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CHARCOAL PRODUCTION FROM EUCALYPTUS
IN SOUTHERN BAHIA FOR IRON AND STEEL
MANUFACTURE IN MINAS GERAIS, BRAZIL

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Uziel Batista Nogueira

has been accepted towards fulfillment
of the requirements for

Ph.D. degree in Forestry

Major professor

Lee M. James

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CHARCOAL PRODUCTION FROM EUCALYPTUS IN SOUTHERN BAHIA FOR IRON AND STEEL MANUFACTURE IN MINAS GERAIS, BRAZIL

By

Uziel Batista Nogueira

A DISSERTATION

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ABSTRACT

CHARCOAL PRODUCTION FROM EUCALYPTUS IN SOUTHERN BAHIA FOR IRON AND STEEL MANUFACTURE IN MINAS GERAIS, BRAZIL

BY

Uziel Batista Nogueira

This study focuses on the Brazilian charcoal-based iron and steel industry in the State of Minas Gerais and its rapidly increasing problem of charcoal supply. It describes the technology of forest operations and charcoal manufacture. It analyzes the supply and demand for charcoal and relates the need for wood raw material for charcoal production to the economic feasibility of establishing Eucalyptus tree plantations in southern Bahia.

A comprehensive analysis of the major charcoal producers in Minas Gerais shows that the charcoal producing region boundary has been expanding steadily farther from the iron and steel mills. Distance from the charcoal producer centers to the consumer centers now averages 600 kilometers. Increasing transportation distances reflect the exhaustion of natural forests in areas closer to the mills.

Charcoal manufacturing in Minas Gerais is based exclusively on beehive brick kilns. The large integrated iron and steel firms have subsidiaries which produce a portion of the needed charcoal and purchase the remainder of their charcoal needs from independent suppliers or from contractors producing under company supervision. The

independent pig iron producers rely on charcoal supplied by hundreds of independent charcoal suppliers.

A survey of the remaining natural forests in Minas Gerais reveals that under sustained yield, these forests can support a production of 2.2 million tons of pig iron annually. Eucalyptus tree plantations will be available for charcoal wood harvest in 1985. These plantations will allow a production of 642,000 tons of pig iron. Even if the 1978 level of pig iron production (3.5 million tons) should be maintained without any expansion whatsoever, the sustained-yield capacity of natural woodlands and the anticipated yield of established plantations (a combined yield which may be sufficient for 2.8 million tons of pig iron) will pose serious problems of charcoal supply.

Statistical data support the evidence that the mandatory goals of charcoal self-sufficiency imposed in the industry by government (50 percent in 1985 and 100 percent in 1995) cannot be reached under present programs. The iron and steel industry needs to engage in massive efforts of reforestation for charcoal supply far beyond the efforts visualized to date.

The financial analysis of Eucalyptus plantations in southern Bahia shows that with the use of the government's program of fiscal incentives plantations are an attractive investment. Internal rate of return is 21 percent with land costs of Cr$ 10,000 per hectare, and more than 9 percent when land costs are Cr$ 15,000. The iron and steel industry can well afford to establish the maximum area of plantations that qualifies for fiscal incentives. Plantations established without fiscal incentives are not financially attractive enterprises. Internal rate of return reaches 6 percent only when land cost approaches zero. However, the broader perspective requires that the industry establish plantations, not merely to meet government regulations, but to insure an adequate charcoal wood supply for pig iron production. It is essential that iron and steel be produced profitably, not that plantations, established to insure an adequate charcoal supply, be grown profitably.

Under the assumption that one million hectares of plantation should be established, an estimated 152,000 man-years of employment would be created from plantation establishment and 353,000 man-years of employment would be created from charcoal manufacturing centers in the region. It is not improbable to visualize that the establishment of large-scale tree plantations and charcoal kilns in southern Bahia would induce the location of new iron and steel mills closer to the charcoal source.

DEDICATION

Elena "Nishi" Nishihara -- Wonderful Human Being

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

Since iron was first made in the world, charcoal has been the traditional thermo-reductor for the smelting of iron ore and was used almost universally in the small blast furnaces and other reducing furnaces until the 18th century when metallurgical coke[1] was introduced as an alternative.

Today charcoal is still used for ironmaking in blast furnaces in a number of countries.[2] The world leader in this activity is Brazil where a large proportion of its iron and steel industry is based on charcoal to reduce iron ore to pig iron. The extraordinary development of charcoal ironmaking in Brazil is due to the scarcity of native coal supplies with good coking properties, their remoteness from the high grade iron ore deposits in Minas Gerais, and a history of government restrictions on imports of foreign coke. These factors permitted the development of what is now the world's largest iron and steel industry based on wood charcoal as a reducing agent.

In 1979, Brazil produced 4.4 million tons of pig iron (IBS Instituto Brasileiro Siderurgia - Anuario Estatistico 1978-79). The State of Minas Gerais contributed 3.8 million tons or 86 percent of the total production. Minas Gerais has consistently accounted for more

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[1]Metallurgical coke is obtained out of coal from which most of the gases have been removed by heating.

[2]The charcoal-based iron and steel industry in Australia, Argentina, India and Sweden is discussed in Appendix B.

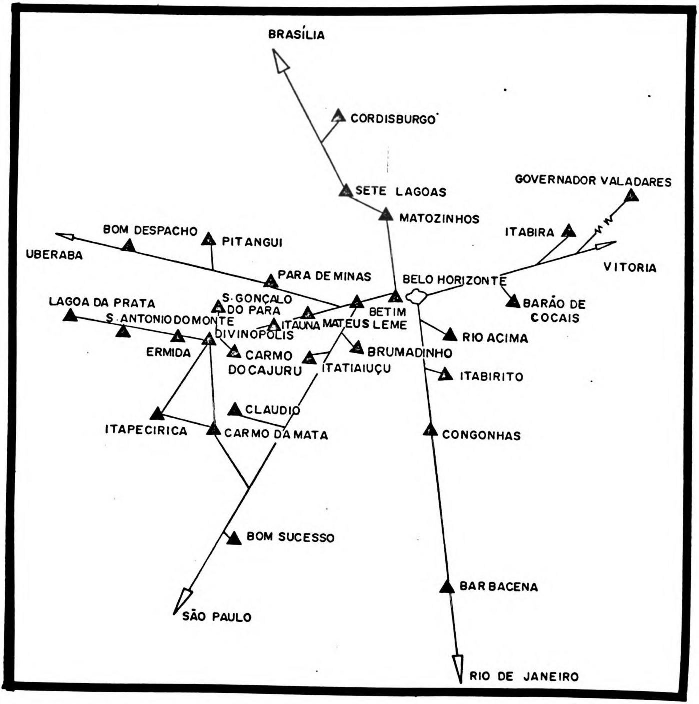
than 80 percent of Brazil's pig iron which reflects the concentrated nature of the Brazilian charcoal industry in that State.

