implemented. Income-generating activities will not be significantly expanded, and it is possible that the ixtle and candelilla resources will be exhausted. Net out-migration is likely to continue.

B. Potential Socio-economic Impacts of Guayule Commercialization

Guayule industry development in the Mazapil region will generate new employment opportunities resulting in direct and indirect economic benefit to residents of the area. Guayule commercialization will be especially important to the groups that depend most on harvesting native plants, although other sectors of the population may also benefit from guayule development.

1. Impacts on land tenure: Much of the land proposed for guayule commercialization is federal land under ejido control, but mixed

throughout is an unorganized pattern of various size parcels of private land. Two different problems related to land tenure may arise with commercialization of guayule. The first relates to harvesting shrub in the wild, and the second relates to clearing and conversion of land for farming.

Because the distribution of shrub in the region does not correspond to the land tenure pattern, a program relying on wildstand harvest could cause conflicts over access, harvest rights, and compensation for resources removed or damaged. Optimum use of the wildstands will require agreements between land holders. Such an agreement could include terms for land rental, cooperative harvest of joined production units, harvest fees, or other provisions designed to facilitate mutually beneficial shrub harvest.

Reforestation and improvement of wildstands could create conflicts among ejidos and between ejidos and private landowners regarding who will benefit from these programs. Managers of the processing plant may want lands closest to the facility to be developed in order to reduce transportation costs.

Intensive reforestation of wildstands and farming on new land may dramatically affect land use patterns and land tenure. The central issues are: whose land will be developed for farms, how landholders will be compensated for appropriation of the use of the land, and who will control use of the land. A corollary to the last question is the size of production blocks. Small blocks could be worked more easily under local control than large blocks where economies of scale might dictate a machinery-intensive operation that could exclude local residents from any substantial involvement in farm operation.

There is a gradual transition in Scenario B from wildstand harvest only to dominance of farming. As the program is implemented incrementally, production units could be kept within the administrative boundaries of the ejidos or transcend them. Under the latter structure, land use decisions would likely be dominated by the government agency overseeing guayule development. The development schedule necessary to meet rubber production quotas projected in Scenario B would require federal planning assistance that might preclude substantial local input. The degree of local control in decisions affecting land use and development and the transition rate from familiar activities to the more sophisticated guayule farming will greatly influence land tenure impacts.

The LFA, if implemented, would allow ejidos to join in association with private landholders so that small units could be united into large tracts to increase agricultural production efficiency. This could greatly aid a guayule project. It allows the federal government to promote the creation of larger production units in Scenario B.

Divergent opinions have been offered regarding the potential effect of implementing the LFA. One contends that permitting the combining of capital and land base would increase the agricultural productivity and economic advantage of both ejidatarios and private interests. The LFA is designed to expand production and by legalizing existing arrangements between ejidos and private landowners could encourage ejidatarios to rent their lands, hire out their labor, and curtail their small-scale farming. Critics of the LFA contend that this would transform the ejidatarios into wage laborers (Aguilar Camin, 1981) and that production would tend to favor exportable cash crops rather than commodities for local consumption.

2. Impacts on population: The guayule program may affect population size, density, and distribution in the area as well as sex and age distribution. The changes may result from altered birth and death rates, movement of residents already in the area, or from immigration to the region in response to guayule commercialization.

COPLAMAR programs being initiated will improve regional health care and education. Better health care tends to reduce the high infant mortality often found in remote rural areas. Birth rates are ususally also high in these areas, and until they are reduced to a degree corresponding to the decrease in infant mortality, the population may expand rapidly. But improved economic conditions, such as the guayule program may bring to the area, are often accompanied by the desire to reduce family size. The long-term net result can be reduced population growth after an initial increase.

Improved economic status could also encourage out-migration in some rural areas. Families previously lacking the resources to permit a family member to leave may acquire the means through new jobs in the guayule industry. Underemployed family members may then be able to migrate to a city to seek work. However, if the guayule program is sufficiently attractive, out-migration of young males may diminish and previous migrants may return to the region. This would move the sex ratio closer to 1:1 and lower the mean and average age, which might well increase the marriage rate, reduce marriage age, and ultimately increase the birth rate. The results would be a larger population and perhaps a more rapidly growing one.

3. Impacts on employment: The intent of the guayule program is to increase employment in the Mazapil region, but it will not affect all job sectors in the same way or with equal magnitude.

a. Change in migration patterns: Under both Scenarios A and B new employment opportunities will be created by guayule development, but in Mexico there exists such a complex employment pattern that changes are difficult to predict. A complicated interplay of forces determines whether a potential worker will remain and work in guayule, migrate to the city, or be involved in other work.

Migration is essentially a social phenomenon based on economics. Decisions are usually made by family production units and it is difficult to predict how they will view guayule development. Migrants from the

Mazapil region have a comprehensive network of communication concerning job possibilities outside the region. They will be pragmatic and will weigh alternatives in assessing the participation of family members in the guayule industry. Two of the most important factors in that decision are job security and income. If the minimum wage is paid and the potential worker views the job situation as secure, it is likely that people who would otherwise migrate would stay and work with guayule, or additional workers would be attracted to the region. If, on the other hand, guayule wages were not viewed as competitive with other revenue-generating activities available in large Mexican cities or in the United States, the high rate of migration would continue. On a six-month trip to the United States a worker might be able to save as much as $1,000 US (Camau, 1979). This involves an often difficult and costly border crossing, but is very attractive to a worker whose gross earnings in Mexico for a year may be little more than $1,000 US.

It is also possible that the number of people attracted to the region by new jobs in the guayule industry will exceed the number of jobs available. This would have a negative impact in that it would further strain the already limited community services, and would compound, rather than alleviate, the problem of unemployment and underemployment.

Given the experience in other Mexican development projects, both urban and rural, one must be prepared for in-migration in numbers that far exceed the number of available jobs. This occurred in Nogales, Sonora, in the early 1970s shortly after the opening of the "in bond" plants ("maquiladoras") by U.S. companies. Many more people migrated to Nogales than there were jobs available. A similar situation is being created by the recently developed automobile industry in Saltillo, where impacts of in-migration exceeding job opportunities will soon begin to appear.

Since guayule is located on a controlled and restricted land base, either ejidos or private holdings, the attraction of possible new jobs in wildstand harvesting in the Mazapil is likely to be limited unless the federal government works out some agreement with those who control the Mazapil land base. Job seekers would be less likely to go to areas where employment might be restricted to residents. Jobs related to operation of the processing facilities would probably attract more job seekers than would wildstand shrub harvesting.

In Scenario B, jobs in farming and support industries, and especially in the processing industry, would be a great attraction to job seekers. Land clearing, farm operation, and construction and operation of processing plants would create many more jobs, including more skilled, specialized, and more highly paid jobs, than the limited harvest and processing of wildstand guayule in Scenario A.

An important phenomenon that will affect guayule development in the Mazapil region is the rapid expansion of the industrial sector in the nearby large city of Saltillo. Both General Motors and Chrysler Corporation have opened plants which together employ 10,000 workers. Radio advertisements and flyers attempt to attract people to Saltillo. Many do not possess the necessary skills for employment in the motor industry, but are likely to fill the jobs of those who shift their employment to the automobile companies or will work as bricklayers or domestics. This could result in a rapid out-migration from the Mazapil region and could necessiate importing labor for guayule work there.

United States federal policy on immigration and border control could affect the Mazapil region. There is no clearly articulated plan, but several general statements can be made about probable impacts of U.S. policy. A "guestworker" program limited to 50,000 workers per year, coupled with stricter border patrol, could greatly increase the difficulty and cost of crossing the border. In considering the net benefits of migrating temporarily to the United States versus working regionally for less income, the balance for many might be swayed in favor of staying in Mexico. However, an alternative would be to make fewer trips and stay longer in the United States to minimize the possibility of detection during an illegal border crossing. The net result then would be fewer workers in the region available for work in the guayule program.

A substantial number of ejidatarios from some areas illegally "rent" their land to others (Dinerman, 1981). Yielding their land base while gaining some financial return encourages these ejidatarios to seek nonagricultural work. Combining blocks of land, through renting land or other arrangements, to grow guayule could lead to labor shortages in the region if work in the cities and in the United States appeared attractive, especially if peasants were unable to accumulate enough money prior to the land rent agreement to pay for a trip to a city or to the United States.

Under Scenario A it is estimated that a full-time labor force of approximately 900 persons would be involved in harvesting, transporting, and processing guayule. In this scenario little migration into the Mazapil region is likely, as a large potential work force already exists there. Technical personnel for the processing plant would need to be imported; the vast majority of the new guayule work force would be needed for the collection of guayule plants. Employment in the guayule program is likely to be considered another activity in the potential job pool rather than as an industry that will displace people from their current employment. However, to achieve a year-round shrub supply and rubber production, there must be an assured work force. An adequate labor force can probably be assured through payment of an adequate wage for harvesting.

Under Scenario B many more workers may be needed than are available in the region. The rapid rate of land clearing and farm land development, infrastructure development, and construction of processing plants will certainly require skilled labor not presently available in the region in sufficient numbers. Skill centers to train local residents could be created to supply a certain number of these. The large pool of presently underemployed laborers in the region could provide most of the manpower needed for development, provided they wanted to work in the guayule agroindustry. As the program develops, the momentum of support industries, additional services required, and urbanization would create new labor demands. Rather than trying to decide whether the guayule program will increase, decrease, or not change migration numbers and patterns, it is more realistic to conclude that Scenario A and Scenario B will do all these things in different areas. The net effects on migration cannot be predicted.

b. Agriculture: The small-scale subsistence farming common in the Mazapil region is a high risk, low return venture. Most of the production is crops that preserve well and are consumed locally. The surplus from a good crop is sold in local markets.

A loss of agricultural production in the region during a good year would increase food imports from producing areas outside of the region and increase dependency on the national production of corn and beans. Although regional food production is small, its loss could be important locally. Under Scenario A, harvesting guayule would not compete with agriculture for land use. There might, however, be competition for the work time of the harvesters since much of the potential work force is also engaged in subsistence agriculture. This would be especially true in years of good rainfall. If rainfall is adequate, a significant part of the potential guayule work force might abandon guayule harvesting to tend their own food crops. The value of a good crop during a wet year could exceed the value of wages paid for guayule harvesting during the growing season. Loss of guayule harvest time would reduce processed rubber output and undermine agreements on rubber delivery.

Extensive farmland development under Scenario B would have a similar but greater effect on agriculture than would wildstand harvest. Potentially a far more significant impact on agriculture is future competition for land and labor if the SAM project operates in the same areas as the guayule project.

c. Native plant industry: Harvesting native plants has been a major economic activity and is compatible with the employment pattern of many part-time peasant activities. Although the market is unstable and the value of the crops highly variable, it was still common in 1970 for a family to earn 1,500 pesos per month (about $70 US). In the Mazapil region this amounted to a total of about 1.8 million pesos ($70,000 US). The manner in which the guayule program proceeds will determine its impact on the candelilla and ixtle industries. Both of these industries are much more active to the north of the Mazapil region, so that any impact, positive or negative, on the industry as a whole will be minor.

Wildstand guayule harvest in Scenario A could compete directly with other native plant industries for the work force, but this seems unlikely. Because of the decline in the volume of other plants harvested, due in part to overharvest and in part to a decrease in their value, it is more probable that this slack would release the labor necessary to harvest guayule. The ixtle industry is not likely to recover the market it has lost to synthetic fibers as long as petroleum is relatively cheap in Mexico. Resurgence of demand and a higher price for candelilla wax could create labor competition; however, with government control of shrub harvest, it would be possible for the guayule agency to facilitate candelilla harvest when guayule was not being harvested. The level of underemployment in the region is such that the guayule industry in Scenario A will not utilize all the available labor. Peasants with free time who wish to harvest other native plants will probably meet the reduced demands for wax and fiber.

The intensive use and reforestation of guayule stands in Scenario B is a greater threat to other native plant industries. Most of the economically important species occur together and probably compete for water and nutrients with guayule. For this reason, and because guayule seedlings do not grow well in competition with other species, those species would probably be removed or their numbers reduced to allow effective reforestation and rapid growth of commercial stands of guayule.

Areas not used for intensive guayule harvest would then be subjected to more intensive harvest of remaining economically important plants, eventually reducing the sustainable harvest of these plants.

The farming operations projected in Scenario B require clearing 200,000 hectares. Clearing the land would curtail local harvest of these other plants and increase harvest pressure on remaining stands. It is doubtful that these other industries could continue in the Mazapil region.

d. Herding: Because nearly all ranching in the area is small-scale herding of goats and sheep, any restriction of access to open land will affect a large number of families. Livestock herding accounts for about one-half the total value of forestry and agricultural production in the region (CONAZA, CONACYT and CIQA, 1981).

The degree of grazing restriction in areas containing guayule will depend on the value of the forage consumed or destroyed by the grazing. If wildstand harvest is not perceived to be materially diminished by grazing, the two activities could coexist. Grazing would probably be prohibited in stands where guayule was replanted at moderate densities. Areas might have to be fenced to protect them from intentional or accidental grazing. This would create conflicts over use of communal land. A family that lost its grazing lands might not be able to, or wish to, replace the lost value by harvesting guayule. Typically, fencing is paid for by the ejido community, but the benefits go only to the families that own livestock to be kept in the fenced area. In general, the costs of and benefits from communal investments are not equally shared. If income from work in the guayule program is used to purchase livestock, herding and grazing pressure on pastures, including those containing guayule, would increase. This might increase the conflict between guayule growth and grazing on the same land.

Land use changes in Scenario B will differ qualitatively as well as quantitatively from those resulting from the wildstand harvest proposed in Scenario A. The changes will be incremental but will occur at a relatively rapid pace. Wildstand harvest initially will be similar to that in Scenario A, but with the beginning of the reforestation program, and consequent greater value of guayule lands, conflicts over multiple use will increase. There will be a gradual but substantial loss of grazing land as farms are developed. Grazing the same number of animals on the remaining land base will reduce those lands' productivity, eventually resulting in a loss of income to those families still dependent on grazing. Excessive use of the land could permanently reduce their productivity and make grazing infeasible.

Large blocks of farm land could also disrupt movement patterns and in effect restrict access to pastures geographically separated by farmland "barriers." Conflicts could arise over surreptitious livestock grazing on guayule farms. Although this would benefit livestock owners, it would have a deleterious effect on shrub production.

The production of bagasse forage is an anticipated benefit from guayule commercialization. Large amounts of material will be available at or near the processing plant, where the bagasse can be converted to animal feed. This might lead to the creation of feedlots where animals are concentrated near the feedsource.

Feedlots near population centers could become health hazards due to the animals' wastes, but the wastes also would be a new source of fertilizer for small farms or for guayule farms. A feed distribution system would have to be established and a price for the feed determined. Conflicts could arise between the rural elite with money to buy the feed and livestock and the peasants who had lost grazing lands to guayule farming. Bagasse-derived feed probably will not be developed until several years after the farming operations have begun. By that time more than 15,000 hectares will have been cleared for farming, and many peasants may have lost grazing lands and livestock.

e. Mining: Impacts on the mining industry would be related primarily to secondary development rather than to the direct effects of the guayule program. Most mines in the area are in hard rock and are developed on land too steep or rocky for farming, thus land use conflicts are unlikely. The type of mining practiced requires relatively little land, but waste piles and tailings could disrupt a large enough area so that reforestation zones should not be planned near active mining sites. Mining potential should be considered when deciding which areas to replant with guayule. The high value and relatively small land area of a mine would probably preclude use of its land for guayule if potential conflicts arose.

The infrastructure improvements which accompany development of wildstand harvest and extensive farming could stimulate mining exploration and production where the cost of building roads and bringing in power and water is a limiting factor in developing a mine. Increased mining creates more jobs and attracts more workers to the area. Work in mining is full-time and involves developing a skill. Mining and farming are often separate skills, so that concurrent growth of farming and mining would not normally compete for the same laborers.

4. Social impacts: Raising the standard of living for inhabitants of the Northern Arid Region, and the Mazapil region in particular, is an indirect goal of the guayule commercialization program. However, there are also many other federal programs with the same goal. The guayule program would create jobs in the region and, in addition, the infrastructure necessary to support the program would also benefit the local villages and cities. The net benefits or impacts of the guayule program would in part depend on the extent to which the other federal programs achieve their stated goals without the stimulus of guayule development.

Guayule commercialization would bring social benefits, costs, and risks. Positive impacts will be both direct and indirect. The immediate benefits include income from new jobs, allowing people to buy more or better food, housing, and other goods and services that a federal program may bring to the area. The program may stimulate improvements in water and power delivery, sewer systems, and roads for better access into and out of the rural villages. The program may also stimulate delivery of federal social services such as housing and education programs and health services. A united voice through a guayule harvesting organization would give the peasants greater local power and improve their ability to influence local and regional planning.

The small sector of the society that owns or controls most of the capital in the area has been termed the rural elite. Their capital base allows the group access to credit for purchases and operations. Not being restricted to a cash-only basis gives this group great advantage in operating flexibility. The group includes shopkeepers, truck and vehicle owners, and ranchers. Infrastructure improvements and capital investment in the region often benefit this group disproportionately because they act as operating agents and funnels for operating expenses for the peasants. This could increase the high disparity of income between the target groups and the rural elite.

Improved access speeds the flow of new ideas and goods into remote areas. This has both positive and negative aspects, for "middlemen," money lenders and hucksters, are typically among the first to enter a newly opened rural area. The concentration of people and influx of outside influences also change the rural nature of these areas, perhaps bringing urban problems such as more crime, different moral standards, and changes in family and social structure and interactions. Changes may be considered beneficial or deleterious, but they are often viewed with fear and distrust by rural residents. The magnitude of these changes would be determined somewhat by the nature of the guayule project. Harvest of wildstand guayule and small-scale development would not represent a profound change in the present nature of the region. Some population concentration would occur at shrub collection centers and at the processing plant, but the harvesting work would be spread over the countryside.

In contrast to limited wildstand harvest, the reforestation program and guayule farming would concentrate a larger number of people at more processing centers. More people would be attracted to the region, and a more urban environment would be created.

Changes in employment patterns can alter the amount of time spent at home by the main wage earners and affect the time available for family and community support tasks. In areas from which a large number of men have migrated, many tasks, such as road and community building repair, are not being done, and women are assuming other tasks that were traditionally done by men (Dinerman, 1981). Permanent employment that increases the number of people and the time they spend in the community could significantly alter the social dynamics of the family and community.

If an industry based on a single resource closes down because the resource is exhausted, or for political or economic reasons, considerable disruption may occur. In the Mazapil region there would be serious economic disruptions because of the adjustments that had been made to accomodate the commercialization of guayule. If many harvesters lost future work options in the traditional diversified activities because of the guayule program, the shutdown of the guayule industry could be disastrous for the region.

One serious potential problem is the uncertainty of shrub supply. Current estimates of total biomass and sustainable harvest are highly variable. More accurate estimates probably cannot be arrived at without highly detailed field studies made in conjunction with harvest control. Because of this uncertainty a program evaluation is scheduled for the fifth year of full capacity operation in Scenario A. If continuing surveys show an insufficient amount of shrub to operate the plant at full capacity for the ten years deemed necessary for natural revegetation and growth, the plant operating level could be reduced fifty percent and the operation would still be self-supporting. This would reduce the number of jobs in harvesting and support but would not eliminate the entire program. However, complete shutdown would be possible after the tenth year of operation if regrowth of the wildstands was insufficient. Other options could be considered to maintain the harvest, including reforestation and expanding the harvest area.

The rapid development program in Scenario B could result in other negative impacts on the region such as those seen after the construction of the two large automobile plants in Saltillo. Such development can create shortages of housing, potable water, sewage facilities, and electricity, and can strain the transportation systems and educational facilities. Shortages resulting from a large influx of people filling the new jobs or seeking jobs rapidly drive up any prices not governmentally controlled. Price escalation is especially sharp when pay scales rise and when higher paid workers enter the region and bid up prices for housing or commodities in short supply. Uncontrolled prices for necessities can rapidly rise above the level that local residents can afford, thus worsening rather than improving their financial status.

C. Environmental Assessment

The environment of the Mazapil region is typical of much of the Northern Arid Region of Mexico. Most of the area is in hot, dry intermountain valleys in the Sierra Madre Oriental. Wide, nearly level valleys with deep alluvial soil lie below generally gentle slopes of the mountain foothills. Overland waterflow is restricted to ephemeral streams, except for the Aguanaval River in Western Zacatecas outside the Mazapil region. Little is known about groundwater supplies in the area and very few wells have been developed. The rocky, thin soil here supports a wide variety of native and desert plants and animals. Vegetation is generally sparse, except near waterways and in moist, small canyons. It consists mostly of small and medium shrubs, grasses, and annual herbs. Trees, tree-like cacti, and shrubs are common in some areas. Summers are hot, with maximum daytime temperatures often near 100° F; winters are cool, but temperatures seldom dip below freezing. Rainfall is highly variable but is usually less than 16 inches (400 mm) per year. These conditions greatly restrict the area in which traditional dryland agriculture can be successful.

The main economic activities in the region rely on natural resources exploitation and many uses compete for limited resources. Commercial guayule development in Mexico can have both positive and negative effects on the environment and its natural resources. Three categories of impacts are analyzed:

- impacts resulting from harvest of guayule wildstand populations (Scenario A);
- impacts resulting from guayule dryland agriculture (Scenario B); and
- impacts resulting from processing guayule shrub into rubber and byproducts (Scenarios A and B).

Secondary and associated general development impacts for all the above categories will also be considered.

1. Wildstand harvesting of guayule: Harvesting wildstands will, in most cases, increase the amount of activity and travel in the countryside rather than initiate it, as harvesting other native plants is already a common activity in the guayule region. Harvesting procedures, described in detail in Chapter III, call for teams of harvesters with burros to walk through the guayule stands, cutting shrubs that are at least 25 centimeters (10 inches) tall. Shrubs are to be cut off at ground level and transported by mules to regional collection centers. At the centers the shrub will be compressed and shipped by wagon, truck, or rail to the processing center.

Commercial harvesting could totally destroy the guayule wildstands. Pulling the plant rather than cutting at ground level is usually lethal, but cutting may allow for some regeneration from the roots or from lateral off-shoots, called _retoños_. Harvesting mature plants may decrease the replacement rate by removing the most prolific seed producers, but since younger guayule plants normally produce many seeds, this effect may be insignificant. However, if the harvest rate is greater than the replacement rate, continued harvest will eventually remove all the mature plants. Current estimates of sustainable yield from wildstands vary greatly, but most show a significant likelihood that continued harvest to maintain output from the 5,000 metric ton per year plant will deplete available shrub in less than ten years. Experience has shown that without monitoring and control of native plant harvest, local populations may be entirely removed. In this case, unique and irreplaceable genetic strains from local populations could be eliminated.

Removal of plants and more travel in the guayule region will increase soil erosion. The heavy rainfall typical of desert storms erodes soils more rapidly if plants are removed, as vegetation normally reduces rain impact and slows water traveling over the ground in the form of sheet runoff. Removing shrubs will decrease the amount of ground cover and expose disturbed soil. Increased traffic in the areas will cause more soil compaction and water channeling, potentially increasing soil erosion and making natural stand regeneration more difficult. Additional roads probably will be extended into the guayule growing areas, allowing greater access to all the natural resources, and the roads themselves will be sources of erosion. Loss of topsoil results in long-term impacts because the formation rate of topsoil in arid regions is very slow. Decreased productivity resulting from soil and nutrient loss could continue for decades.

Increased use of guayule areas and improved access might also strongly impact other economically important species by encouraging increased harvest of plants such as candelilla and lechugilla. Some local populations of these species are already greatly reduced. Monitoring guayule wildstand populations and controlling the harvest of designated stands is an important element in coordinating guayule harvesting and processing. Coordinating these activities with controlled harvesting of other wild plants would be possible through cooperation with the candelilla organization or a new agency. Reforesting guayule stands might also stimulate reforestation of other valuable wild plants.

Sheep, goats, and cattle graze or browse lands supporting populations of guayule. Because animals may eat guayule and may trample or uproot small plants, intensive use of these areas in reforestation projects, as suggested in Scenario B, and the increased value of guayule plants would make shrub harvest and grazing incompatible. Reforested areas would have to be fenced to keep out grazing animals. Restricting the animals to a smaller area could create severe over-grazing on the remaining lands.

The guayule plant itself might cause some discomfort to those who handle the harvested shrub. One of the resin components causes a contact dermatitis in laboratory animals and may produce similar reactions in humans. Harvesters normally wear gloves and a thick vest to protect themselves from the plant sap, but prolonged contact may sensitize individuals. Previous experience did not show this to be a problem, but health concerns are easily overlooked in remote areas where medical care is scarce.

2. <u>Dryland agriculture</u>: The environmental impacts from guayule farms are those of a row crop with a five-year harvest cycle. However, because all guayule will be grown on newly developed farmland, classified as marginal for traditional agriculture, there will be a number of environmental impacts resulting from land clearing and soil preparation for planting guayule seedlings. Land area to be prepared each year is considerable (Table V-5), 5,000 hectares to 36,000 hectares (12,000 to 89,000 acres) in a year.

Removing vegetation from such a large area creates the potential for substantial environmental impacts. Because guayule farms would be developed from seedlings on nonirrigated land, cleared land would be left exposed to wind erosion when there was insufficient rainfall for planting. Isolated, intense rain storms could also erode significantly and still not leave enough moisture in the soil to allow planting. After a complete harvest, erosion potential is high. The land may be barren until the next spring planting. Because rainfall variability is high in the entire region, it is extremely likely that in some years soil moisture accumulation in the cool months of spring and early summer would not be sufficient for transplanting seedlings from nurseries to farms.

A similar potential for wind and water erosion of exposed soil exists even if a guayule crop is established. If rainfall is insufficient to permit rapid growth in the first years, the shrub will not cover the exposed soil. Under irrigation the space between plants within rows closes at the end of the second season, and the space between rows closes during the second or third growing season. Without irrigation these rates of canopy closing would normally be slower. The danger of erosion would continue for three or four years, with the erosion potential decreasing as the percentage of ground cover increased.

A number of examples demonstrate the risk involved in dryland agriculture in arid and semiarid regions. The high variability of rainfall was previously mentioned. Both anecdotal evidence on small-scale farming and data from the Federal Bureau of Statistics show that a significant area of potential nonirrigated farmland in the Northern Arid Region is left fallow or lost to drought on a regular basis, or crop yield is very low, in a significant number of years. These conclusions are all based on traditional agricultural crops, and presumably guayule is better adapted to growing in arid conditions; however, until there is more experience with dryland guayule farming, the probability of a significant area of farmland lying fallow or producing very little biomass is high. Windbreaks, soil contouring to prevent sheet runoff, and other methods could be incorporated into the land development program to reduce erosion potential.

Another consequence of preparing new farmland is destruction of the native vegetation and wildlife habitat. A major portion of the Mazapil region is grazing land, and most of that is controlled by ejidos, although there are many small private land holdings spread throughout the area. The botany of the area is not well known, but endemic species of plants have been reported there (Britton and Rose, 1919). Because the area to be cleared is so large, it is likely that local populations of some plant species will be seriously depleted or eliminated. Clearing the land may also greatly reduce populations of culturally or economically important native plants, such as traditional medicinal herbs. At the least, the available area for harvesting native plants will be reduced, thereby increasing the intensity of the harvest in the remaining land. Since much of the displaced land would also have been used for grazing, a greater number of animals may graze on lands not converted to farming. Overgrazing could destroy many populations of palatable plants, leading to increased soil erosion and the invasion of undesirable and unpalatable species, such as creosotebush (Larrea) and tumbleweed (Salsola).

Destruction of the native vegetation would also remove animal habitats. Those animals large enough to migrate out of the area would likely have difficulty in establishing themselves in areas already occupied by the same species. Food sources and nesting sites for migrant animals would also be destroyed. Large blocks of farmland, especially if fenced, could disrupt migration patterns of some large mammals.

Large-scale farming of guayule would also introduce new or additional pesticides into the region. Weed control during guayule stand establishment is a serious problem. Effective control requires considerable hand labor, or herbicides, or both, during the early growth years until guayule plants are large enough to shade out competing plants.

Guayule is subject to common plant diseases and to infestations by a limited number of insects. Growing guayule in monoculture near reservoirs of pests and diseases in wildstands and growing the crops on a five-year cycle will likely increase the incidence of plant diseases and insect infestations. Using good farming practices, including disease, insect, and weed control, should limit the problems.

No herbicides or insecticides have yet been recommended for guayule, and little is known about optimal application rates and schedules. Major concerns regarding pesticide applications to non-food crops are: 1) safety and health of applicators and field workers, 2) residues and drift problems that could contaminate nearby fields and communities, and 3) damage to indigenous plants and animals, especially pollinating insects and natural predators of guayule. Large areas planted in guayule may also disrupt host-predator-prey interactions and disrupt normal plant and animal populations. Guayule cultivation may also require fertilizers, growth regulators, and soil conditioners, but their application is still experimental. Runoff and contamination are potential problems associated with such practices. Because guayule is still an experimental crop, the potential magnitude of these hazards cannot be assessed.

Several methods of harvesting have been tried, but none has yet been shown to be superior. Mature shrubs can be harvested by undercutting, windrowing, and baling. These operations disturb the soil relatively little compared to traditional farming operations, but leave the soil uncovered. The roughness of the remaining soil surface should reduce erosion hazards. The shrub can also be topped (known as pollarding) after several years and the harvested portions loaded and baled. This would open the soil to some erosion, but the canopy would probably regrow quickly. Compared to annual crops where the soil is disturbed greatly every year, guayule production in a five-year cycle would require that only 20 percent of the acreage be disturbed by planting and harvesting operations.

Nursery operations require intensive land, labor, and materials use. The nursery area required even at the peak of the program is only in the hundreds of hectares, but the impact on resources would be considerable. Nurseries must be irrigated, fertilized, and protected with herbicides and pesticides. Wells would probably have to be drilled to supply most nurseries.

Seedlings could also be produced in greenhouses. This would require less space than nursery production but a greater capital investment and a higher level of operating skills. Research indicates that greenhouse seedlings should be hardened outside the greenhouses prior to planting. Impacts from the hardening operation would be similar to those from the nursery operation.

3. Processing: Most environmental impacts from processing resolve into two categories: consumption of limited resources and release of toxic materials.

Of all the materials consumed in the rubber extraction process, water is probably the only one likely to be a limiting factor. Water consumption is projected to be about 0.06 acre-feet of water per metric ton of rubber, or 300 acre-feet per year for a 5,000 metric-ton per year processing plant. About 2,700 acre-feet of water per year would be required to produce 45,000 metric tons of rubber. This amount of water would be adequate for growing about 218 hectares of corn (540 acres). Nearly 20,000 hectares are devoted to dryland corn production in the region, but the total irrigated area in the region is only 800 hectares.

Construction of the processing facilities would require an unknown, but probably large, amount of water for use in construction and consumption by contruction workers. Other materials used in the facility would have to be imported from industrial centers such as Monterrey and would have little effect on the region. Collection centers, transportation corridors, and processing centers would concentrate people and the impacts from their activities. Recreational use and gathering of materials from the wild could concentrate impact in a small area and lead to local depletion of resources and damage to ground cover and soil surface. Impacts of this nature occur with any concentration of people from a dispersed rural setting.

A guayule processing plant uses several chemicals which are flammable or toxic and plant resins themselves are potentailly hazardous. Operation of a plant would generate emissions and effluent during parboiling (volatile losses), dust and particulate during grinding of the shrub, caustic effluent with some resins during pulping, effluent with detergent and resins during washing, and effluent with solvents (acetone and hexane) during solvent extraction. Other volatile gasses would be produced in treating the rubber with antioxidants and other additives, during drying of rubber and bagasse, and during recycling and stripping of solvents for reuse in the extraction process. Losses of volatile solvents would require safety procedures that address toxicity and flammability. For safety and economic reasons these effluents would be recovered with little release into the air. Danger to local residents and plant workers would be small.

Disposal of caustic water used in pulping is a problem that must be addressed. It has been suggested that the effluent could be treated to neutralize the caustic water and used to irrigate nearby land, or used in the process of generating protein animal feeds from the bagasse. Both suggestions require more investigation. Ultimately, economics will dictate that the water and caustic agent be recycled, but until those processes are developed and installed, appropriate use or disposal of the waste water must be considered.

The large amounts of bagasse that would be produced as a byproduct might contain volatile solvents, depending in part on whether shrub or rubber is deresinated. Drying and storage might create a fire hazard if the bagasse were kept compacted temporarily prior to disposal or use.