For analytical purposes, the steel industry is divided into two subsectors: (1) Integrated steel mills - vertically integrated mills which carry out all operations from iron ore preparation to the finished alloy steel. (2) Non-integrated mills or independent producers which produce pig iron only.

The independent pig iron producers are located west of Minas Gerais on a radius of 100 kilometers from the State capital, Belo Horizonte (Figure 1). They are distributed among 24 cities of Minas Gerais, concentrated mostly in Sete Lagoas, Divinopolis and Itauna. Some 56 mills, with 116 blast furnaces, produced roughly 1.8 million tons of pig iron in 1977. This figure represents 90 percent of the total Brazilian pig iron production from the independent producers. In the integrated sector, there are 10 companies founded between 1920 and 1950. Eight are private-public companies and two are publicly owned and controlled by the government. Also during the 1950's two large coke-based integrated steel mills were built: Usina Siderurgica Minas Gerais (USIMINAS) and Compannia Siderurgica Paulista (COSIPA) in Sao Paulo (Figure 2).

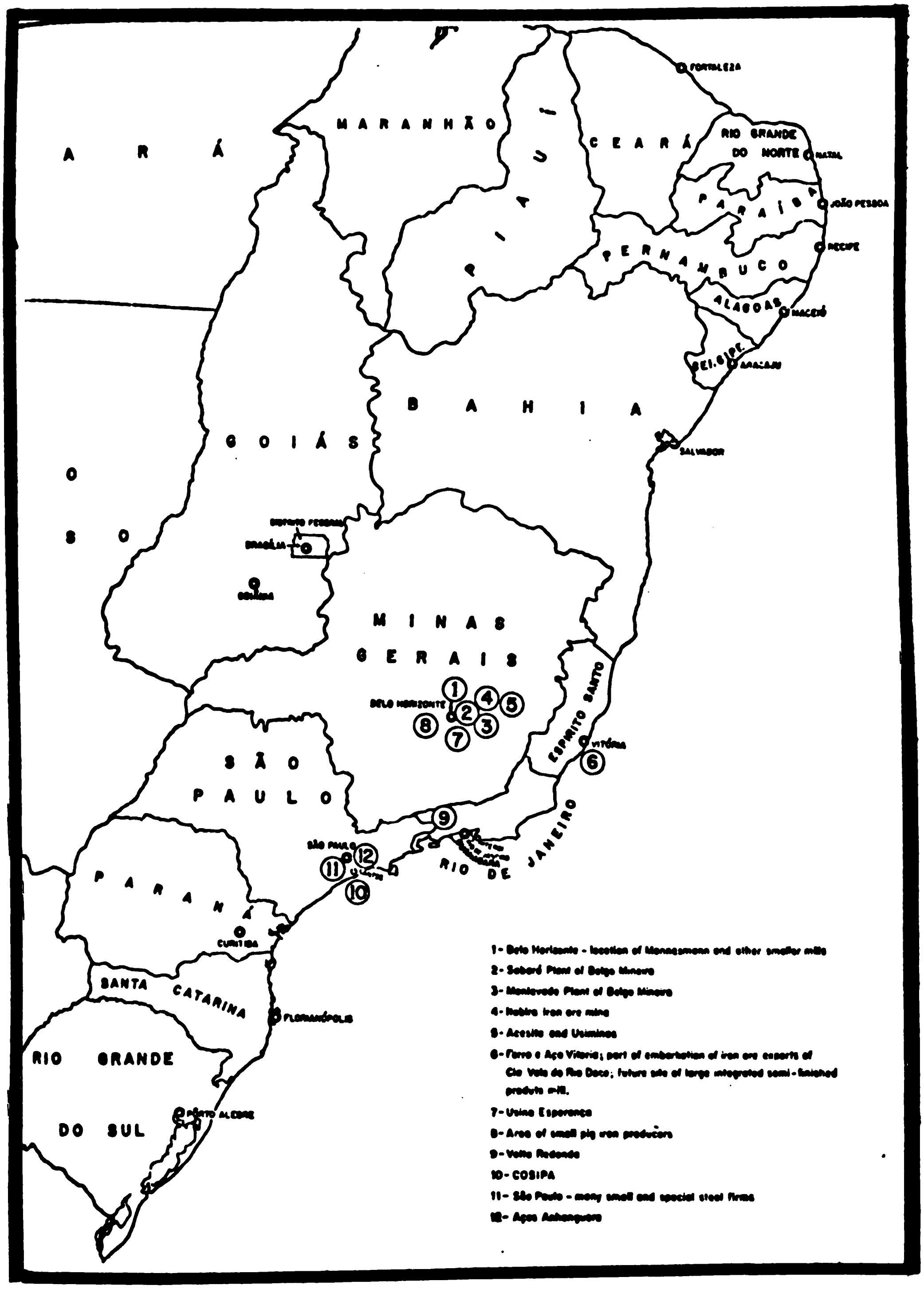
Origin of Charcoal Supply

The large integrated iron and steel firms draw 50 percent of their charcoal from native woodlands of the cerrado (savanna) region, 38 percent from other native forest types, and 12 percent from Eucalyptus plantations. These firms have subsidiaries which produce a portion of



Source: Instituto Nacional Desenvolvimento Industrial

Figure 1 -- Independent Pig Iron Producers in Minas Gerais.



Source: Baer, Werner, 1969. The Development of the Brazilian Steel Industry, Vanderbilt University Press, Nashville, Tennessee.

Figure 2 -- Principal Steel Mills of Brazil.

the needed charcoal and purchase the remainder of their charcoal needs from independent suppliers or from contractors producing under company supervision. The small pig iron mills obtain 93 percent of their charcoal supply from cerrado woodlands, 6.7 percent from other native forest areas, and only 0.3 percent from Eucalyptus plantations. Small pig iron mills obtain their charcoal from thousands of small, independent producers. The charcoal quality is variable and frequently poor due to inadequate technology and poor supervision.

A survey of the major charcoal producers in Minas Gerais reveals that for native charcoal the transportation distance from producer centers to consumer centers is generally from 500 to 600 kilometers. (Table 1). For charcoal from Eucalyptus plantations, distances range from 50 to 600 kilometers.

Table 1. Representative Transportation Distances for Major Charcoal Producers in Minas Gerais.

Company	Producer Center (Municipio)	Consumer Center (Municipio)	Transportation Distance (Km)
Cia. Siderurgica	Itauna[1]		
Pains	Divinopolis[1]		
	Alto Medio Sao Francisco[1]	Divinopolis	80 to 600
	Tres Marias[2]	Divinopolis	600
Florestal	Janauba[1]	Sete Lagoas	
Acesita	Vila de Palma[1]	Monlevade	600
Cimetal	Alvinopolis[1]	Barao de Cocais	200
	Bom Jesus Amparo		
	Carbonita		
	Corinto	Betim	500
	Campo Florido	Itauna	550
	Morada Nova Minas		
Rural Minas	Unai[1]	Caete	700
Sid. Valina	Itapecerica[2]	Divinopolis	500
	Buritizeiro		
	Caete		
Rural Minas	Caete[2]	Caete	50
Resa	Sacremento[2]	Uberaba	260

[1]Charcoal produced from native forests and cerrado.