Concentrated resins and release of volatile portions may pose a health hazard. The allergenicity of the resin has been established in laboratory mammals. However, during the operation of the pilot processing plant at Saltillo, there were no reports of respiratory, dermatological, or allergenicity problems. Dangers and health hazards inside the plant can be minimized by following standard industrial practices such as using respirators during operations that generate dust and volatiles, venting solvent vapors into the outside air, and using normal industry procedures for handling flammable and toxic materials.

In Scenario B greater volumes of potentially hazardous materials will be generated at a number of sites. The planned intense research program should quickly develop efficient procedures for recycling effluents and stripping solvents.

4. Summary: In sum, guayule commercialization would create several potential adverse environmental and occupational safety and health impacts. Harvesting wildstands would have negative or positive impacts on the guayule stands, other local plants, and wildlife, depending on how the harvest is managed. Destruction or serious depletion of regional guayule populations is a serious concern. Development of large areas of farmland would have a strong negative effect on local plants and wildlife and create a potentially serious erosion hazard on the exposed cleared land. This is perhaps the greatest potential negative environmental impact of commercialization. Processing shrub would create potential pollution and health hazards, but these could be mitigated by following standard industry procedures.

A large, and perhaps the greatest, environmental impact would be the concentration of people and increase in population in both the urbanized areas around the processing and collection centers and in the agricultural areas. This would increase the use of resources, especially water and firewood.

D. Impact Workshop Results

In addition to information gathered from documents, the TA team wished to gather first-hand responses from the people and agencies likely to be involved in the proposed guayule commercialization. This information confirmed the first analysis and also established priorities for the areas of concern expressed by the involved parties.

Interests and concerns of the parties-at-interest were gathered and assessed in three open meetings regarding a potential guayule agroindustrial system. Representatives of federal, state, and local government and research institutions attended. At the first meeting, an outline for the system, based on wildstand harvest in the Mazapil, was presented by the staff at CIQA and the TA team and discussed by the attending parties-at-interest. Potential impacts of the program were discussed at the second meeting. The third workshop was concerned with policy options and conflicts. Attendees of the impact workshop are listed in Table VI-3.

Table VI-3

NUMBER OF IMPACT WORKSHOP ATTENDEES

Federal Government		State and Local Government		Research
Federal District	Local			
5	10	4	4	3

The meeting had two primary objectives:

- determine principal areas of impact in the social, economic, environmental, and political sectors;
- establish the order of importance of the impacts in each area.

Each attendee was asked to list areas of impact and rank in order the four most important issues. Results of this first round were presented to the group and the definitions of categories of impact refined. After mutual agreement as to the meaning of each category, participants were again asked to rank potential impacts in each area and indicate whether the impact would be positive or negative or both. The results are listed in Table VI-4 in descending order of importance as determined in the second round.

Impact categories as defined by the participants are listed below.

<u>Economic</u>

Employment:	More jobs and greater diversity of jobs in the area.
Investments:	New investments by the guayule agroindustry in the region.
Other activities:	• Native plant harvest - guayule and agroindustry competition for labor with candelilla and ixtle industries. • Herding goats and sheep - competition for land (-), new source of food from bagasse (+). • Agriculture - competition for land for dryland farming. • Mining - competition for manpower.
Infrastructure:	Increased cost for greater infrastructure to support guayule agroindustry (-), benefits from greater infrastructure (+).

TABLE VI-4
IMPACTS IDENTIFIED BY PARTIES-AT-INTEREST*

	Number of Responses			Number of Responses			Number of Responses			Number of Responses	
	Round			Round			Round			Round	
Economic	1	2	Social	1	2	Political	1	2	Environmental	1	2
+ Employment	18	22	+ Immigration	16	29	Regional plans	9	16	- Process waste	7	18
+ Investments	14	17	+/- Services	11	19	Legal problems	9	15	- Densification	13	16
- Other activities	11	15	+ Commerce	9	15	Labor organizations	10	14	- Aquifers	8	14
+ Infrastructure	8	15	+ Work force	11	13	Producer organizations	2	13	- Impact on other plant species	4	10
+ Guayule harvest	11	12	- Inflation	9	8	Land clearing	4	5	- Land clearing	4	5
+ Economic feasibility	7	11	+/- Groups benefitted	9	7	LFA	13	0	- Land clearing	4	5
+ Rubber market	7	9	+/- Training	7	3				+/- Land access		
			- Intermediaries	8	2						

* Twenty-two attendees rank four most important impacts identified during discussion.
** Included in regional plans in Round 2.

Guayule wildstand harvest:	Poor overlap of distribution of harvesters and guayule.
Economic feasibility of processing shrub:	Level of development of processing technology.
Rubber market:	Competitiveness of guayule rubber with hevea rubber in an unstable and variable rubber market.

A qualitative summary of the results shows that the parties-at-interest considered the program to have strong positive economic benefits, mixed but slightly positive social benefits, and strong negative environmental impacts. Social impacts are nearly all related to economic issues in a social context. It is important to remember, however, that these workshops only considered guayule commercialization in the limited context of Scenario A. Impacts and especially priorities would probably differ for a program of the size and nature proposed in Scenario B.

E. National Focus

Guayule commercialization may have some effects on a national scale. The low level of development proposed in Scenario A essentially precludes widespread impacts; however, Scenario B proposed a much greater rubber and materials production that would have impacts on a national scale.

A primary result of the Scenario B program would be the annual production of about 45,000 metric tons of rubber and equal or greater weights of resins and bagasse. While Mexican guayule rubber production would be too small to affect the international rubber market, it would have an effect on Mexico's imports. Future costs of natural rubber are difficult to predict, but even assuming a low value of $1 US per pound, domestic Mexican production of rubber in 1990s would save nearly $100 million US each year. To this amount can be added the value of the resins and bagasse and to the extent that these products reduce imports, they would also contribute to improving the national balance-of-payments. However, large-scale guayule farming and shrub processing could increase imports if specialized farm equipment or processing machinery were not initially available in Mexico.

Mexico is also struggling with the problem of large numbers of rural residents migrating to the cities. It is clear that the impact of rural agricultural development or agrarian reform cannot be generalized or accurately predicted, but it is safe to say that either projected level of development would change migration patterns and that the size of the changes would reflect the magnitude of the program. Attempts to reduce rural flight to the cities and to maintain or increase rural productivity must be tailored to localities to produce relatively predictable results. Even under the best of circumstances, such predictions are often hopes.

Mexico is pursuing a policy to decentralize planning and operation of federally initiated and financed development programs. The success of a guayule program of either scale could serve as an example that might stimulate further attempts to decentralize federal control and strengthen local participatory and inter-institutional planning.

VII POLICY ANALYSIS

This chapter focuses on public policy issues that might accompany guayule agroindustrial development and on the agencies and groups that shape, implement, and endure policy in Mexico. Figure VII-1 graphically illustrates the course of this study leading to analysis of policy issues.

The preceding chapters cast two scenarios and analyzed their possible impacts in the existing technological and physical setting in which they might emerge. Any policies selected to affect guayule commercialization must be formed in consideration of their interaction in the social sphere; however, values and goals of a society are difficult to define precisely and are constantly shifting. This chapter attempts to define the salient, but previously undefined, social, economic, and political context in which the scenarios unfold. It first examines current policies from a national and regional perspective, and then identifies the interest groups, critical questions underlying the main issues at stake in the scenarios, and the existing instruments that comprise current policies that affect or might affect a guayule agroindustry. This examination reveals policy needs, policy conflicts, and institutional problems that might stimulate, accommodate, or restrict commercialization. The chapter concludes with a brief structural analysis of possible government options to deal with the technological challenge.

A. Context of Policy Formation in Mexico

Inasmuch as development programs are shaped by the social and political context of a country, it is useful to review some history and the growth of political and institutional frameworks in Mexico.

The political and attendant economic power in Mexico is in the form of a pyramid, with the President of the Republic at the apex. The

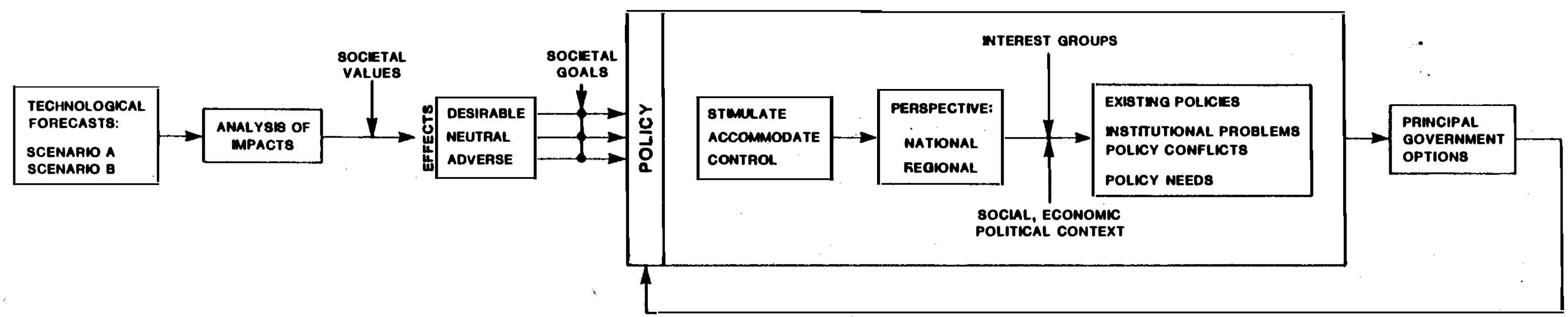


Figure VII-1. Structural Approach to Policy Analysis

President and the institutionalized office of the President, the head of the federal government, have great influence, extending to state and local governments. The President influences appointment of state gubernatorial candidates for his party and selects all ministry and agency heads. Federal dominance is achieved largely through control of economic and political support of all levels of government. Although federalism reinforces independence of state and local governments, they tend to act in close collaboration with the national government.

Mexican politics is dominated by one party, the Institutional Revolutionary Party ("Partido Revolucionario Institucional", PRI). The roots of the PRI are in the social and agrarian reform goals of the Mexican Revolution, which started early in this century. Numerous opposition parties exist and occasionally win local elections, but no party has threatened the PRI's dominance of federal control. The President is the leader of the PRI and strongly influences the selection of the party's next presidential candidate. PRI candidates have established a "pattern of perennial electoral victory" (Padgett, 1966) that has never been broken.

The President, who serves a single six-year term, the "sexenio," initiates most legislation in the National Congress and may issue decrees initiating actions; thus, development programs in general are federally sponsored and financed following top level bureaucratic planning.

Mexico is a country characterized by centralization. Historical and cultural precedents have contributed strongly to a centralized political structure supported by a concentration of wealth, population, educational and scientific institutions, planning for national and regional development, and the ultimate concentration of political power in one political party and one president. The importance of this concentration can best be viewed in an historical context. Friedman, Gardels, and Pennink (1981) analyzed what they termed the politics of space in Mexico. For nearly a century after achieving independence from Spain, Mexico remained fragmented. Spatial and sociocultural isolation augmented the proliferation of local personal governments, especially well represented by the hacienda system with its complete economic, military, and political organization. A key element in the system was the dependence on personal loyalties rather than commitments to a party or institution. The administration of President Calles in the 1920s initiated an effective unification of central authority. The interest of local powers was tied to the ascendancy of a new party, the National Revolutionary Party (eventually transformed into the PRI). In the stable decades that followed, industrialization proceeded around three centers: Mexico City, Guadalajara, and Monterrey. This growth occurred at the cost of increasingly unbalanced production and capital accumulation in the urban centers.

In the 1970s President Echeverria took steps to bolster the PRI image as bearer of revolutionary ideals of social and economic growth. Rural and agrarian reform increased in importance, and urban and regional development was incorporated into national policies. Economic activities and planning were decentralized through creation of provincial centers, but these centers were not autonomous, and their only function was to coordinate and channel federal programs and money. Results of many of these policies fell short of high expectations, while some policies failed entirely, largely due to lack of resources and authority to allocate state and federal funds or to lack of local infrastructure.

Early in his administration President Lopez-Portillo forged a policy articulated in the Global Development Plan, a scheme of centralized planning to guide development of heavy industry and of oil and gas exploration. Income derived from petroleum was to be canalized to solve problems in several sectors, including employment and natural resources development in marginal areas, basic foods production, and standards of health and primary services. Two additional policies called for political reform: the first promotes participation of minority parties in the political process; the second seeks to modernize public administration and decentralize its functions by transferring authority to the regional level.

Under the umbrella of the Global Development Plan there grew a multitude of centrally directed, but regionally applied projects and programs. A large portion of the programs were aimed at marginal groups, many of which live in arid northern Mexico. In the 1982 campaign, De La Madrid, in two of four major platforms, called for decentralization of federal activities and for democratic planning of federal projects and programs.

1. National level policies: In the mid 1970s the government recognized the need for more coherent and coordinated planning and policy development. The Mexican government established the Global Development Plan in 1979 as a comprehensive framework for planning the development of Mexico. The general goals of this plan are:

- Reinforce national independence;
- Provide employment and a minimum level of well-being;
- Promote a rapid, efficient and sustained economic growth;
- Improve the distribution of income among people, in different productive sectors, and in different regions.

These global objectives were to be met through the implementation of a series of policies concerning food production, the agro-forestry sector, control of population growth, and others outlined in many documents such as the National Agroindustrial Development Plan, National Plan for Industrial Development, and the Mexican Food System (SAM). All of these plans are designed to use oil production revenues to finance regional development, especially emphasizing the utilization of renewable resources.

With the establishment of the Global Development Plan the President also established the "Coordinacion General del Plan Nacional de Zonas

Deprimas y Grupos Marginados" (COPLAMAR) in the office of the President of the Republic, and established a National Plan for Depressed Areas and Marginal Groups, which is coordinated by COPLAMAR. The objectives of this plan are to promote actions at the national scale that will foster economic activity by creating jobs and social infrastructure to improve the well-being of social groups and areas that have not yet benefited from previous development policies.

Listed below are some of the most important elements of national policy that would affect the formation and operation of a Guayule Agroindustrial System (SAIG).

- Agricultural Promotion Law (LFA) and Productive Units. In 1981 a new agricultural law was introduced that drastically modifies political perspectives in the organization of land. This new legal instrument allows restructuring or integration of ejido and private land into large productive units. If implemented it will be one of the most important national policies directly related to guayule development alternatives.

- Food Production Policy. To seek sufficiency in basic food grains the Mexican Food System (SAM) was established. SAM programs to expand cultivation may well conflict with a guayule agroindustrial system by competing for investments at the regional level (non-food agroindustrial activity versus food production) and for the use of the land. Conflicts which may disrupt agriculture can have especially large effects in arid regions where the natural constraints imposed by soil, water, and climate already create high risk for dryland farming.

- Agroindustrial Development Plan. In 1977 the Ministry of Agriculture and Hydraulic Resources (SARH) started a program for agroindustrial development planning and evaluation. Potentially this could promote SAIG, but SARH has not included guayule in this program.

• National Plan for Industrial Development. This plan establishes development strategies for the industrial sectors, concentrating on those that can take advantage of the abundant supply of petrochemicals. These include the secondary petrochemicals such as synthetic rubber. The rapid growth of industries producing rubber goods, other than tires, has been an important element in the development plan.

• National Policy for Strategic Materials. Although no explicit strategic materials policy exists, it is implicit within plans such as the National Plan for Industrial Development. Economic development of the country during the next 20 years will depend to a great extent on the inputs of strategic materials, particularly natural rubber for fabrication of tires, and even more specifically tires for agricultural equipment, trucks transporting agricultural products, and buses. In Mexico there are a few explicit inter-sectoral policies for the planning of the supply of materials like iron and cement products. The National Petrochemical Commission indirectly develops strategies for balanced production of synthetic materials. There is no specific inter-sector planning policy for rubber, however.

• Natural Rubber Policy. The Rubber Trust (FIDHULE) was established by the Mexican Government in the 1970s. One of its functions is to promote natural rubber production, regardless of its source, and it has been responsible for the small amount of natural hevea rubber produced in Mexico. There have been many tentative programs for increasing the area cultivated for rubber production and proposals to reduce dependency on imported natural rubber, but to date these have not been put into practice. FIDHULE has not been able to build a solid technical base to produce a high quality natural rubber, and the users frequently complain about poor quality.

• Employment Policy. Job creation has been one of the most important policies since the Echeverria administration, high unemployment being one of Lopez-Portillo's principal concerns. The most conspicuous national employment policy resulted in the creation of COPLAMAR to administer the National Plan for Depressed Areas and Marginal Groups. Depressed area job stimulation policy has included strengthening of cooperatives, generation of work through road building projects and other infrastructure creation, industrial development, and reforestation and revegetation projects. These infrastructure improvement projects coupled with industrial development policies have prompted some large companies to settle in communities with relatively limited industrial development. For example, two automobile manufacturers (Chrysler and General Motors) recently opened large industrial facilities in Saltillo. If job markets in Monterrey and Saltillo, and consequently their attraction for immigrants, were to decline, regional projects and agroindustrial development policies in arid regions would affect job availability and migration patterns in greater proportion.

- <u>National Science and Technology Policies</u>. A particularly important event in 1970 was the establishment of the National Council for Science and Technology (CONACYT). CONACYT was charged with promoting and coordinating Mexico's scientific and technical development. CONACYT established specific science and development programs in national and regional development areas considered to have critical need, including arid lands.

Many of these policies are subject to rapid change as a consequence of sexennial changes in administration. Policy shifts can be especially rapid and sweeping due to the concentration of power in the presidency. Programs, such as COPLAMAR and SAM, directly joined to the Office of the President and not supported independently within a Ministry are particularly susceptible to cancellation.

Political reform is occurring in Mexico as a consequence of crises surrounding official power and the emergence of stronger opposition political parties. Impetus for political reform is especially strong when the inability of government to handle important socioeconomic problems is perceived to result from political corruption.

Regional expression of national policy lines has still not been generally manifested in powerful regional political groups. In particular, EONCAN and La Forestal still maintain their regional hegemony. Introduction of important development projects, with significantly large numbers of employees, could gradually modify the framework of behavior and political control, which has not evolved for many years. Whether new political institutions emerge will depend largely upon the ability of the PRI to absorb the emerging political powers, as it has done in the past. None of these reforms seem likely to alter the fundamental fusion of political and administrative entities in the PRI. Because of this close tie political changes are rapidly felt in agencies that administer federal programs.

2. Regional level policies: The most important policies which might directly or indirectly involve guayule development at state or regional levels are listed below:

- Regional Expression of National Plans. Almost all the programs mentioned at the national level have their expression through various dependencies and delegations at the state level where they are, in general, better coordinated. Planning and integration of the general perspectives of the federal budget operate through the state delegation of the Ministry for Programming and Budget (SPP).

New federal governments' desire for administrative reform and the pressure to decentralize and improve integration of planning at a state level stimulated creation of state planning agencies. The delegation of the SPP cooperates with the state government to form the State Planning Committees (COPLADES), generally the most important state planning agency. The SPP appears to be enlarging its influence in national centralization of planning at the expense of diverse Ministries. From this action emerges a fundamental conflict between the expressed desire to decentralize and the need for coordination of a multitude of overlapping and sometimes conflicting programs and projects.

Policies supporting state planning agencies may be important in either of the guayule scenarios. Because of this, it is important to identify those areas in which state planning could represent a benefit or a conflict for guayule. Several policy areas may interact significantly with a guayule agroindustrial system.

- Food Production. A number of policies at national, state, and regional levels affect food production in the northern arid regions of Mexico. Of special concern here are conflicts between national goals, the process of extending federal dependencies, distribution of federal funds, and state policies for soil conservation, water resource planning, land use, and local utilization of science and technology. National food production policies expressed through SAM and SARH are coordinated regionally through the state agricultural planning offices. Important policy conflicts can develop if national agricultural development schemes place food and fiber in competition for scarce land and water resources. Such trade-off considerations require evaluation of soil and water conservation of various crops, the natural constraints upon agriculture in the region, and the relative economic, social, and environmental advantages of traditional versus new cropping systems.

- Exploitation of Forestry Resources. For decades, two regional political organizations, the agency for candelilla promotion (FONCAN) and La Forestal, the ixtle organization, have controlled renewable natural resources exploitation. Candelilla and ixtle are the most important forestry activities, and although recently their exploitation has been coordinated by COPLAMAR, the two organiztions still define structures and mechanisms and strongly influence political views. Actions of FONCAN and La Forestal have been inconsistent during the last two decades, as various federal decisions have reduced interest in the exploitation of these resources while at the same time service distribution policies, especially related to health, education and commerce, have increased the number of ejidos dedicated to these forestry activities. These conflicting measures result from the lack of an integrated long-range plan.

One of the principal objectives of these organizations is political control of the rural sector, critical to achieving regional improvement. This influence is strengthened by the united front of political leaders clearly identified with the organizations. They are beginning to experiment, through the incorporation of the COPLAMAR programs, to gradually modernize production systems and administration, and to search for new uses of fiber.

- Industrial Development. Regional industrialization has depended on companies' interests in establishing in large communities such as Saltillo and on state incentives to attract investment. Manpower availability is perhaps one of the most important factors in the implementation of large agroindustrial projects. Migration in response to industrial development in Saltillo, for example, has far exceeded the number of jobs created by that development, showing that development projects can have important impacts on human settlements and that national policies and their implementation at the state level must be coordinated and mutually supportive.

- Policies for Social Concerns and Benefits. Policies to assist groups living in marginal conditions are coordinated by regional COPLAMAR delegates working with the Mexican Institute of Social Security (IMSS) and Ministry of Human Settlements and Public Works (SAHOP). COPLAMAR and the National Company for Price Support of Staples (CONASUPO) are intensifying their efforts to establish food supplies and warehouses. Although it is not a formal, much less an explicit, policy one of the most frequently mentioned topics in considering agroindustrial development is the flow of benefits. Their historical distribution through social and political structures has, without doubt, been profoundly unjust. Frequent use of subsidies to direct resources or benefits and avoid the diversion of investments to powerful groups or persons represents policy actions designed to correct these misdirections of benefits. One of the most important alternatives to improve distribution of benefits could be to generate permanent jobs in agroindustrial projects. In these projects, where resources are widely distributed, product transportation is one of the principal economic activities, and therefore one of the most important controls on the flow of benefits is control of product transport.

- Employment Policy. High levels of unemployment have represented an acute problem in the Mazapil Region. Job creation in depressed regions through employment programs has been one of the central policy concerns of COPLAMAR and other federal programs. Employment policies which are concentrated in specific areas or communities can exacerbate migration and settlement problems, so employment programs must consider overall regional impact.

- Science and Technology. CONAYCT established specific programs in areas critical for national or regional development. Arid regions were considered to be critical problem areas.

In 1974 the Applied Chemistry Research Center (CIQA) was founded as a part of CONAYCT's policy to encourage specialized regional centers of scientific excellence. In 1976 CIQA was designated, by Presidential Decree, as a Decentralized Public Institution as part of a decision to decentralize and institutionalize research and development. CIQA was directed to do basic and applied research on the development of arid lands' natural resources and undertook scientific and technological studies of production based upon plants native to Mexico's arid lands. These investigations produced significant technical advances such as the aqueous extraction process for guayule rubber.

3. Arid lands policy: Development of arid and semiarid lands has been an enduring concern of the Mexican government. Plans and programs have stressed land reform, investment, and technical assistance for these regions. At the same time, the government has searched for promising development strategies by supporting research and development applicable to arid regions. During the 1950s and 1960s, programs in arid regions

were established in the Departments of Agriculture and Hydraulic Resources (SARH), Public Works and Human Settlements (SAHOP), and Education and Health (SEP). In 1970, policy for arid lands development planning was embodied in the National Commission for Arid Zones (CONAZA). In 1972, CONACYT and CONAZA jointly initiated renewable resources development projects in Mexico's arid land regions.

The ongoing guayule research in Mexico has, since its initiation, formed part of the activities or strategies of this policy and in this way was expected to be an element in regional development. However, there are no explicit regional policies, no clear long-term strategies for development and investment in these regions, and the regional role of a guayule project is still unclear. The lack of an integrated regional development policy has hindered the acceptance and implementation of projects such as the guayule agroindustrial system.

Intensification of COPLAMAR programs added more complexity to the rural assistance program without adding a regional policy framework. First projects introduced or expanded medical services to the rural areas and later efforts continued reforestation programs. These first efforts reflect national policy with a huge impact at the regional level. Particularly during the last few years, activities and programs were designed to create jobs, and, although these were not always permanent jobs, they generated large increases in income even though they paid the legal minimum salary. Another potential benefit of the COPLAMAR programs is that there now exists in the region a precedent for programs which generate jobs, although to a great extent they are subsidized.

B. Analysis of the Issues

Table VII-1 (p. 213) summarizes four policy areas surrounding guayule commercialization under Scenario A: identifiable issues, critical questions, parties-at-interest (or actors) and existing policy instruments and studies forsmall-scale development based on wildstand shrub harvest and a single processing facility. The critical question arose during public meetings.

Table VII-2 summarizes policy needs and conflicts for Scenario A. Further efforts by the research team refined and extended the tables. Table VII-3 and VII-4 address Scenario B, large-scale development based on extensive dryland farming and four additional processing facilities. The latter information was derived by the research team, and was based on a logical extension of the first scenario. Because sustained harvest of wildstands is a part of both scenarios, policy considerations shown in Table VII-1 apply equally well to Scenario B. These considerations are not repeated in Table VII-3 to avoid repetition.

The tables are keyed to identified issues. Fourteen issues in Scenario A are lettered A through N; these issues are repeated in Scenario B and four additional issues are identified with the letters O through R. The first column in each table contains the critical questions identified by the actors, which are linked to perceived issues. The number of each question links it to relevant agencies and parties-at-interest in column two and to policy instruments and studies in column three. Unnumbered entries in columns two and three concern the entire whole issue rather than one individual question within the issue.

1. Scenario A: There are two parties-at-interest that are involved, although to different degrees, with all the issues surrounding SAIG: the rural residents of the guayule region and the Office of President of the Republic. The residents will be affected by any policy (or the lack of a new policy), and the Office of the President will be the ultimate arbiter of change for any natural resource policy in the area, whether the effects and scope are regional or national.

The following, are discussions of the issues listed in Table VII-1 (p. 213) and of the policy needs and conflicts identified in Table VII-2 (p. 217).

A. Economic Feasibility: The issue of economic feasibility involves only a few actors. There are relatively few policy instruments concerning this although a large number of studies have been conducted which provide good data on which to base policy. Critical policy elements might be rubber import taxes and natural ruber prices in the national market and determination of the profitability criteria for this kind of project, which must eventually be self-supporting. Conflicts resulting from competition among potential rubber producers and conflicts between industry and federal agencies are expected. Conflicts may arise over changes in natural resource policies. The need to support SAIG with import taxes on rubber or by other indirect subsidies may bring into conflict the current policies permitting subsidies to resource-based industries and policy requiring economic self sufficiency in federal projects.

B. Regional Economic Development. Regional economic development has two separate policy aspects: direct assistance and indirect benefits resulting from the increased cash flow or from the positive precedent the project sets. The establishment of a guayule agroindustrial system would create a relatively small number of jobs, but it would accelerate regional investment and increase productivity in the agroindustrial sector. It would also increase the need for other agencies to provide public services, especially water, transportation, and communication. Although there has been a detailed study of investment needs for the industrial plant, there is no integrated or general investment policy for natural resource or agroindustrial development.

One of the important local issues that may require policy intervention to assure achieving the intended goal is directing to rural areas the tax revenue generated by industrial development. Important tax sources will be salaries for professionals, technicians, administrators, and executives. However these positions are frequently concentrated, due to administrative structure, in larger cities where impacts from increased taxes are diminished by the size of the existing tax base. This is true of La Forestal and FONCAN inasmuch as administrative posts are concentrated in Saltillo and technical support posts are in other cities. The best organizational strategies to direct the flow of taxes at the local level could include policies to further decentralize administration and other economic activities.

C. Distribution of Benefits. Distribution of benefits resulting from developing and operating a guayule agroindustrial system largely concerns improvement or creation of public services. The obvious policy instruments to direct benefits and to assist ministries involved with health and welfare are already in place. What is needed to insure this distribution are administrative decisions to direct programs to these rural areas. This could be imbedded in an instrument creating the agroindustrial system with a work contract for collective organizations ("collectivos") that specifies benefits for guayule harvesters.

D. Structure and Capability of the Guayule Organization (SAIG). The structure of SAIG and its ability to operate effectively is a major concern to almost all of the actors in government, in industry and in the private sector. It will be a critical issue of any presidential decision to promote a guayule agroindustry. Each major group may wish a controlling influence in the organization to maximize their benefits. Harvesters will wish to maximize their wages and the number of jobs and to assure continuity of SAIG; the entity responsible for processing shrub will wish to control the processing operations to assure the highest possible quality rubber and will want an assured supply of clean, high quality shrub to process. The creation of SAIG as a mechanism for social improvement may cause minor conflict between the rubber industry, which will have to purchase the rubber, and the federal government which must promote social welfare as well as business. However, the quantity of rubber produced will be small enough to be easily absorbed by the producers of rubber products that do not require the highest quality rubber. Management of the various sectors of the agroindustry can be modeled after private industry, quasi-government companies, coopertives, "fideicomisos", or state planning agencies. The Federal Work Law defines how workers may be involved and in what ways they must share in the profits of companies; however, these regulations may not apply to the new agroindustry. This implies a need for a Presidential decree defining SAIG, its objectives, the participants, and perhaps the means to reach the objectives.

E. Institutional Conflict/Coordination. No technology is institutionally neutral so the likelyhood of institutional conflicts will depend in large part on how adroitly the structure of SAIG accomodates the desires of the involved actors, and how well SAIG coordinates with the multitude of agencies and groups with which it will interact. This may be an important issue if SAIG operation crosses state and jurisdictional lines, as it is likely to do.

Several areas of conflict are likely to arise because of the wide geographic distribution of the project: agencies representing the harvesters, (CNC, FONCAN, La Forestal) may be in conflict with the private small property owners' agency (CNPP) in disputes over harvest of the diffuse resource or payments for right to harvest shrub. Because the processing facility may be located in Zacatecas while shrub is harvested in adjacent states, especially Coahuila, jurisdictional disputes may arise. Collection, transportation, reforestation, and perhaps negative environmental impacts may occur in one political jurisdiction while the main benefits from processing occur in another. The establishment of support infrastructure, especially roads, with the accompanying increase in traffic, will require regulations which may conflict with state tax and environmental policies. The intersectorial and interstate nature of SAIG would require coordination with agencies that provide regional service. Social service agencies may have different agreements with different states while interagency agreements, such as those made with COPLAMAR, may conflict with the desires of the state planning agencies (COPLADES). A major policy need is to define the roles of the federal, state, and private sectors.

F. Integration of Guayule with Other Renewable Natural Resource Activities. Specific conflicts may be expected between promoters of activities dependent on ecologically intertwined natural resources: harvest of candelillia and ixtle, farming, and grazing livestock. The issue is volatile because the livelyhoods of many rural residents are precariously dependent on these marginal resources. There are no policies directly dealing with this issue, and promotion of guayule may be viewed as detrimental to other natural resource-based industries' activities. For this reason SAIG should be coordinated with these other activities or at least integrated by formation of policy considering regional effects.

G. Land Tenure. The issue of land tenure is like a live coal lying in tinder: it may be quiescent, producing a little heat for a long time, but it may suddenly flare. Mexico is polarized over this question in the political and theoretical arena, and SAIG may be regarded as a testing ground for a real confrontation over agrarian reform. A driving force in this issue is to attempt to reconcile the need for increased agricultural output with the demand to sustain revolutionary land reform ideals of returning land control to the peasants.

Resolution of conflicts involving land tenure policies that address availability and ownership of guayule is critical to the success of SAIG. Land on which guayule grows has little economic value and so is not in much dispute; however, if a guayule agroindustrial system is implemented, these nearly idle, marginal lands will rapidly increase in value and may become sources of conflicts over ownership or control. Resolution of these conflicts would be vastly important to an agency trying to assure a reliable and continuous supply of guayule.

The long history of social and ecological abuse that characterizes exploitation of natural resources would probably be repeated if there were no legal instruments to guarantee the continued flow of guayule shrub regardless of where the shrub is found. This instrument must assure remuneration to the land owner and reforestation of the harvested land to preserve guayule populations. The Agricultural Promotion Law (LFA) may in part support the formation of a more adequate organization to assure resource availability, avoiding from the outset the traditional conflicts of land and resource use. Representatives from the Ministry of Agrarian Reform (SRA), Ministry of Water and Hydraulic Resources (SARH), involved ejidos, from private property owners, and from states and state planning agencies should participate in formation of a broader approach to the issue. Policy should cover two areas: the land and soils, and the renewable resources.