[2]Charcoal produced from Eucalyptus plantations.

Source: IBDF records.

The figures on transportation distance from the producer centers to the consumer centers reflect the exhaustion of natural forests in areas close to the consumer centers. In a recent example reflecting the trend, charcoal has moved as much as 800 kilometers to steel mills.

Wood Charcoal Cost

The important variables in charcoal costs are the concentration of wood source (volume per hectare), raw material cost (which is significant in plantations and not in natural stands), storage costs in wood drying, hauling distance to kilns, charcoal technology, and mode and distance of transportation to iron and steel mills. The total costs involved are very significant since they represent nearly 60 percent of the total production cost of pig iron (MIC - Ministerio Industria e Comercio / CONSIDER - National Council of Steel Industry).

Transportation cost has become the most important ingredient in delivered charcoal costs. As charcoal transportation distance increases, it becomes increasingly relevant to examine the economics of charcoal production from tree plantations established closer to the iron and steel centers. Firewood obtained from plantations represents a much greater cost than firewood obtained as a free gift of nature from natural stands, but this greater cost must be weighed against the considerable savings in transportation which can be obtained from strategically located plantations.

Coke versus Charcoal - The Political Variable

There is a strong sentiment in Brazil that national security objectives make it unwise to allow such an important sector as the steel industry to become dependent on foreign raw material supplies. Bolstering this sentiment is the view expressed by Constantine (1963) that

> " ... under modern conditions charcoal can be as economic and efficient as coke for smelting iron ore in a standard blast furnace subject only to the provision of an adequate supply of raw materials."

Brazil's steel industry has expanded on the assumption that competitively priced supplies of domestic charcoal would be available for the reduction of iron ore. Without the availability of charcoal, it is more than likely that iron ore in Minas Gerais would have been exported rather than used to build a domestic steel industry.

The importance of forest-based manufacturing in accelerating economic development has been pointed out by Westoby (1963), who emphasized the importance of forward and backward linkage effects. Forest industries have a relatively high demand for labor and locally produced or existing raw materials and have well-developed multiplier effects, external economies, foreign exchange earnings, and import-replacement capacities which can combine to make significant contributions of the kind generally needed for economic development. Although Westoby was thinking of forestry and forest industry in general, his deductions can be applied with equal force to the forest-fuel sector of forestry.

Other arguments are stated in favor of continued use of charcoal as a raw material in iron and steel manufacture: (1) The wood material used in Brazil has better characteristics for manufacturing charcoal than that of countries where charcoal has already been abandoned in iron and steel manufacture. (2) The charcoaling industry employs large numbers of workers in poorly developed rural areas which offer few other alternatives for gainful employment. (3) The charcoaling industry uses resources (timber and land) which have little or no alternative commercial value. (4) Foreign exchange earnings or savings are directly affected by the use of domestic in place of imported coke. (5) Charcoal manufacture offers opportunities to produce chemical by-products.

Despite the many advantages of a domestic charcoal industry in supporting the Brazilian iron and steel industry, it is important that economic analysis of the iron and steel industry consider the holistic returns to society from all the resources committed to the sector regardless of who in society contributes them and who in society receives the benefits. As it was pointed out by Earl (1975)

> "The development of an indigeneous forest fuel industry cannot be considered independently of its viability in terms of world market prices. Although it may be economically advantageous, up to a certain point, to produce something rather than import it, there is no particular economic advantage in self-sufficiency in itself, particularly if it is obtained at a high opportunity cost in terms of scarce, skilled labour and

> capital resources. The development advantage for that matter, would soon disappear if there were no comparative advantage after taking into account all relevant social cost and benefits. The chief difficulty in establishing a quantitative basis for assessing the contribution which the forest fuel industry makes to development is confounded by the fact that products of the industry tend to be dispersed and accepted as social goals."

Expansion Plans for the Iron and Steel Industry

All the charcoal-based steel companies have plans to expand their production capacities, following the guidelines of the Master Plan for the Steel Industry, laid out by CONSIDER (National Council for the Steel Industry). These plans pointing toward production increase and efficiency include the following goals:

(1) Install new, large blast furnaces of improved design to increase pig iron outputs beyond the present maximum of some 700 tons per day.

(2) Install more efficient sinter plants which will lower the rate of charcoal use and increase iron output.

(3) Install larger Cowper stones to raise blast furnace temperatures from 850° C to 1150° C and reduce the rate of charcoal use.

(4) Modernize charcoaling methods to increase charcoal yields from firewood. Insure charcoal supply by an adequate steel-company tree plantation program.

Objectives of the Study

Given the basic problem facing the Brazilian iron and steel industry of obtaining an adequate supply of fuel for iron ore smelting this study was undertaken with the following objectives:

(a) To describe the operations and logistics of charcoal production for the Brazilian iron and steel industry.

(b) To analyze the supply and demand for charcoal and to relate goals of charcoal supply to available sources of raw material.

(c) To relate the need for wood raw material for charcoal production to the economic feasibility of establishing Eucalyptus tree plantations in regions close to the iron mills.

Study Procedure

This study is based principally on field interviews conducted in Brazil during February and March of 1980. Interviews were conducted with officials of IBDF (Brazilian Institute for Forestry Development) in Brazilia, Belo Horizonte and Salvador; the Ministry of Mines and Energy; and the Ministry of Industry and Commerce with CONSIDER (National Council for Steel Industry). Interviews were also conducted with representatives of reforestation companies operating in Minas Gerais and Bahia, with charcoal companies and with officials in a number of iron and steel companies (5 integrated mills and 10 independent producers).

Information on methanol production was obtained from CESP (Energy Company of Sao Paulo State) in Sao Paulo. Other relevant data were obtained from miscellaneous publications. Relatively little material relevant to the subject of this dissertation is available in published form.

Study Area

The southern part of Bahia was selected for analysis of the economic feasibility of establishing Eucalyptus plantations for charcoal manufacture. This is an appropriate location for study. It is reasonably close to the iron and steel centers. The region has been depleted of natural stands of timber. Land use alternatives are limited; land is relatively cheap; unemployed and underemployed labor is available; tree growth is good; and a full tax incentive for reforestation projects is available.

CHAPTER II

LITERATURE REVIEW

Specific aspects of Brazil's iron and steel industry have been discussed in occasional papers, but few formal studies have been reported in technical publications. The most extensive analysis of the iron and steel industry to date was done in 1973 by the Charcoal Steel Industry Work Group of the IBDF (GT - CVS) using data from its own questionnaires, the Brazilian Steel Institute and the National Steel Council.