H. Migration, Manpower, and Employment. There are several issues that are so highly interrelated that it is often easier to discuss them together: employment, manpower availability, and migration. Employment is the central point of Scenario A. The harvesters are directly affected by this issue, but there are many who may benefit or be harmed indirectly. Employment is often the keystone in a decision to migrate to cities or to the United States, and since SAIG may act as a precedent for regional employment programs it is of interest to national, regional, state, and city planners. The few laws or policy instruments that address this issue, such as the Minimum Wage Law, Federal Work Law, and employment and production objectives of SAM and COPLAMAR, deal with general standards. No instruments relate guayule to regional or local employment policies and none coordinate guayule program objectives with peasants' needs for jobs, job security, and an adequate wage.

It has been demonstrated frequently that employment alone is not a total solution to local or regional economic problems. Clear policy in the first several years of the project should anticipate the effects of rapid local inflation due to the external income. This income may result from the high salaries of technicians and administrators. The policy should also seek to reduce the effects of the boom-town phenomenon, perhaps diluting these effects by offering permanent sources of public services, better transportation, and increased commerce. The policy should take into account the overall goals of employment generated through secondary sources such as commerce in Cedros, transportation, and support services. It is important to consider the impact of short-term jobs during the first four or five years of the project. Permanent jobs will pay minimum wage and thus may displace the workforce in activities which pay poorly and are at the lowest level of the social value order, such as gathering candelillia and fiber for ixtle. Most workers seem to want jobs in the industrial sector of the agroindustry; pay is better, the work is generally less demanding physically, and it confers a higher social status.

Migration often results from economic forces, but the way in which SAIG will effect migration is uncertain. The larger the industry and the better the economic incentives, the larger the effect is likely to be. No migration policy can be directly implemented but other policies can affect migration.

I. The Role of Labor Organizations. Several labor organizations are interested in the role that labor will play in SAIG: FONCAN and La Forestal, (which already represents some plant harvesters) and national unions such as the CNC and CTM. The Ministry of Labor and Social Welfare could help define the role of a labor group in SAIG.

Labor organizations in Mexico have several significant roles. They are agents to bargain for wages and working conditions, and they represent their members politically. This political strength can bring social services and benefits to the region. The labor organization is also a mechanism for trading political favors. An organization representing peasants and workers that has their strong and vocal backing can gain significant bargaining power at a regional or even a national level. The first objective of a group representing guayule workers might be to get a Presidential decree establishing a guayule collective work contract. There will be conflicts among FONCAN and La Forestal and existing or proposed organizations which want to represent guayule workers. Over recent decades, the two local natural resource unions have not shown an interest in improving productivity, conserving the basic resources, or improving work standards. They have not been able to attract investment, but have had some success in bringing social services to the area. Which labor organizations represent workers in a guayule agroindustry may depend on the organizational structure of SAIG. Existing political parties and labor organizations could have a role in the guayule agroindustry, especially if ejidos organize shrub harvest; or a new organization could combine harvesters and industrial workers. The latter labor structure would look after only the interests of workers in SAIG.

J. Infrastructure Development. Some services will be provided as a result of the implementation of SAIG. Some infrastructure improvements will be necessary to set up the industrial facility and to transport shrubs, rubber, and supplies. These would have to be provided for in the agreements to establish SAIG, and should include water, roads, utilities, and communications at the industrial center and the collection centers. Medical services and other public assistance in food, education, and housing would be sought in the political arena. Competition among federal agencies for funds for other projects and for jurisdiction in SAIG can be expected.

K. Environmental Pollution. Environmental pollution is not expected to be a serious problem in Scenario A. Some hazardous materials will be used in processing and some will be generated, but the amounts of both will be relatively small. Current laws cover workers' health and environmental degradation only in a general way, so specific standards may have to be established. Environmental and worker protection will depend on enforcement of the laws.

L. Ecological Concerns. Ecological concerns in SAIG mainly relate to depletion of the resource, although there is a possibility of soil erosion. The small scale of the harvesting program should have little detrimental effect on the land. The impacts of harvesting guayule are not expected to be as great as the impacts from current plant harvesting that occurs sporadically in the region. Protection of guayule stands will require setting and enforcing standards for harvesting, initiating reforestation, and monitoring populations. Precedents for all of these exist in recent research. Implementation and enforcement of the rules and standards will be a major challenge. A policy conflict may arise if the economics and short-term needs of SAIG conflict with schedules for sustained yield harvest and high cost of reforestation.

M. Management of Soil and Water Resources. Although water is critical to the operation of the processing facility, the use of groundwater resources is considered a minor issue in Scenario A. Use of large amounts of water for non food agriculture or industry could be politically volatile; however, nurseries for reforestation and industrial processing should use very little water.

N. Science and Technological Capability. Is the level of technology and scientific knowledge high enough to enable an accurate assessment of the chance of success of the SAIG undertaking, and does the skill exist to successfully complete the project? This last issue is an underlying concern of all actors in this scenario, but it is of special concern to the scientific groups whose reputations are at stake. Their own studies, reviewed by outside agencies, answer these questions in the affirmative. Where specific answers are not at hand, the scientific community has the ability to seek and find them. All that is needed is the desire to seek these answers and the funds and staff to allocate to the work.

Table VII-1

POLICY ANALYSIS GUAYULE WILDSTAND HARVEST
SCENARIO A

ISSUES AND CRITICAL QUESTIONS	AGENCIES AND PARTIES-AT-INTEREST	EXISTING POLICY INSTRUMENTS AND STUDIES
A. Economic Feasibility		
1. Will the price of guayule rubber be competitive with hevea and synthetic rubber?	1. Mexican rubber industry; FIDHULE; PEMEX; SPP; SECOM; SEPAFIN	1. Taxes on imported rubber; marke analysis (CONAZA, CIQA, CONACYT
2. Will SAIG be self-supporting?	2. SPP	1,3 Feasibility studies (CIQA, CONA CONACYT); preinvestment studies (CONAZA, CIQA); studies of guay rubber and byproduct use (CIQA, CONAZA); detailed engineering a rubber production cost studies (CIQA, CONAZA); wildstand inven tories, studies (CIQA, CONAZA; Native Plants)
3. What is the appropriate scale for the processing plant?	3. SARH; CIQA; CONAZA; CONACYT	2. Self-sufficiency requirement fo all federal projects.
4. Will industry be required to buy Mexican guayule rubber?	4. Mexican rubber industry; FIDHULE; SECOM	3. Studies on sustainable yield harvest (IIASA, this study)
5. What will be the impact of inflation on guayule rubber cost and devaluation?	5. SPP; SECOM; Hacienda	4. Hevea purchases required by government (FIDEHULE)
		5. None
B. Regional Economic Development		
1. Will reforestation concentrate the project in one area?	1. COPLAMAR; CONAZA; local residents	1. COPLAMAR Regional Plan; Soil an Water Conservation Law (SARH)
2. What will be the impact of SAIG on other natural resource economic activities?	2. COPLAMAR; CONAZA; FONCAN; La Forestal; SRA; SARH; SPP; Governors of Coahuila, Zacatecas	2. None
3. How many will be employed in harvesting and how many in processing?	3. Peasants; workers; STPS; COPLADES	3. Federal Work Law; Feasibility studies (CONAZA, CIQA); Agricultural Promotion Law
C. Distribution of Benefits		
1. Will potential benefits flow to targeted groups and communities?	Peasants; workers; labor unions; CONAZA; COPLAMAR; IMSS; SRA; SARH; SAHOP; STPS	1. Federal Work Law
2. Who besides harvesters will benefit from guayule development?		2. Social Security Law
3. How will prices for guayule shrub be determined?		3. None
4. Who will own and operate the transportation system?	4. "Intermediaries" (middlemen); private truck operators	4. None

Table VII-1 (continued)

POLICY ANALYSIS GUAYULE WILDSTAND HARVEST
SCENARIO A

ISSUES AND CRITICAL QUESTIONS	AGENCIES AND PARTIES-AT-INTEREST	EXISTING POLICY INSTRUMENTS AND STUDIES
D. Structure and Capability of the Guayule Organization (SAIG)		
1. How will the organization be structured?	1. President; federal agencies with regional development programs; ejiditarios; Mexican rubber industry; FIDHULE	Federal Work Law
2. Will the target groups participate in the design, administration, and earnings of the project?		Enabling law for para-state companies and COPLADES are examples of ways to form and structure a guayule organization
3. How can quality control of rubber and byproducts be maintained?	2. Local residents	Enabling laws for cooperatives and Fideicomisos
	3. SAIG; Rubber industry	
4. What are the implications of a processing plant shutdown?	4. Local residents; all development agencies	
5. What will be the role of the rubber industry?	5. Rubber industry	
6. Who will operate the processing plant?	6. SPP; SRA; SARH; STPS; SEPAFIN	
E. Institutional Conflict/Coordination		
1. How will ejidos be involved?	1. Ejiditarios; SRA	1. Agricultural Promotion Law
2. Will conflicts arise among public sector agencies that participate in the project?	2. All federal agencies involved with regional development and rubber industry	2. COPLAMAR agreements with federal agencies
		3. None
3. How will political parties influence the operation of SAIG?	3. All political parties	4. None
4. What will be the impact on guayule development of a change of federal administration?	4. All parties concerned with guayule development	5. Decrees creating COPLADES
5. Will there be conflict among municipios and states about implementing the project in one region?	5. Local and state governments; SPP	
F. Integration of Guayule With Other Natural Resource Activities		
1. Will guayule development compete with herding in the region?	1. Local residents; La Forestal	1. None
		2. None
2. Will guayule development compete with the candelilla and ixtle industries?	2. FONCAN; La Forestal; candelilla, ixtle harvesters	3. None
3. Will guayule development compete with small-scale farming?	3. Local residents	

Table VII-1 (continued)

POLICY ANALYSIS GUAYULE WILDSTAND HARVEST
SCENARIO A

ISSUES AND CRITICAL QUESTIONS	AGENCIES AND PARTIES-AT-INTEREST	EXISTING POLICY INSTRUMENTS AND STUDIES
G. Land Tenure		
1. How will conflicts among ejidos and private property owners over resources use and land control be resolved?	1. Ejiditarios; small private land owners; SRA	1. Agricultural Promotion Law; SRA policies
2. Will guayule commercialization affect the implementation of the LFA?	2. Federal government; political parties; local residents	2. Agricultural Promotion Law
H. Migration, Manpower and Employment		
1. How will migration be affected?	1. Migrants; local residents; employers in large Mexican cities; U.S. Immigration and Naturalization Service	1. Minimum wage law; programs to improve standard of living in Mazapil
2. Will SAIG provide secure jobs with an adequate wage?	2. STPS; local residents; migrants; National commission on minimum wages	2. Federal Work Law; minimum wages law
3. Will there be competition between the local populations and migrants, and if so, how will the problem be solved?	3. Local residents; religious groups	3. None
4. If campesinos are involved in guayule project, will this affect the goals of SAM?	4. SAM; peasants; SARH	4. SAM objectives
I. The Role of Labor Organizations		
1. What will be the role of ixtle and candelilla organizations in SAIG?	1. FONCAN; La Forestal; campesinos; CNC	1. Statutes of FONCAN and La Forestal, Candelilleros and Ixtleras (CNC)
2. Will labor organizations be created for harvesting or processing guayule?	2. CNC; CTM; workers; CCI; STPS	2. Federal Work Law
J. Infrastructure Development		
1. What additional social services will be required?	Local residents; COPLAMAR; COPLAMAR agreements; IMSS; SEP-CONASUPO-SAHOP-STPS; SSA; SECOM	Social Security Law
2. Will SAIG stimulate infrastructure development and improvement?		INFONAVIT
K. Environmental Pollution		
1. Can process wastes be efficiently recycled?	1. CIQA; CONAZA; CONACYT; local residents	1. Studies of residual process water quality
2. Will process wastes contaminate surface and groundwater?	2. Local residents; SSA; SARH; CONAZA; SAHOP	2. Federal Water Law; Environmental Protection (SSA); Acuario Program (CONZA)
3. How will the health and safety of guayule workers be protected?	3. Local residents; SSA; IMSS; STPS	3. Federal Work Law

Table VII-1 (continued)

POLICY ANALYSIS GUAYULE WILDSTAND HARVEST
SCENARIO A

ISSUES AND CRITICAL QUESTIONS	AGENCIES AND PARTIES-AT-INTEREST	EXISTING POLICY INSTRUMENTS AND STUDIES
L. Ecological Concerns		
1. What will the impacts of reforestation be?	COPLAMAR; CONAZA; SARH; local residents; SAIG	1. COPLAMAR reforestation programs; Environmental Protection Law (SS Soil and Water Conservation Law (SARH)
2. How can harvest of young plants be prevented?		2. None
3. What is the ecological impact of harvesting such a large amount of guayule?		3. Environmental Protection Law, (S Soil and Water Conservation Law (SARH); National Plan to Combat Desertification
4. Will guayule reforestation maintain wildstand populations?		4. Ecological studies (CIQA, CONAZA
M. Management of Water Resources		
1. How much water will be required for processing and reforestation stock in nurseries?	SARH, resident farmers	Studies of nursery production, UAAAN
N. Science and Technology Capability		
1. Does the technology exist for exploiting the resource?	1. CONAZA; CIQA; CONACYT; local residents; rubber industry; Mexican federal government	1. CONAZA; CIQA, and CONACYT studie on process engineering, plant siting, and project feasibility
2. Can it be determined if there is a sufficient resource to provide a sustained supply?	2. CONAZA; CONACYT; CIQA; local residents	2. CONAZA, CIQA, CONACYT, IIASA guayule inventory studies

Agricultural Promotion Law	Ley de Fomento Agropecuario
Cooperatives Law	Ley de Cooperativos
Environmental Protection Law	Ley de Protecion Ambiental
Federal Water Law	Ley Federal de Aguas
Federal Work Law	Ley Federal del Trabajo
Fideicomiso Law	Ley de Fideicomisos
Minimum Wage Law	Ley de los Salarios Minimos
Quasi-governmental Organization Law	Ley de Organismos Paraestatales
Social Security Law	Ley de Seguro Social
Soil and Water Conservation Law	Ley de Conservacion del Suelo y Agua

Table VII-2

POLICY NEEDS AND POTENTIAL POLICY CONFLICTS
SENARIO A

A. Economic Feasibility

- Conflicts may result from natural resource policy shifts (from subsidy to self-sufficiency).
- Federal assistance programs may conflict with private industry desires and operations.

B. Regional Economic Development

- Create a program to implement, manage, and monitor guayule program as part of a regional natural resource-use program.
- Competition among agencies over priorities and management of regional development programs.
- Clear definition of how regional development programs and LFA will be implemented.
- Integrated regional investment policy.

C. Distribution of Benefits

- Federal/private disagreement over where benefits should flow.
- Need a Collective Work Contract

D. Structure and Capability of the Guayule Organization (SAIG)

- Presidential Decree: Recommendations for SAIG defining involved parties and their responsibilities and goals.

E. Institutional Conflict/Coordination

- Resolution of roles of private/federal sectors in planning, implementing, and operating SAIG.
- Policies for integrated management of forestry resources.

F. Integration of Guayule With Other Natural Resource Activities

- Coordination of natural resource development program.
- Promotion of natural resource industries in ways that are detrimental to other such industries.

G. Land Tenure

- Conflicts among land owners, land holders, and federal agencies over implementing LFA and guayule program.

H. Migration, Manpower and Employment

- Coordination of guayule program objectives and campesino needs for job security, and adequate wage levels.

I. The Role of Labor Organizations

- Integration of workers' activity in wild plant harvest and representation of industrial workers.
- Collective Work Contract.
- Competition among labor organizations for representation on SAIG.

J. Infrastructure Development

- Regional development plan integrating SAIG and infrastructure support.
- Competition among federal agencies and programs for funds.

K. Environmental Pollution

- Definition of health and safety standards for harvesters and industrial workers.
- Economic feasibility of guayule program conflicts with cost of implementing health and safety standards.

L. Ecological Concerns

- Create a sustained yield guayule harvest program based on monitoring of resources and a reforestation program.
- Conflict between goals of SAIG and resource and environmental protection laws (due to technological or ecological limitations) of harvest and reforestation program.

M. Management of Water Resources

- Competition for water--human consumption or food production versus for guayule production.

N. Science and Technology Capability

- NO policy conflicts foreseen

2. Scenario B: Most of the issues identified in Scenario B are the same as those identified in Scenario A, but there are some additional issues that arise from the more intensive and extensive nature of SAIG in Scenario B. Table VII-3 (p. 225) shows the issues and questions, parties-at-interest and existing policy instruments and studies relevant to Scenario B. Table VII-4 (p. 231) summarizes policy needs and conflicts associated with Scenario B. The components of these issues, the critical questions, often differ substantially from the questions that arose around agroindustry based on wildstand harvest. Existing policies and studies generally apply equally to both scenarios. The scenarios differ in the actors associated with the issues or the level of the actors' involvement in an issue; perhaps they differ most strongly in the policy conflicts and potential policy needs. Because Scenario B has a national perspective the policy conflicts and needs in federal agencies are pronounced. Some local issues, especially land tenure, assume national proportion because they set a precedent for federal programs.

A. Economic Feasibility. The economic feasibility of SAIG in Scenario B is determined on an entirely different basis than in Scenario A. To be economically acceptable a relatively large-scale guayule rubber program must be competitive in the international rubber market and must be a better investment than a program to increase domestic Hevea production. Feasibility determinations would substantially involve federal agencies dealing with industry and commerce. At present there are few studies that pertain to this issue and only a few general policies regulating hevea rubber purchase in Mexico.

B. Regional Economic Development. Large-scale guayule farming could be viewed as a mechanism for innovation and profound change through a gradual increase in productivity, mechanization, and sophistication in agricultural production and processing. This type of development would require constant interactions among local and federal agencies and groups to achieve the production goals without exceeding social constraints. COPLAMAR and CONAZA projects address some aspects of regional development of natural resource use, but no integrated regional resource policies exist.

C. Distribution of Benefits. There is a possibility of widespread deleterious effects on peasants and rural residents if the history of large government rural development projects is any guide. Distribution of benefits to the most needy groups will depend in large part on how the program is structured and administered. One major question will concern the degree of mechanization in SAIG. Mechanization may not benefit small farms but would probably increase per hectare-productivity. Policies promoting rapid development of efficiently run productive units may conflict with policies promoting development of local farms and local self-sufficiency. No policies exist to guide these efforts.

D. Structure and Capability of Guayule Organization. As in the first scenario the structure of SAIG and its ability to successfully carry out its objectives is critical to guayule development. There is no policy direction for such an undertaking. Intensive planning to design SAIG is more important in Scenario B than in the first scenario due to greatly increased complexity.

E. Institutional Conflicts/Coordination. Coordination of SAIG and the conflicts arising among institutions for influence or control of its activities looms as a problem of magnitude. Because SAIG is a large project at a national level federal, state, private, and other agencies will compete and will promote potentially conflicting objectives; because the project will dramatically affect the guayule region, local institutions may well have goals that conflict with business interests and national goals of SAIG. Many institutional conflicts can be expected simply as a result of the complex nature of the productive chain and the need for intimate coordination of its parts. No specific policy directives exist to form an agroindustry.

F. Integration of SAIG With Other Renewable Natural Resource Activities. Although the acreage of guayule farms is to be increased gradually over a number of years, the total impact on other resource activities in the area will be great. There will be a profound disruption, perhaps even a replacement by guayule of other harvesting and grazing activities. These disruptions will not necessarily be direct. If SAIG provides more jobs, better wages, or better working conditions, labor will be drawn from the other resource based industries as surely as if the land base or the resources were taken by SAIG. The Rangeland Reclamation Policy promotes revegetation of rangelands. Some lands might be left ungrazed if herders work in SAIG. Policies promoting these projects would have to coordinated with SAIG. No policies currently exist to support such coordination.

G. Land Tenure. Potentially major conflicts over land tenure are anticipated in large-scale guayule farming. Such an enterprise requires a high level of coordination and integration of production and processing capacity. Productive units that combine ejido and private lands and leasing of ejido lands to private interests in accordance with the LFA will be viewed by some as an abandonment of revolutionary ideals of agrarian reform. Participation of ejidos in SAIG in a way that insures protection of their lands and rights could resolve this issue, but creation of such a policy is likely to be very difficult.

H. Migration, Manpower and Employment. There are many studies by federal agencies and research institutions that document local responses to changes in jobs and economic opportunities, but out of this has emerged no coherent understanding of the process. It is still impossible to predict what effect regional programs will have on migration. A large program that employs thousands and generates considerable money flow will certainly attract workers from within the area and from surrounding regions. A large labor pool and high demand for relatively few jobs tends to lower wages. This creates a potential conflict between desire to make SAIG profitable, or more profitable, and the efforts to improve wages and welfare of the rural workers.

I. The Role of Labor Organizations. As in Scenario A, strong competition will emerge between existing labor groups representing rural workers, La Forestal and FONCAN, and National unions, including the National Confederation of Small Landowners (CNPP). National unions may show more interest in taking a role in SAIG under Scenario B farming-based operation due the number of potential members. The number of potential new workers is small compared to the size of national unions, but the importance of labor representation will be great because the program sets a precedent for unions in a new resource-based projects. There are no policies concerning the role of labor organization in SAIG.

J. Infrastructure Development. A large-scale agroindustry will require extensive infrastructure to support its activities. This will probably exceed planned development and be a strong impetus for further commercial and community growth in the region. Such rapid growth will change the rural nature of the area, and this may be unacceptable to some local residents. There are no policies designating lead agencies or organizing agencies' activities.

K. Environmental Pollution. With modern large-scale commercial farming one can anticipate increased use of biocides in the region. There are several federal laws concernng soil, water, environmental, and worker protection. These are not specific to guayule and its particular needs and potential problems; such laws may be needed. Enforcement of environmental laws has not been actively pursued in many cases. Lax enforcement of laws to avoid impeding economic growth is common in developing countries, as well as in developed countries, and may be at the heart of this issue.

L. Ecological Concerns. Ecological concerns for the area center on the possibility of desertification. Much of the area proposed for farming is not rich biologically, although there may be small enclaves of special significance within the area. Failure or slowdown of the industry could lead to abandonment of areas cleared for farming.

Experience with farm development in other arid regions of the world could serve as a guide to assess the potential for desertification. There is no policy addressing this issue, but many policies are being formed in the federal Institute for Political, Social and Economic Studies.

M. Management of Soil and Water Resources. Federal agencies do not have sufficient data on regional aquifers to assess their adequacy to support large scale farming, although the water requirements for SAIG could be estimated. Federal laws consider the general aspects of soil and water management to avoid misuse and desertification, but, since the greatest threats of desertification arise from abandonment of a developed agroindustry, these laws do directly affect the program. SARH and SAHOP policies expressed in the National Hydraulic Plan define general restrictions of water use in each defined water district. SAIG agricultural and industrial water use must comply with these rules or new policies which exempt SAIG must be created.

N. Science and Technology Capability. Achieving the goals of Scenario B will require a considerable research effort in agricultural production and industrial processing. The issue has two components: individual capability, and the capability of the research and development organizations to recognize and respond to SAIG research needs. There is no question that there are many excellent Mexican scientists, but conflicts may arise among universities and research centers over what research is needed and who can or will accomplish it. The issue raises the question of whether political and institutional constraints will allow universities to adapt to research and development schemes proposed by SAIG. Difficulties may occur if the SAIG structure includes private or quasi-governmental (para-estatal) participants with which universities do not normally collaborate. Current federal policy may strengthen the capability of universities and research centers to perform the research needed to support SAIG objectives.

O. National Economic and Industrial Development. A program to produce 45,000 to 50,000 metric tons of rubber per year will be expensive to initiate, although under the right circumstances it could produce a net savings over the purchase of imported rubber after some years of operation. Rapidly changing conditions in Mexico and scant information do not permit an accurate analysis of the economics of such a large undertaking. The Global Development Plan outlines the administration's intent for national development. These general policies indicate how a program such as farm-based SAIG could fit into national plans, but there are no studies specific to guayule. The costs and benefits of SAIG would have to be determined and compared to the many other existing or proposed development plans.

P. National Rubber Plan. Any development of a farm-based guayule agroindustry awaits a federal determination of guayule importance in the national economy and to national economic security. There is no policy outlining a national rubber plan.

Q. Competition with Food Production. SAIG policies promoting guayule rubber production may conflict with federal policies promoting food crop production to achieve self sufficiency. The SAM program, specifically, is very active in the guayule region. Guayule will be grown on land that is not suitable for crops, so there will be little competition for land; however, the programs may compete for development funds and for resources necessary to any farm practice in the region. Part of the attraction of growing food crops is a federally guaranteed price. Changes in this policy and other agricultural support policies, such as subsidies for fertilizer, could increase the attractiveness of growing guayule on farm land in the guayule region. SAIG does not anticipate using food crop land, but a decrease in price supports might generate pressure to allow purchase of guayule grown on former crop lands.

R. United States Interest in Mexican Guayule Commercialization. Mexico and the United States have established a pattern of promoting science and technological exchange. SAIG should be a part of this continuing formal and informal process. Both countries are pursuing a path of research, although of widely fluctuating intensity, that may lead to a commercial agroindustry. Both countries may advance their efforts through information exchange and collaboration. There is some concern in Mexico that multinational corporations and the United States Department of Defense may may seek to involve themselves in guayule commercialization in ways that are not in Mexico's best interest.

Table VII-3

POLICY ANALYSIS - GUAYULE FARMING
SCENARIO B

ISSUES AND CRITICAL QUESTIONS	PARTIES-AT-INTEREST	EXISTING POLICY INSTRUMENTS AND STUDIES
A. Economic Feasibility	Federal government (SPP, SEPAFIN, SARH, SECOM) Mexican rubber industry; Multinational rubber exporters.	
1. Is guayule farming the least expensive alternative to domestic natural rubber production?		1. None
2. Can guayule rubber be produced with acceptable wage rates at a price competitive with imported hevea?	Banco Nacional de Credito Rural	2. Feasibility studies only consider wildstand harvest and low volume rubber production.
3. Is a production target of one-third of domestic demand realistic?		3. ?
4. Will industry be required to buy Mexican guayule rubber?	4. See A-4 Table VII-1	4. Current policy requires purchase of domestic hevea rubber.
5. Will SAIG be self-supporting?	5. See A-2 Table VII-1	5. Federal policy requires Federally supported industries to be economically self-sufficient.
B. Regional Economic Development		
1. Will the guayule program (SAIG) provide jobs, and raise the income level and standard of living of Mazapil residents?	COPLAMAR; local residents; Federal agencies involved with regional development programs; SPP; SARH; SRA; COPLADES; CONAZA	1. None. CIQA-CONAZA-CONACYT-CIDER studies only considered small scale development.
2. Will Mexico's social needs constrain development of critical materials?		2. ?
3. Will SAIG increase regional inflation?		3. ?
4. How does SAIG compare with alternative regional development programs?		4. ? COPLAMAR, CONAZA, policies to promote native plant use.
5. Will rapid development create shortages of energy, skilled labor, supplies and materials?		5. ?
6. Will SAIG stimulate other industrial or agricultural development?		6. ?

Table VII-3 (continued)

POLICY ANALYSIS - GUAYULE FARMING
SCENARIO B

ISSUES AND CRITICAL QUESTIONS	PARTIES-AT-INTEREST	EXISTING POLICY INSTRUMENTS AND STUDIES
C. Distribution of Benefits	See C Table VII-1	Federal Work Law
1. Will local residents' needs and regional social benefits be overlooked because of critical materials needs? Will SAIG be machinery intensive to decrease labor costs?	1. Local residents; Federal government; SAIG	1. None
2. What will be the role of large Mexican companies and multinational companies in the guayule program?	2. Mexican and multinational rubber companies and farm equipment manufacturers.	2. None
3. How will prices for guayule shrub be determined?	3. See C-3 Table VII-1	3. None
4. Who will own and operate the transportation system?	4. See C-4 Table VII-1	4. None
D. Structure and Capability of Guayule Organization		
1. How will the organization be structured?	1. See D, Table VII-1	See D, Table VII-1
2. Will local groups participate in the design and administration of the project?		
3. How can quality control of rubber and by-products be maintained?		
4. What are the implications of a processing plant shutdown?		
5. What will be the role of the rubber industry?		
6. Who will operate the processing plant?		
E. Institutional Conflict/Coordination		
1. Who will control and operate guayule farms and bagasse feed distribution system?	1., 2. Ejidatarios; SARH; all Federal agencies involved with regional development; the rubber industry	1. None
2. Will conflicts arise among public sector agencies that participate in the project?		2. None
3. How will ejidos be involved?	3. Ejidatarios; CNC; CCI; CNPP	3. LFA; SRA policies

Table VII-3 (continued)

POLICY ANALYSIS - GUAYULE FARMING
SCENARIO B

ISSUES AND CRITICAL QUESTIONS	PARTIES-AT-LARGE	EXISTING POLICY INSTRUMENTS AND STUDIES
E. Institutional Conflict/Coordination (continued)		
4. What will be the influence of political parties?	4. All political parties	4. ?
5. What will be the impact on guayule development of a change of federal administration?	5. Guayule agency	5. ?
6. Will there be conflict among municipios and states about implementing the project in one region? How will they be solved?	6. Municipal and state government	6. ?
F. Integration of SAIG With Other Renewable Natural Resource Activities		
1. Will large-scale farming disrupt existing agriculture?	1. Ejidatarios; SAM; CONASUPO; small landowners	1. SARH policies
2. Will large-scale farming disrupt herding?	2. Local residents	2. ?
3. Will bagasse feed production offset grazing losses or augment livestock production?	3. Local residents	3. CIQA-CONAZA studies; Range land improvement policy
4. Will guayule development disrupt the candelilla and ixtle industries?	4. La Forestal; Foncan; local residents	4. ?
G. Land Tenure		
1. Who will control or own the guayule farmland?	Mexican government; ejidatarios; small property owners; political parties.	1. SRA policy (Agrarian Reform Law)
2. Will farms be developed in small plots or larger combined production units?		2. None
3. How will conflicts among ejidos and property owners over resource use and land control be resolved?		3. None
4. Will guayule farming affect the implementation of the LFA?		4. Agricultural Promotion Law (LFA); Agrarian Reform Law

Table VII-3 (continued)

POLICY ANALYSIS - GUAYULE FARMING
SCENARIO B

	ISSUES AND CRITICAL QUESTIONS	PARTIES-AT-LARGE	EXISTING POLICY INSTRUMENTS AND STUDIES
H.	Migration, Manpower, and Employment	STPS; SAHOP; local residents; employers in La Laguna area and nearby large cities; regional development agencies	Many studies by federal agencies and research institutions
	1. Will an adequate labor force be available in the region?		1. 1980 census; CONAZA, CIDER; CIQA, STPS studies; Agarian Reform Law
	2. Will any displaced residents have acceptable local job opportunities?		2. None
	3. Will the guayule program attract more workers than it can employ?		3. None
	4. Will SAIG provide secure jobs with an adequate wage?		4. None
I.	The Role of Labor Organizations	Foncon, Forestal, CNC, CTM, CCI, peasants, workers	
	1. Will new labor organizations be created for guayule farming or will an existing one have jurisdiction?		1. None
J.	Infrastructure Development		
	1. Will intensive farming and processing require extensive infrastructure improvements beyond those already planned for the region?	1. COPLAMAR; SEP; SAHOP; STPS; SSA; SECOT: CFE; CONASUPO, rubber industry.	1. PIDER
	2. Will infrastructure improvements for SAIG be made to the detriment of other industries or other regions?	2. Rubber industry; nearby municipios; states	2. None
	3. Will the development of the infrastructure cause a significant change in the rural nature?	3. residents, churches	3. None
K.	Environmental Pollution	Research institutions.	Environmental Protection Law; Soil & Water Conservation Law; Federal Water Law
	1. Will extensive farming require widespread use of large amounts of biocides?	1. Agrichemical industry; environmental protection groups, SSA, SARH	1. Agronomic studies in Mexico (UAC, UAAAN) and United States
	2. Will sewage facilities adequate to prevent water contamination be built in time to handle the influx of workers and the concentration of people at work centers?	2. SSA; SAHOP; SARH	
	3. Will a large guayule industry attract and concentrate other industrial pollution sources?	3. ?	
	4. Will environmental pollution be monitored and controlled?	4. SSA; SARH	

Table VII-3 (continued)

POLICY ANALYSIS - GUAYULE FARMING
SCENARIO B

ISSUES AND CRITICAL QUESTIONS	PARTIES-AT-LARGE	EXISTING POLICY INSTRUMENTS AND STUDIES
L. Ecological Concerns	Research institutions	
1. How much will extensive guayule farming and processing damage plant and animal populations?	SSA; SARH; local residents	1. None
2. Will extensive land clearing and dryland farming cause significant soil erosion?		2. Comparable experience with traditional crops in arid Mexico and United States
M. Management of Soil and Water Resources		National Hydraulic Plan
1. Is there enough water in the region to construct and maintain an expanded agroindustry and population?	1. SARH; CONAZA; residents; involved industries	1. Incomplete data; (SARH studies (Programa de Acuario)
2. How much water is needed for industrial processes and nurseries?	2. CIQA, CONAZA	2. CONAZA, CIQA studies of small scale project; SARH ; Soil and Water Conservation Law
3. Is sustainable dryland guayule farming possible on marginal soils?	3. SARH	3. None
N. Science and Technology Capability	Universities; research centers	INIA, INIF
1. Does SAIG have the capability to design a research plan to achieve industrial and agricultural goals?	CONAZA, CIQA, CONACYT, rubber industry	None
2. Will universities and research centers be willing to participate in SAIG research plans?	All agencies involved, residents, Mexican government, Mexican and U.S. rubber companies	
3. Does SAIG have the desire and capability to internally establish and carryout these research plans?		
O. National Economic and Industrial Development		National Development Plan; National Agroindustrial Development Plan; National Industrial Development Plan; Development Program for Agriculture and Forestry
1. How does SAIG compare to other options for development in Mexico?	1. Federal government	
2. How does the cost of SAIG compare with the benefits of domestic guayule rubber production (e.g. equipment imports)?		