The GT-CVS study addressed questions related to the viability of the sector and its contribution to the government's expansion plans. Detailed analysis is made on the following points: (1) Charcoal requirements per ton of pig iron produced and the estimated demand for charcoal in 1980; (2) Charcoal potential from natural forest areas; (3) Charcoal potential from Eucalyptus plantations; (4) The price of charcoal and the costs of pig iron production; (5) Comparison of costs from charcoal and coke; (6) Costs of production of a coke mill with two million tons-per-year capacity vis-a-vis a charcoal mill; (7) Comparison of coke- and charcoal-based production for various capacities and levels of pig iron manufacture; (8) Cost of conversion from coke to charcoal use and vice-versa.

The work group concluded that if the iron and steel industry is to meet goals for expansion of pig iron production there will have to be significant improvement in charcoal technology including wood production per hectare for both plantation and natural forests, charcoal production per unit of wood raw material, and charcoal consumption per unit of pig iron or ferro-alloy output. The study indicates that charcoal-produced pig iron is significantly cheaper than coke-produced pig iron. In all cases this cost difference is entirely due to the relative prices of the fuels used -- (i.e., charcoal and coke) -- to reduce the ore.

A comprehensive study of an up-to-date practice in the manufacture of pig iron was done in 1978 by UNIDO (United Nations Industrial Development Organization). It outlines the main features, economies and advantages of making pig iron with charcoal under Brazilian conditions. It gives a detailed description of the technology of forest operations, reforestation and charcoal manufacture in simple kilns. Details are also given of the plant operation and design provided by the main Brazilian charcoal iron-making and engineering companies.

In southern Bahia, one focus of this dissertation, there has been no previous analysis of the feasibility of establishing plantations to provide charcoal for the iron and steel industry.

Fundacao Joao Pinheiro (1979) in Minas Gerais produced a general report on the steel industry and its impact in regional development. This study analyzes the structure of the steel industry in Minas Gerais and its potential. It focuses particularly on the sector impact on regional income, employment, and regional industrial integration and diversification.

Beattie (1975) outlined the history and growth of iron and steel-making in Brazil with particular emphasis on the development of the charcoal steel industry, the circumstances which led to its development, and a brief statement of its prospects for the future.

CHAPTER III

CHARCOAL FOR THE IRON AND STEEL INDUSTRY

Charcoal is produced as a result of the chemical reduction of organic material under controlled conditions. The carbonization process can be summarized as follows:

	Stage	Approximate Temperature	Products
1.	Combustion (kilns only)	Ambient to 600°C, then down to stage 2 temperature.	Carbon dioxide Water
2.	Dehydration	100 - 120°C	Acetic acid
3.	Exothermic	Starts at 270°C; rises to 400 - 600°C	Alcohol Carbon dioxide Carbon monoxide Hydrogen Methane Methyl Alcohol Nitrogen Pitch Tar - Water
4.	Cooling	400 - 600°C to ambient	Nil

The charcoal produced has 50 percent of the volume of the wood raw material, but its weight represents only 30 percent of the dry weight of the wood raw material.

Charcoal for industrial use usually has to meet precise specifications.[1] These can be fulfilled only if the end-product has been made from suitable species, necessary adjustment of the carbonization process has been carried out, and appropriate methods of analysis have been used to insure quality control during production.

The choice of the best method of carbonization must depend heavily upon the location and costs of transporting the raw material. Fixed installations are ideal for undertakings which have available sufficient continuous supplies of low-cost raw material which can be usefully upgraded to charcoal on the site. Most wood available for charcoal manufacture, however, is not concentrated at depots and is usually widely dispersed within forests in the more remote areas. It is in these situations that portable kilns can best be utilized to reduce cost of accumulation and transport of raw material.

Carbonization systems differ widely, but they can be grouped as follows: (1) Kilns -- in which partial combustion of part of the load is used to initiate carbonization; (2) Retorts -- in which the charge is heated by means of an external source of heat applied to the outside of the container; (3) Partial retorts or Continuous Kilns -- in which the wood charge is mechanically driven through a furnace under controlled conditions.

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[1] The technique of charcoal blast furnace operations differs from normal coke-based iron making. For instance charcoal is weaker than coke and is more easily crushed. This factor limits the size and capacity of charcoal blast furnaces. Nowadays, these have reached outputs of 1,000 tons per day but cannot compare with the largest coke-based furnace outputs of more than 10,000 tons per day.

Each system has advantages and disadvantages. For kilns, which are used almost exclusively in Brazil, the major advantages are: low capital costs, no external fuel requirement, low technological requirements, labor intensiveness, and relatively large pieces of wood may be used. Moisture content is not critical. As a major disadvantage, quality and quantity of charcoal are difficult to control and byproducts (energy) are lost. Also, very small material such as chips, sawdust, and bark cannot easily be utilized.

It should be mentioned that charcoal has many different uses for industrial purposes. Besides its use as a thermo-reductor in the steel industry, charcoal can be used for direct drying purposes, e.g., for maturing and curing hops, tobacco and other commodities where a special atmosphere is required. Charcoal can also be used for indirect drying purposes, e.g., in central heating systems for the circulation of heat in tobacco barns. Charcoal can be used as an internal fuel in lime and cement manufacture. It is mixed with limestone and fired to obtain quicklime or pulverized and used in place of oil in fuel-injection equipment. Its main application as pulverized fuel has been in the manufacture of cement--approximately one ton of charcoal is needed to make four tons of Portland cement.