Table VII-3 (continued)

POLICY ANALYSIS - GUAYULE FARMING
SCENARIO B

ISSUES AND CRITICAL QUESTIONS	PARTIES-AT-LARGE	EXISTING POLICY INSTRUMENTS AND STUDIES
P. National Rubber Plan		
1. Is it essential for Mexico to increase its domestic rubber supply?	1. Federal government	None
2. Should Mexico depend on foreign sources for much or all of its natural rubber?	2. Federal government; hevea suppliers	
3. Does the lack of a national rubber policy hamper guayule or hevea commercialization?	3. ?	
Q. Competition with Food Production	SAM; SARH; CONASUPO, SAHOP	Price guarantees and food subsidies (CONASUPO) 1. SAM
1. Will SAIG compete for labor and other resources that would support food production?		
2. Will SAIG compete for land with food increase projects?		
R. United States Interest in Mexican Guayule Commercialization		Federal Register for the Transfer of Technology
1. Will SAIG promote scientific and technological exchange?	1. Mexican and U.S. governments; CONACYT; NSF	1. Binational agreements on science and technology
2. What interest do U.S. based multinational corporations have in Mexican guayule?	2. Mexican government multi-national corporations; SRA; SEPAFIN	2. Agrarian Reform Law ; Industrial Property Law (Ley de Propiadad Industrial)
3. Does the U.S. Department of Defense view Mexican guayule as a source of strategic material?	3. Mexican government; U.S. DOD	

Table VII-4

POLICY NEEDS AND POTENTIAL POLICY CONFLICTS
SCENARIO B

A. Economic Feasibility

- Conflicts regarding devaluation and exchange related to the price of imported natural rubber.
- Conflicts between international rubber stockpiling policies and internal Mexican rubber pricing policies.
- Need for national rubber plan that addresses rubber prices, subsidies, taxes on domestic and imported rubber and differences in production costs of hevea, guayule, and synthetic rubber.
- Need for coordination of financing for production and processing sectors.

B. Regional Economic Development

- Conflicts between price guarantees for guayule and food crops.
- Need to consider policies regulating minimum wage for industrial work outside urban areas and minimum wage for non-industrial work. Need for industrial wages in rural areas.
- Conflicts between guayule production and processing wage policies.
- Possible need for regional planning to govern conflicts for guayule development among states/regions.

C. Distribution of Benefits

- Conflicts between national guayule rubber development policies and regional policies for development and social programs such as COPLAMAR.
- Need for profit distribution policy to apply to agricultural and processing sectors in the guayule development program.

D. Structure and Capability of Guayule Organization

- Presidential decree needed to establish SAIG.
- In the absence of SAIG, conflicts between policies for agricultural and industrial development.

E. Institutional Conflicts/Coordination

- Conflicts between planning policies at different governmental levels e.g. COPLADES vs. National Rubber Plan.

F. Integration of SAIG with other Renewable Natural Resource Activities

- Conflicts between guayule development policies and existing rangeland improvement policies.
- Conflicts between guayule development policies and ixtle and candellia policies.

G. Land Tenure

- Conflict between policy expressed by the LFA and the Agrarian Reform Law expressing the traditional support for agrarian ideals.
- Possible need to enforce the intent of the LFA to increase production without abandoning the ideals of agrarian reform.

H. Migration, Manpower, and Employment

- Possible need to adapt COPLAMAR employment policies to the new policies created by SAIG.

I. The Role of Labor Organizations

- Conflicts may develop among labor organizations for political control of guayule labor groups.

J. Infrastructure Development

- Possible competition among agencies with existing development programs like PIDER (Projects for Development in Rural Areas), and SAIG for funds and authority to operated in the rural area.

K. Environmental Pollution

- Need to enforce existing laws concerning environmental pollution.

L. Ecological Concerns

- Need to address desertification. (Policies emerging from IPES [Institute for Political, Social, Economic Studies] to define ecological protection of Mexico's natural resources may meet this need.)

Table VII-4 (continued)

POLICY NEEDS AND POTENTIAL POLICY CONFLICTS
SCENARIO B

M. Management of Soil and Water Resources

- Need to integrate management of SAIG agriculture with policies of SARH and SAHOP to limit water use and define permissible uses in the regional water districts.

N. Science and Technology Capability

- Need for a research and development policy that includes INIA, INIF, CIQA, and regional universities.

O. National Economic and Industrial Development

- Same conflicts and policy needs as for Regional Economic Development (B).

P. National Rubber Plan

- Need for a national rubber plan.

Q. Competition with Food Production

- Possible conflict of SAIG policies promoting guayule rubber production and SAM policies and other policies that support food production through price supports and indirect subsidies of agricultural production supplies.

R. United States Interest in Mexican Guayule Commercialization

- Possible policy conflicts in Mexico due to desires or perceived desires of multi-national corporations to invest in guayule rubber production, and concern that the United States Department of Defense will wish to acquire Mexican guayule rubber.

3. General policy summary of scenarios: Table VII-5 summarizes general policy implications for both scenarios. The scenarios are compared in economic, social, political, environmental, and research and development levels. Because the political and institutional parties-at-interest are similar in the two scenarios, it is important to distinguish between the levels of involvement of main institutional actors. Table VII-6 summarizes the intensity of political and institutional involvement for both scenarios at the national, regional and local levels.

C. Policy and Organizational Structure

One of the central issues that emerged from the policy analysis of guayule commercialization in Mexico is the organizational structure of SAIG. There are many options, and each combination of management elements has definite advantages and restrictions. The optimum organizational structure for SAIG in Scenario A is not necessarily the optimum for Scenario B.

The trans-sectorial character of SAIG requires decisions in designing the elements of its organization that have important policy implications. The design should reduce the risk of agroindustry failure through organizational control which assures that the following critical goals will be attained:

- timely delivery of shrub in spite of many uncertainties, i.e. shrub price, climatic disasters, political support;
- achievement of annual production goals and long-term production objectives;
- maintenance of a cash/or credit position to provide adequate operations funds to cover large seasonal expenses;
- development of the capacity to incorporate and diffuse technological advances that raise productivity and assure resource sustainability;
- permanent follow-up of the political, social, and economic goals. This includes a review of the goals themselves as well as measurement of progress toward achieving them.

Table VII-5

COMPARISON OF SCENARIO A AND B
POLICY IMPLICATIONS

LEVEL	SCENARIO A	SCENARIO B
ECONOMIC	Economic aspects are fundamentally regional, included within the economic development policies for marginal regions. Economic objectives generate income and increase regional output through production of small quantities of rubber (5,000 tons per year). Policies include occasional subsidy. SPP, CONAZA, and other dependencies such as COPLAMAR will be key agencies.	Economic aspects are fundamentally national, immersed in the national policy for natural rubber supply. Seeks regional economic specialization through cultivation of guayule and large-scale production of significant quantities of natural rubber (50,000 tons per year). Includes national price and tax policies, formation and implementation of a National Rubber Policy concerning guayule, hevea and synthetic polyisoprenes. Roles of SEPAFIN, SPP, Banrural and SARH will be important at this level
SOCIAL	Strong social orientation seeks to increase employment, raise income, canalize direct benefits, promote indirect social benefits, and promote organizational capacity to innovate and plan, especially reforestation, transportation organization and harvesting. Could be an element of a more complete regional development plan where guayule exploitation initiates a chain of actions to generate income and employment and attracts investment. Important roles for COPLAMAR, CONAZA, CONASUPO, IMSS.	Profound changes and innovation throughout the scenario: gradual increase in mechanization and technical sophistication in cultivation and industrial processing. Need social organization in productive units with consequent social constraints. Promotes larger rural settlements and increases internal and external migration. Need for clear and well-coordinated public service policies, especially health and regulation of commerce. Important roles for the same general actors in Scenario A.
POLITICAL	Probable development of guasi-governmental organization with integral control over supply, processing and distribution. Predominant influence of existing local political organizations could inhibit transfer of political controls and diffusion of innovation needed to increase and maintain productivity; many policy interactions with instuments such as the Agriculture Promotion Law are unclear. Need: policy clearly defining institutional roles, and instruments to promote organizational innovations and renewable resources policies. Important roles for the President, State Planning Committees, state governors, SPP. At the regional level, CONAZA, FONCAN, SRA. SARH, CNC/PRI will be important, as well as peasant organizations (CNC/PRI) and opposition parties.	Close links with national policies, especially industrial development and commerce; eventually tied to potential changes in federal policy toward transnational rubber companies. Serious conflicts among guayule, livestock, and food crop-producing actors and policies supporting them. Definite displacement of political organizations' renewable resources activities. Need for a clear policy framework for agro-industry and intensification of highly technical productive units. Most active participants: the President, industrial development groups, SEPAFIN, SPP (including COPLADES), SARH, Chamber of Rubber Producers and Consumers, SECOM, SRA, SAM, FIDHULE, labor unions (CTM and others), peasant organizations (CNC), and small property owners (CNPP).

Table VII-5 (continued)

COMPARISON OF SCENARIO A AND B
POLICY IMPLICATIONS

LEVEL	SCENARIO A	SCENARIO B
ENVIRONMENTAL	Strict organization control required to reduce ecological risk of deforestation and to assure resource sustainability. Need 7-10 year plan; without replanting programs, resource economic availability will diminish. The requirements greatly limit the type of organization and system required. Need: integrated exploitation system for the principal economic activities (plant, harvest, livestock heading, farming); monitoring and control of processing wastes. Important actors: guayule organizations, FONCAN, La Forestal, ejiditarios, small land owners, SARH, SSA, environmental research institutes and research centers.	Scenario initiation through wildstand exploitation requires a policy of resource maintenance via revegetation. Proposed guayule farming activities require studies of erosion control methods, since clearing thousands of hectares of erosion-susceptible land is envisioned. Policies and plans for land clearing, erosion control, and combating desertification should follow these studies. Needed policies include controls of water use and pollution associated with guayule farming and processing. Planning policies will be required for nursery establishment and maintenance of genetic diversity. Important roles for the same actors as in Scenario A, but with greater involvement of research institutions
RESEARCH AND DEVELOPMENT	Needed: studies oriented toward optimizing harvests to assure sustainable yields; monitoring guayule populations; reforestation plans. Management oversight to coordinate sectors of guayule production, processing, and transportation will be important. Scenario A project size will permit internal R & D; this to be conducted by existing research centers. Principle research organizations involved will include CONAZA, CONACYT, CIQA, INIF, and SPP.	Intensive research programs in nursery irrigation and dryland cultivation; genetic improvement; use of bioregulators; machinery development; and innovative plans for increasing guayule product to be established. Industrial process innovation will require research, especially in optimization of material and water use; utilization of wastes; and identifying uses and markets for resin products. Scenario's magnitude will require intensive R & D efforts through establishment of professional research units concentrating on guayule agronomics, cost reductions, optimization of soil and water use. Needed: long-term plan with fixed goals; participation of institutions specializing in various aspects of guayule development. Principle agencies and research organizations should include CONAZA, CONACYT, CIQA, SARH, INIA, CIANOC and SPP.

TABLE VII-6

INTENSITY OF POLITICAL AND INSTITUTIONAL INVOLVEMENT
NEEDED TO ACHIEVE GOALS OF GUAYULE COMMERCIALIZATION SCENARIOS

	INTENSITY OF INVOLVMENT IN SCENARIO	
	A	B
<u>NATIONAL LEVEL</u>		
National Policy for Strategic Materials (Non-existent)	none	high
Development in arid zones	high	moderate
National Plan for Agroindustrial Development	low	high
National Plan for Industrial Development (projections to 1990)	none	high
Natural rubber policy FIDHULE	low	high
Agricultural Promotion Law (LFA) (1981)	moderate	high
Food policy (especially the Mexican Food System (SAM))	low	moderate
Anti-desertification program (in design)	moderate	moderate
Employment policy (especially through COPLAMAR)	moderate	low
<u>REGIONAL LEVEL</u>		
Decentralization of planning through the establishment of state Committees (COPLADES)	moderate	high
Food policy (managed by the Ministry for Agriculture & Hydraulic Resources and the Mexican Food System)	moderate	high
Industrial development (mining plans and the Saltillo Industrial Corridor)	moderate	high
Human Settlement Policy	moderate	moderate
Renewable resources forestry policy (carried out by La Forestal and FONCAN)	high	low
Policy to aid marginal groups (COPLAMAR agreements)	high	low
<u>LOCAL LEVEL</u>		
Strengthening municipalities	moderate	moderate
Policy for groundwater use	low	high
Soil Conservation Policy	low	high

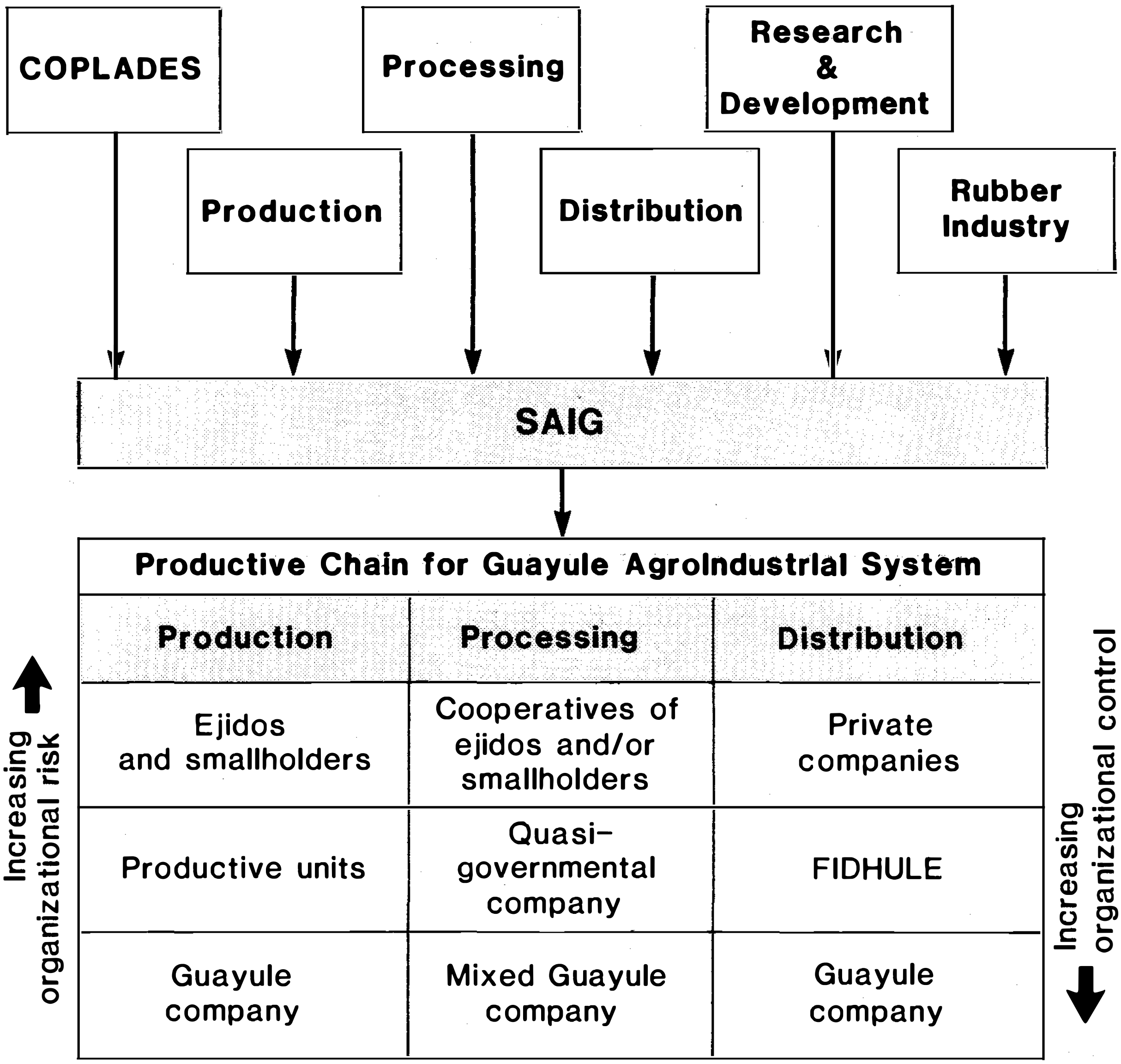
A workable relationship between the participating organizations is critical for effective functioning of SAIG. Figure VII-2 summarizes some of the structural options for SAIG. The figure arranges each of the elements of the three sectors of the productive chain along a continuum. On this scale organizational risk increases toward the top and organizational control increases toward the bottom. This arrangement assumes that increased centralized organizational control tends to decrease the risk of system failure; however, high levels of organization may inhibit the flow of benefits or direct them away from those groups targeted as primary beneficiaries of the guayule development program. The optimum mix of management elements strikes a balance between involvement of participants at the lowest organizational level and strict system control.

In this arrangement a central planning body (SAIG) has the ultimate authority to set policies, long-term plans, and annual production goals. It consists of representatives of the three sectors in the productive chain as well as the consumer (the rubber industry) and state planning agencies (COPLADES). The choice of the operational unit within each of the three sectors should be based on a plan to assure:

- o efficient operation within the sector
- o the ability to help set reasonable operational goals
- o capability to incorporate innovation
- o organizational capability of integrating production, processing and distributuion.

Each element should pursue a clear policy of providing benefits (profits, employment, etc.) that were established as goals in the initial plans for SAIG. In addition, selection of compatible levels of organization across the production, processing, and distribution sectors is critical. This structural organization schema is designed to show relationships among sectors, as well as possible choices within sectors.

Two options for organizational structure of SAIG are shown in Figure VII-3. These appear to provide a good balance between risk and rigid control. A middle pathway is chosen for all three sectors in Scenario A. In Scenario B a higher level of organizational control is selected for



Productive Chain for Guayule AgroIndustrial System

Production	Processing	Distribution
Ejidos and smallholders	Cooperatives of ejidos and/or smallholders	Private companies
Productive units	Quasi-governmental company	FIDHULE
Guayule company	Mixed Guayule company	Guayule company

Figure VII-2. Some Options for SAIG Organizational Structure.

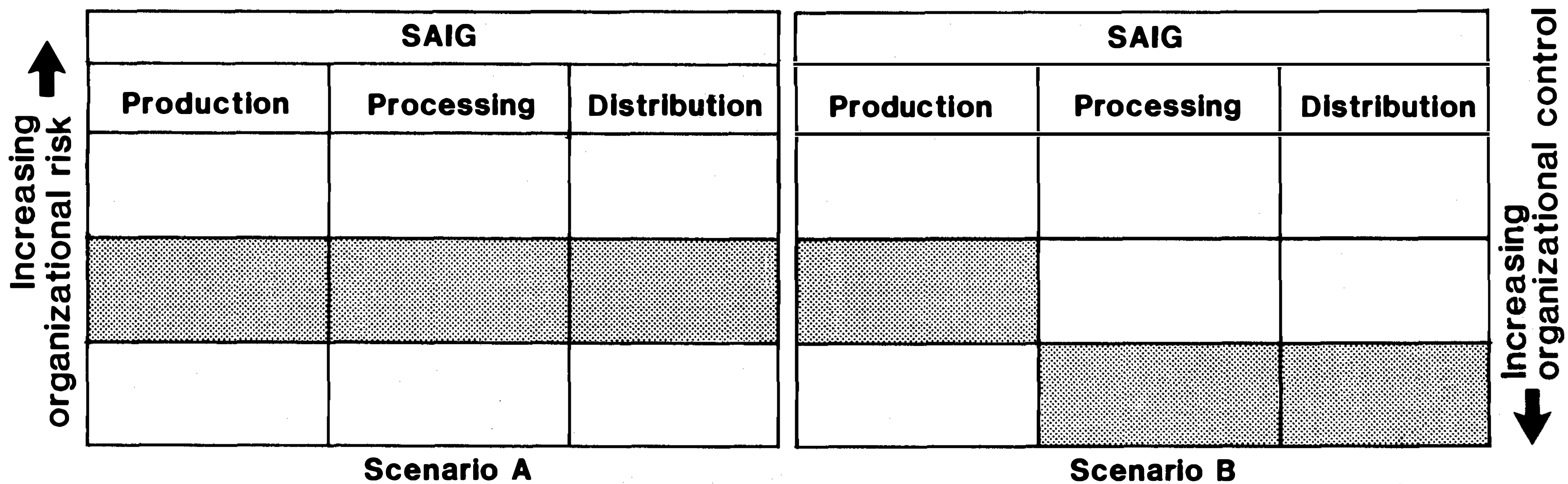


Figure VII–3 Suggested Levels of Control/Risk in SAIG Operation for Scenarios A and B.

processing and distribution. The alternatives are <u>not</u> offered as the only recommended mix of organizational elements. They are options that should serve as a guide for elaboration of policies that will permit rational management of the resource as well as promotion of a better livelihood for residents and future residents of the guayule region.

D. <u>Conclusions on Guayule and the TA Process</u>

The publication of this study in Mexico and the United Sttes publicly marks the completion of the first technology assessment jointly funded by the National Science Foundation and the National Council on Science and Technology (CONACYT). It is thought to be the first TA conducted in Mexico. This assessment follows a TA conducted in the United States on a similar topic. The work on these studies has been enlightening to all the participants. Drawing on these experiences, we would like to relate a few insights and observations on this technology assessment and on TAs in Mexico.

- Mexican guayule development differs from U.S. development: recent efforts in Mexico aim at social improvement; efforts in the U.S. center on economic and strategic considerations.
- In either scenario SAIG could be an important project with impacts on a regional and national level. The necessary capabilities for carrying out technological innovation projects in arid regions can be achieved with adequate planning and organization.
- A successful agroindustrial system, whatever the scenario, will require integrated long-term planning based on appropriate decisions by the President of the Republic and governors of the affected states.
- SAIG cannot proceed at the margin of the political process. A national policy for planning of renewable resource exploitation is essential. It should focus on resource sustainability and social, economic, environmental, and political criteria to achieve it. Without integrated planning, existing conflicts and entrenched political and administrative habits will hinder innovations in resource use.

- It is possible to initiate planning for SAIG, but most agencies do not now have the methodological and organizational skills to complete the planning.

On the TA process in Mexico:

One of the most difficult problems encountered in regional and national development is the transfer of technology from the research and development stage, or from outside of the Mexican context, to the implementation stage. This requires actions primarily by governmental agencies and private entrepreneurs. Technology assessment can be one of the most effective tools for catalyzing this transition, especially when the TA involves government and private actors.

- Mexico's need for technology assessment may differ substantially from the United States' need. Scientists in Mexico envision TA as a tool in planning and promotion of technological development, and in program implementation. In the United States, public sector agencies conduct most TAs, generally to avoid deleterious effects resulting from technologies with potentially large impacts.
- Integrating TAs into the planning process can support effective planning. An evaluation of state and national legislation is recommended to gradually incorporate assessment techniques into medium range planning, especially in ecological and environmental evaluation for arid lands projects. This would require the creation of suitable groups to study development issues in arid zones and develop priority lists.
- The process of conducting this TA has made it possible to initiate training in technology assessment.

- Technology assessment can be one of the most effective means of informing local residents about a developing technology that might significantly affect them. They can participate directly at the start of the planning process.

- This study of guayule commercialization has revealed numerous conflicts and problems, many of which arise from inexperience and existing institutional deficiencies. These have frequently impeded integrated planning.
- Project scheduling in cooperative international TAs should be very flexible. National political and economic constraints can differ greatly for the research teams, necessitating unilateral changes in the initially agreed upon schedule.

APPENDIX A

AGENCIES PARTICIPATING IN PUBLIC WORKSHOPS

	FIRST	SECOND	THIRD
Bureau of Geography and National Territory		1	
CONAZA (Mexico)	3	1	1
CONAZA (Saltillo)	2	1	1
COPLAMAR (Saltillo)	1	1	1
CONAFRUT (Mexico)	1	1	1
FIDHULE, FONCAN (Mexico)	1	1	1
National Commission for Agroindustrial Development (Mexico)		2	
SARH			
Agroindustrial Development			
(Mexico)	2		
(Saltillo)	2	2	
(Zacatecas)	1		1
Ecology and Environmental Protection (Mexico)		2	1
Irrigation Districts (Mexico)	1	2	
CIFNE	3	2	3
INIA	1		
INIF	1	1	3
SPP			
Coahuila	1		
Zacatecas	1		
Mexico	2	1	1
Economic branch	2		
SRA (Zacatecas)	1		
Governor's Office			1
Mayors in Zacatecas			
El Salvador	1	1	1
Mazapil	1	1	1
Concepcion del Oro	1	1	1
Melchor Ocampo		1	1
Autonomous University Zacatecas	2		
Autonomous Agrarian University	3	3	4
Antonio Narro		1	

APPENDIX B

BENEFITS OF UNITED STATES-MEXICO COOPERATIVE RESEARCH ON GUAYULE COMMERCIALIZATION

The process of developing this technology assessment and its successful completion have been widely beneficial. The TA is fulfilling its main purpose, to improve our understanding of guayule development and commercialization, and use of the document in Mexico and the United States will further advance this process.

A growing understanding of the process began with the personal involvement in Mexico of many scientists and local, regional, and federal planners and decision-makers. The project has continued the consultation and collaboration of CIQA and OALS on guayule commercialization and regional planning for natural resource development. Staff of the two institutions have worked together since 1977 and will continue the relationship in future projects.

The personal contacts and interactions during the study and the development and use of systems analysis methods have helped penetrate the communication haze that historically has separated scientists from planners and policy-makers. It has brought about a greater awareness of the tasks each group must accomplish to have a successful program and of the role each has in regional development planning.

One may identify several groups that have benefitted directly from this TA:

- planning and development funding agencies that use the TA
- the institutions and scientists that participated
- agencies that funded the TA
- scientific communities involved with guayule development and arid land resource development in Mexico and the United States

Suggestions for future binational cooperative research projects:

- A research schedule with milestones and completion dates should be established by mutual agreement and with a clear understanding that project schedules may be altered by one or both research groups in response to economic and political situations in sponsoring institutions or countries. Therefore open communication and a flexible schedule is an absolute necessity. It may be possible to avoid problems of the two teams working at different schedules if funding for the entire project comes from one source.

- Perhaps the best way to improve communication and maintain a high level of coordinationwould be to exchange scientists for the duration of the project. Several funding agencies support programs to bring promising scientists to U.S. institutions. Funding to send a U.S. scientist to a cooperating country is more difficult to arrange and may have to be partially covered in the initial project grant.

- It is important to involve regional experts and planners to consider projects of regional scale. Less than satisfactory results can be expected by trying to solve regional problems by working solely with centralized planners and policy makers.

- Public meetings can be an important part of an impact evaluation process; however, to get the most from such meetings, especially where there is a series of meetings in one project, the TA teams should evaluate the format and conduct of the public meetings. Their evaluation should include an evaluation by the participants and their perception of their role in the decisionmaking process.

- Whenever possible institutions about to begin a cooperative research project should discuss the process, its difficulties and benefits, with an experienced investigator.

APPENDIX C

GLOSSARY OF MEXICAN AGENCIES, INSTITUTIONS, AND TERMS

Agencies and Institutions

BANRURAL	National Rural Credit Bank	Banco Nacional de Credito Rural
CCI	Independent Farmers Confederation	Confederacion de Campesina Independiente
CFE	Federal Electrification Commission	Comision Federal de Elecrticidad
CIDER	Rural Development Research Center	Centro de Investigacion in Desarollo Rural
CIQA	Applied Chemistry Research Center	Centro de Investigacion en Quimica Aplicada, Saltillo, Cohauila
CNC	National Peasants Confederation	Confederacion Nacional Campesina
CONACYT	National Council for Science and Technology	Consejo Nacional de Ciencia y Tecnologia
CONAFRUT	National Commission for Fruit Production	Comision Nacional de Fruticultura
CONASUPO	National Company for Price Support of Staples	Compania Nacional de Susistencias Populares
CONAZA	National Commission for Arid Zones	Comision Nacional de Zonas Aridas
COPLAMAR	General Coordination for the National Plan for Depressed Zones and Marginal Groups	Coordination General del Plan Nacional de Zonas Deprimas y Grupos Marginados
COPLADES	State planning groups	Comites Promotores del Desarrollo Estatal
CTM	Mexican Workers Confederation	Confederacion de Trabajadores de Mexico
FIDHULE	Mexican Rubber Agency	Fideicomiso del Hule
FONCAN	Agency for candelilla promotion	Fideicomiso para el Fondo Candelillero
FORESTAL, FCL, La	Cooperative Forestry Association	Forestal, Federacion de Cooperativas Limitades
IMSS	Mexican Institute for Social Security	Instituto Mexicano del Seguro Social
INIA	National Institute for Agricultural Research	Instituto Nacional de Investigaciones Agricolas
INIF	National Institute for Forestry Research	Instituto Nacional de Investigaciones Forestales
INFONAVIT	National Institute for Funding Housing for Employees	Instituto del Fondo Nacional para la Vivienda de los Trabajadores
PEMEX	Mexican Petroleum Company	Petroleos Mexicanos
PIDER	Program for Investment in Rural Development	Programas de Inversion en Desarrollo Rural
PRI	Institutional Revolutional Party	Partido Revolutionario Institucional
SAIG	Guayule Agroindustrial System	Sistema Agroindustrial Guayule
SAHOP	Ministry of Human Settlements and Public Works	Secretaria de Asentamientos Humanos y Obras Publicas
SAM	Mexican Food System	Sistema Alimentario Mexicano
SARH	Ministry of Agriculture and Hydraulic Resources	Secretaria de Agricultura y Recursos Hidraulicos
SEP	Ministry of Public Education	Secretaria de Educacion Publica
SEPAFIN	Ministry of National Property and Industrial Promotion	Secretaria de Patrimonio y Fomento Industrial
SECOM	Ministry of Commerce	Secretaria de Comercio
SCT	Ministry of Communications and Transport	Secretaria de Comunicaciones y Transportes
Hacienda	Ministry of Finance	Secretaria de Hacienda y Credito Publico
SPP	Ministry of Programming and Budget	Secretaria de Programacion y Presupuesto
SRA	Ministry of Agrarian Reform	Secretaria de la Reforma Agraria
SRE	Ministry of Foreign Relations	Secretaria de Relaciones Exteriores
SSA	Ministry of Health and Welfare	Secretaria de Salubridad y Asistencia
STPS	Ministry of Labor and Social Welfare	Secretaria del Trabajo y Prevision Social
UAC	Autonomous University of Chapingo	Universidad Autonoma de Chapingo
UAAAN	Antonio Narro Autonomous University at Coahuila	Universidad Autonoma Agraria Antonio Narro de Coahuila

Terms

candelilla	*Euphorbia antisyphilitica* - source of hard wax.
ejido	Group of peasants (campesinos) which has received lands under Mexican agrarian law; the lands given under this law.
ejidatario	An ejido member.
ixtle	Fiber from lechuguilla, *Yucca carnerosona* and some other *Yucca* and *Agave* species.
lechuguilla	*Agave lechuguilla* - source of fiber in ixtle industry.
municipio	Municipality equivalent to a county.

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To save space, several agencies are referred to by their acronyms. The full names of these agencies are listed below.

CIDER	Centro de Investigaciones del Desarrollo Rural
CIQA	Centro de Investigacion en Quimica Aplicada
CONACYT	Consejo Nacional de Ciencia y Tecnologia
CONAZA	Comision Nacional de las Zonas Aridas
INIF	Instituto Nacional de Investigaciones Forestales