Charcoal Production in Minas Gerais

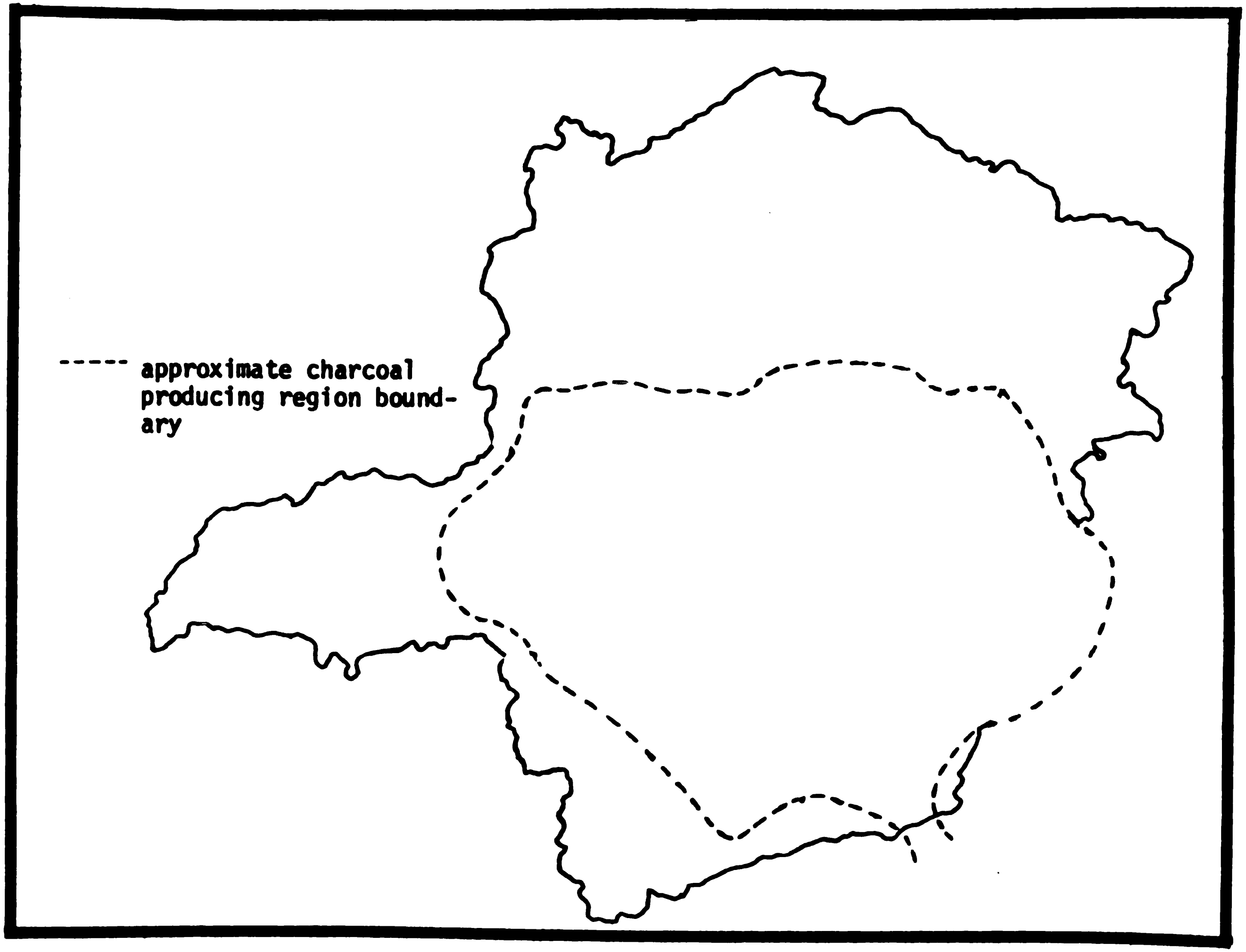
Unlike the activity of coal mining and the manufacture of metallurgical coke, which are always concentrated on a small area, the manufacture of charcoal -- as practiced in Minas Gerais and Espirito Santo --

occupies an area of approximately 200,000 sq. km. Some 8.5 million cubic meters of charcoal are produced on this area (Figure 3).

Charcoal Supplied to Independent Iron and Steel Producers

Apart from the larger well organized charcoal manufacturing centers operated by the integrated steel mills, charcoal is produced by hundreds of independent charcoal suppliers in thousands of beehive brick kilns. These kilns are circular, four meters in diameter, and built into a slope or hill which forms the side and rear walls of the circular kilns. This type is referred to as a "slope type kiln." Many thousands of these kilns are in operation in Minas Gerais and Espirito Santo. They are very popular among the small independent charcoal producers because they can be operated somewhat more easily than the beehive brick kilns because they have only one air-port to control against 18 for the beehive kilns. Small independent charcoal suppliers, as well as the rural labor occupied in the charcoal-related activities, have generally a poor educational background and little knowledge of the art of charcoal manufacturing. Their production is very primitive, using heterogenous wood in remote places where supervision is impossible. As a result, the average operational practice is rudimentary and charcoal quality is not the best suited for blast furnace operation. A good part of the charcoal supplied by these small producers is a byproduct of large scale land-clearing operations by farmers for livestock projects.

The typical charcoaling operation is done by extremely small producers (one or two men) who turn out only two or three cubic meters



Source: Thibau, Carlos E. et al., 1973. Grupo de Trabalho Carvao Vegetal Siderurgia (GT-CVS), IBDF Relatorio Final. Brasilia.

Figure 3 -- Charcoal Producing Region in Minas Gerais.

of charcoal per week. The bags are set by the roadside and picked up by independent truckers who operate over long stretches of road which extend hundreds of kilometers from the consuming centers. In certain regions, with heavy seasonal rainfall, charcoal production is reduced during the height of the rainy season, due to the difficulties of wood gathering, charcoal manufacture and transportation.

Charcoal Supplied to Integrated Iron and Steel Mills

The kilns which are operated widely in Minas Gerais by the large steel mills are the internally heated, fixed, batch type. The important iron and steel companies operate several hundred thousand of them. They are circular, with a domed roof, and are built of ordinary fire bricks. The circular wall is totally in contact with the outside air. This type of kiln is referred to as a "beehive brick kiln." Its design has the following advantages: gas passes through the wood charges; heat contained in the bases is partially used in the process of wood drying and carbonization: yields are good (up to one cubic meter of charcoal from 1.6 steres[1] of wood); and cost is relatively low, about US$ 700 (1978 price) inclusive of access roads for trucks.

Some 20 years ago, the largest charcoal-based steel mill in Minas Gerais, Companhia Siderurgica Belgo Mineira, investigated the use of continuous retorts which promised high yields and the recovery of some

[1] One stere equals one cubic meter of stacked wood.

byproducts, principally tar. Such operations had been demonstrated to be practicable in Australia, Belgium and France. The plan was dropped, both because of the very high initial investment required and the cost of transporting wood from the widely scattered natural forests to the carbonization plants. Because of their size, the proposed continuous retorts would have to be spaced 20 to 50 kilometers apart. Each carbonization plant would also require a large sawmill to cut the wood into pieces of approximately 30 centimeters in length to fit driers and retorts.

Charcoal Manufacture and Byproducts Recovery

As described in the last section, pyrolysis is essentially the charcoal-manufacturing process used in Brazil. Wood is heated in air-tight ovens in beehive kilns supplied with limited and controlled amounts of air. High-temperature heating breaks down the wood into gases, a watery tar mixture or oil, and char. As a major drawback, the system of pyrolysis does not allow recovery of byproducts such as tar, acetic acid, formic acid, methyl alcohol, and acetone. According to Vargas (1977), an annual production of 16 million cubic meters of charcoal during 1980 will lose byproducts currently valued at Cr$ 16 billion.

A decisive economic criterion for Brazilian charcoal producers is the market price of the finished product, since any industrial process requires that the final products be sold at a price that covers the cost of production and provides a certain margin of profits. Since the chemical industry today can produce the byproducts obtained from the pyrolysis process, the main emphasis of the Brazilian steel companies is on the production of charcoal. For this reason, simple carbonization methods using beehive kilns are more likely to be economical than more complicated plants that emphasize isolating and processing of byproducts.

Nevertheless, with the trend of charcoal manufacturing shifting from natural woodlands to plantations, the iron and steel industry's long-range planning must look into the economics of byproduct recovery. It is possible that charcoal manufacturing in the future will depend on byproducts recovery in order to cover the higher costs of establishing Eucalyptus plantations.

By process modification it is possible to change the product output from pyrolysis operations to produce less charcoal or none at all, and to manufacture either more oil and gas or all gas. At the Engineering Experiment Station of the Georgia Institute of Technology, a new pyrolysis process has been developed to produce a fuel composed of a 50-50 mixture of char and oil plus a combustible gas. If the char-oil mixture can be used satisfactorily for heating or other purposes, this process will help improve efficiency of wood fuel usage -- the overall heat loss of the pyrolysis process is only eight percent. Use of gas generated from modified pyrolysis processes can also be an efficient way to extract energy from wood. Various kinds of gasifiers yield products of varying degrees of combustibility containing variable amounts of impurities. However, if the gaseous products can be burned before dropping much below the temperature at which they are generated, process efficiency may be 85 percent or higher.

Charcoal Production Centers

The large steel mills operate beehive brick kilns in batteries of seven, or multiples of seven. Each battery is attended by two men, one charcoal operator or burner and one helper. A charcoal production center comprises one or more batteries of kilns, each complete with the infrastructure necessary for continuous operations -- storage space for firewood and charcoal, charcoal loading facilities, access roads and water supply.

Each kiln in a battery of seven is discharged and recharged in an eight-hour period the same day each week. Kiln No. 1 is discharged and recharged on Monday; Kiln No. 2., on Tuesday; Kiln No.3, on Wednesday, etc.

The charge for a beehive brick kiln (which is five meters in diameter) averages 48.94 steres of stacked firewood. This is equivalent to 37.34 steres of solid firewood. As of 1976 the average yield was 17.8 cubic meters of charcoal, a volume yield equal to 48 percent of the solid firewood volume. Charcoal yields have been improving and are currently estimated at 55 percent of solid firewood volume.

In comparison with beehive brick kilns, the slope type kilns used for charcoaling in independent pig iron producer operations are smaller (4 meters in diameter), take a charge of 17.4 steres of solid firewood, and yield an average of 8.9 cubic meters of charcoal per batch.

Transportation and Storage of Firewood

Firewood is transported: (1) by mules when the terrain is very steep and the kilns are nearby or (2) by mechanical means -- agricultural-type tractors pulling variable numbers of carts, depending on road conditions and distances, and by manually loaded trucks.

Drying makes charcoal wood a more efficient fuel, but the drying process incurs storage charges. Wood which is cut and then left to dry incurs interest charges on the costs of cutting and preparation. A balance must be struck between the calorific gain in drying and the costs of storage. When piled in the open air for 90 to 120 days, charcoal wood loses 30 to 35 percent of its weight and 10 percent of its volume, depending on the season. In Minas Gerais, wood is stored about 90 days before being charged in to the kilns.

Wood stockpiles are stored in the forest, at roadside, or at the charcoal kilns. Stockpiles are at their minimum during the dry season. They are increased during the rainy season, when unpaved roads are frequently muddy, and transportation becomes uncertain.

Transportation of Charcoal to the Mills

The technical disadvantage of charcoal lies in its bulk, which when accompanied by comparative inaccessibility, increases its cost to a level at which alternative fuels may have the advantage. The main items affecting the ultimate price of charcoal are the value of the raw material and payments for cutting and preparation, transport and storage. Transportation is the most critical item determining total cost.

Approximately 70 percent of all charcoal produced in the State of Minas Gerais is transported by truck. The charcoal is moved from the kilns to the iron and steel mills immediately after curing. Most independent pig iron mills rely solely on truck transportation. In truck transportation, charcoal is usually carried in burlap bags (about 25 kilos/bag or 11 bags/cubic meter of charcoal). This practice allows general-purpose trucks to be used which, on the return journey, can carry other merchandise. Bagged charcoal is bulkier than loose charcoal which 'sets' during transport with a volume loss of 2 to 5 percent. Trucks loaded with burlap bags also have a greater tendency to tilt (with possible loss of bags) than when loaded with lump charcoal. Unloading of burlap bags must be done manually.

Mules may be used to move charcoal short distances, up to 20 kilometers, before charcoal can be loaded on trucks and transported over passable roads.

All medium and large iron and steel mills have rail connections and use rail transportation as much as possible. Companies like Belgo Mineira and Acesita transport about 40 percent of their charcoal by rail. Belgo Mineira also uses a cable car system. Most railway cars have a capacity of 54 cubic meters. A few carry 80 cubic meters, and recently, some 100 cubic-meter cars have been put into operation. The cars are sometimes loaded at the railway station directly from trucks, but mostly from a reloading and storage depot through hand-operated gates or by conveyors. Belgo Mineira has been transporting charcoal by rail over distances of 700 kilometers in big, plastic, bagshaped containers of 3 cubic meters volume. The plastic containers also protect the charcoal against moisture. Rail freight charges for charcoal are calculated on a standardized weight basis of 300 kg per cubic meter of charcoal. All handling at the loading and unloading stations is done by the iron and steel mills which also supply all the necessary equipment and carry all expenses. The cars, however, belong to the railway company which is government-owned.

Since 1957 Belgo Mineira has used an aerial cable to move a certain proportion of the charcoal produced in one of the principal charcoal manufacturing centers in the Rio Doce region, east of their Monlevade iron and steel mill. The length of the cable way is 50 kilometers; the charcoal is carried at the rate of 40 tons per hour in steel boxes which are suspended from the cable and move at a speed of 10 kilometers per hour.

Firewood Production From Plantations

The large steel companies have forestry subsidiaries concerned with producing charcoal wood from Eucalyptus plantations. Plantation holdings, owned or leased, range from 20,000 ha among medium-sized firms to 250,000 ha for the largest firms. In Minas Gerais, steel company plantation properties are widely scattered geographically, present a great variety of topographies, are situated at altitudes of 100 m to 1400 m,and occur at distances ranging up to 700 km from the plant. Recently, steel companies have sought larger blocks of contiguous lands for plantation establishment.

The planning of the felling operations, as well as the selection of the forests to be cut, is made in advance. A yearly felling program starts in April and ends in March of the next year. The process is continuous. Each area of forest to be felled is divided into four distinct sections to permit all required operations to be rotated: clearing of underbrush, wood harvest and preparation, hauling to roadside and drying of logs, and site preparation for establishment of a new forest stand. Clearing of the underbrush is done 30 days before felling.

Felling of the trees is done with axes or motor-saws. After felling, the tree trunks are cleaned of branches, bucked into lengths suitable for charcoal manufacture, generally 1.30 meters. Wood is piled, in the forest or at roadside, and the volume is measured in steres before wood is transported to charcoal kilns.

CHAPTER IV

SUPPLY AND DEMAND FOR CHARCOAL

The iron and steel industry of Brazil used charcoal exclusively until 1946 when coke furnaces were installed at Volta Redonda in the State of Rio de Janeiro. Subsequently, coke furnaces were installed at large, integrated steel mills in Minas Gerais, notably at USIMINAS, the largest steel mill in the State, but as of 1980, the iron and steel industry of Minas Gerais bases most of its pig iron production on charcoal.

Since the industry's inception in the early 1900's, however, it has been recognized that the native forest resource would have difficulty in supplying charcoal wood to a sizeable and expanding steel industry over the long term. Many of the engineers of the early 1900's urged that foreign coke be imported as a fuel supply. They opposed reliance on charcoal because: (1) The necessary entrepreneurship, infrastructure and technology for converting wood to charcoal had not been developed in Brazil to make the use of forest energy competitive in a world economy geared to the use of cheap and somewhat more convenient fossil fuels; (2) The dispersed occurrence of the wood resource makes it difficult to achieve the economies of scale possible in the exploitation of concentrated resources; and (3) It was doubtful that the wood resource economically available could long sustain the iron and steel industry.

Some of the early skepticism about the adequacy of the wood resource for charcoal has proved well founded. The ever-diminishing wood resource near the charcoal-consuming centers has caused producers to expand the use of coke and to move farther afield in the woodland region of Minas Gerais for their wood supply. The woodland regions now provide some 60 percent of Minas Gerais' charcoal consumption.

Non-Integrated Mills or Independent Producers

The expansion of the independent pig iron producers in Minas Gerais occurred principally after 1950 when the rapid increase in the demand for pig iron could not be met by the existing integrated iron and steel mills. The independent producer mills were established on the following time scale:

Period of Establishment (Years)	New Mills (Number)
Before 1946	2
1946-1951	1
1952-1959	5
1960-1963	26
1964-1970	12
1971-1980	10
Total	56

The rapid rate of establishment of independent producer mills has maintained an excess of production capacity over the demand for pig iron. This is well illustrated in Table 1.

Table 2. Production and Production Capacity in Independent Pig Iron Producer Mills in Minas Gerais, by Selected Years

Year	Production	Production Capacity	Ratio Production to Capacity
	(Thousand tons)	(Thousand tons)	(Percent)
1969	462	924	50
1973	1017	1820	56
1974	1385	1820	76
1977	1470	2336	67

Source: Centro Technologico de Minas Gerais

Excess capacity presents a cost burden to the independent producers, but it does offer the means of meeting immediate production goals. Government planners project domestic pig iron demand from independent producers to 2 million tons per year by 1982. Additionally, the export market has taken between 100,000 tons and 800,000 tons per year over the past decade.

A case can be made in encouraging the development of small producer enterprises to supply the large, integrated iron and steel mills with pig iron: (1) Small industries help to economize scarce capital for employment; their capital/labor ratio is low, since a unit of capital invested in a small undertaking generally creates more employment than a unit invested in a heavily mechanized, large-scale industry. (2) The small entrepreneurs are often able to pool local funds obtained from their families and friends, and thus capital becomes available for production purposes which would otherwise not be utilized.

(3) Small enterprises require fewer managerial and supervisory skills and can take advantage of traditional abilities. (4) Small industries help to preserve a balance between the rates of economic growth in rural and urban areas.

Charcoal Consumption

Charcoal consumption in Brazil is large in absolute terms, but it does not loom large in terms of overall energy consumption. The 1978 edition of the National Energy Balance, published by Ministry of Mines and Energy, indicates that 1978 charcoal consumption was 4,060,000 tons (or 16,240,000 cubic meters). This comprised 2.3 percent of the nation's total energy consumption. Projected consumption of charcoal reaches 5,723,000 tons (or 22,892,000 cubic meters) in 1985, 2.2 percent of the national energy balance in that year. The modest projection may be unrealistic in view of the strenuous government efforts to find domestic substitutes for petroleum and other fuel imports.[1]

The alternative to charcoal in pig iron production is coke (most of which is imported). For Brazil as a whole, as pig iron production increased, charcoal use increased relative to coke use until 1974 and then declined (Table 2). In 1978, when pig iron production reached 10 million tons, only 38 percent of the tonnage was produced with charcoal.

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[1]Appendix B discusses Brazil's active government programs seeking to use biomass for fuel production.

Table 3. Pig Iron Production in Brazil with Charcoal and Coke, 1970-1978.

Year	Total Production	Production with Coke	Production with Charcoal[1]	Ratio Charcoal Production to Total Production
	(Million tons)	(Million tons)	(Million tons)	(Percent)
1970	4,115	2,237	1,878	45.6
1971	4,686	2,499	2,187	46.7
1972	5,299	2.759	2,540	47.9
1973	5,532	2,827	2,705	48.9
1974	5,846	2,689	3.157	54.0
1975	7,053	3,423	3,630	51.5
1976	8,170	4,141	4,029	49.3
1977	9,380	5,537	3,843	41.0
1978	10,043	6,199	3,844	38.3

[1]Includes production in electric blast furnaces.

Source: Instituto Brasileiro Siderurgia, Anuario Estatistico 1978-1979.

In Minas Gerais, pig iron production rests more heavily on charcoal than on coke, although in this instance also, the percentage share of production depending on charcoal is diminishing (Table 3). In 1970, 68.1 percent of total production in Minas Gerais was based on charcoal; by 1978, the percentage share dropped to 58.5 percent.

Natural Forest Base for Charcoal Production in Minas Gerais

A survey of the charcoal woodland in Minas Gerais (78 percent of the State's total area) was conducted by IBDF, CONSIDER and CETEC in 1978. The survey confirmed that rapid reduction was occurring in each of the natural stand formations.

An analysis of the survey data was made by CETEC to estimate the potential charcoal yield from the remaining natural stands on the assumption that these stands would be managed on a sustained-yield basis (Table 4). Calculations were made separately for each formation type to recognize differences in growth productivity and rotation length.

The potential sustained yield in roundwood production was estimated at 23 million steres annually. This converts to 7.8 million tons of charcoal, a yield capable of producing about 2.2 million tons of pig iron annually. Since 3.5 million tons of pig iron were produced in 1978 with charcoal, it is obvious that the current volume of charcoal production in Minas Gerais far exceeds the sustained-yield capacity of the natural stands.

Table 4, Pig Iron Production in Minas Gerais with Charcoal and Coke, 1970-1978.

Year	Total Production	Production with Coke[1]	Production with Charcoal[1]	Ratio Charcoal Production to Total Production
	(Million tons)	(Million tons)	(Million tons)	(Percent)
1970	2,387	761	1,626	68.1
1971	2,693	853	1,840	68.3
1972	3,170	1,062	2,108	66.5
1973	3,493	1,197	2,296	65.7
1974	3,776	1,036	2,740	72.6
1975	4,847	1,679	3,168	65.4
1976	5,728	2,144	3,584	64.6
1977	5,841	2,465	3,376	57.8
1978	5,922	2,459	3,463	58.5

Source: [1]Instituto Brasileiro Siderurgia, Anuario Estatistico 1978-1979.

Table 5. Potential Charcoal Yield from Natural Stands Under Sustained Yield in Minas Gerais, 1978

	All Natural Stands	Cerradao	Cerrado	Cerradinho	Capoeirao	Capoeirinha
Area subject to cutting (km^2)[2]	95,489	16,170	22,162	29,560	6,470	21,127
Area to be cut annually under sustained yield (km^2)	5,392	647	1,108	1,970	259	1,408
Rotation (years)		25	20	15	25	20
Yield at end of rotation (steres/ha)		80	40	15	130	50
Annual roundwood production (thousand steres)	22,968	5,174	4,432	2,956	3,364	7,042
Annual charcoal production (thousand steres)	7,818	1,725	1,343	896	1,246	2,608

[1]Matas (brushwood) and capoeira not included since formations are subject of permanent preservation according to IBDF's regulation.

[2]Area subject to cutting is 80 percent of existing stands. IBDF legislation requires that 20 percent of the natural stands be preserved intact.

Source: Natural Resources - Charcoal Program, CETEC, 1978.

Overcutting in the natural stands is far greater than the above data imply. Fuelwood removal from the natural stands for household heating and cooking cannot be estimated with accuracy, but it is generally understood to be much greater than the volume removed for charcoal production. There is a further problem in that the charcoal operations do not follow an orderly, management scheme, and this aggrevates the effects of overcutting. Harvesting is concentrated where roads are present and passable and here, large-scale land clearing for livestock projects is in progress. As a consequence, stand regeneration and growth will not occur to the extent visualized in the CETEC scenario, where the yields of natural stands are predicted on a concept of orderly sustained-yield management.

Even in the short run, the problems of charcoal supply for the iron and steel industry are serious. Transportation costs rise dramatically as natural stands are cutover and charcoalers must reach farther from the mills to obtain new supplies of charcoal wood. Economically marginal charcoal operations based on exploitation of natural stands are not sufficiently rewarding to prevent charcoalers from moving to more lucrative rural jobs or to migrate to urban areas. As a consequence, charcoal labor shortages appear even in instances where accessible woodlands are available for cutting, and charcoal supply becomes irregular and undependable. Charcoal prices fluctuate wildly as the pig iron producers attempt to maintain regularity in charcoal supply.

In the long run, it is obvious that charcoal from natural stands cannot be maintained to sustain the existing iron and steel industry, and the problem is made more acute by the fact that the iron and steel industry is an expanding industry. Regardless of what programs may be adopted to improve the output of natural stands for charcoal production, considerably more attention must be focused on tree plantations.

Eucalyptus Plantation Base for Charcoal Production in Minas Gerais

Eucalyptus represents the only tree genus used in reforestation for charcoal production. The reason for this is its adaptability to a great variety of climates, soils and altitudes, its rapid development and high yield, its resistance to pests and diseases, its good regeneration capacity by sprouting after felling, and its excellent quality as a raw material for charcoal. From hundreds of existing Eucalyptus species, the following have produced the highest yields in Brazil to date: *Eucalyptus grandis*, *saligna*, *alba*, *paniculata*, *tereticormis*, *citriodora*, *maculata*, and *microcorys*.

Some 939,000 hectares of Eucalyptus plantations were established in Minas Gerais from 1966 through 1978. Thirty-nine percent of the plantation area (365,000 hectares) was under the direct control of the iron and steel industry. The remainder of the plantations, 574,000 hectares, are owned by individuals, independent reforestation companies, and pulp and paper companies. As competition develops for the output of the plantations not under iron and steel industry control -- for charcoal, chemicals, firewood, pulpwood and sawlogs -- it cannot be safely assumed that charcoal use will usually win out over competitive uses.

Beginning with the base figure of 939,000 hectares of plantations, a series of calculations were made to arrive at the expected charcoal wood yield in the year 1985. Calculations were based on assumptions as follows: (1) The area planted was reduced 30 percent to allow for losses from fires, disease and other natural causes of tree loss.[1] (2) The area planted was reduced an additional 30 percent to recognize that a considerable number of hectares will be diverted into fuelwood, pulpwood, sawlogs and other noncharcoal uses. (3) Expected yields are based on a first rotation harvest 7 years after planting, a second rotation in 13 years, and a third rotation in 19 years.[2] (4) Average tree growth was estimated at 30 cubic meters/ha/year.

Under the assumptions stated above, some 65,700 hectares of Eucalyptus plantations will be available for charcoal wood harvest in 1985. The yield of approximately 2 million cubic meters of charcoal will allow a production of 642,000 tons of pig iron.

Supply and Demand of Charcoal in Minas Gerais by 1985

CONSIDER's 1978 analysis projected Minas Gerais' production of pig iron to 6.1 million tons by 1985. In view of the sustained-yield capacity of remaining natural woodlands in Minas Gerais (a yield which can

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[1]This is in accord with IBDF estimates of losses experienced.

[2]The initial planting is based on seedlings grown in the nursery. Following the first harvest, two coppice rotations are possible before seedlings need be planted again. Smith (1962) describes the coppice method of reproduction (vegetative reproduction) as the simplest and most dependable means of approaching the maximum average annual production obtainable from a given species. There is no delay in reproduction and the growing space in the soil remains almost continuously and completely occupied.

support only 2.2 million tons of pig iron production annually) and the projected yield of plantations in 1985 which could support the production of 642,000 tons of pig iron, it is obvious that the anticipated yield of charcoal wood will be less than half of what is needed. It should also be recognized that the projected plantation yield of charcoal wood may be an overly optimistic estimate since the roads, trucks and other equipment and labor force needed to fully utilize the plantations physically available for harvest may not be in place for full utilization of the plantations. Many plantations have been established by individuals and reforestation companies merely to take advantage of fiscal incentives; planning horizons and investment for such individuals and companies do not always extend to harvest and utilization.

Even if the 1978 level of pig iron production (3.5 million tons) should be maintained without any expansion whatsoever, the sustained-yield capacity of natural woodlands and the anticipated yields of established plantations (a combined yield which may be sufficient for 2.8 million tons of pig iron) will pose serious problems of charcoal supply. It is obvious that the industry's mandatory[1] goals of charcoal self-sufficiency (50 percent in 1985 and 100 percent in 1995) cannot be reached under present programs. The iron and steel industry needs to engage in massive efforts of reforestation for charcoal supply far beyond the efforts visualized to date.

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[1]Federal regulation Portaria Normativa DC-10, issued by IBDF in 1975, requires that charcoal-based iron and steel producers become self-sufficient in charcoal supply from the industry's own plantations by 1995. Fifty percent self-sufficiency is required by 1985. Further elaboration of legislation affecting firewood consumption and charcoal manufacture is in Appendix A.

Reforestation in Minas Gerais in 1978 by the Iron and Steel Industry

Not only is the rate of past reforestation by the iron and steel industry wholly inadequate for projected steel manufacture in 1985, but there is no evidence of increase in the current rate of reforestation to suggest that a reversal of the trend in charcoal wood supply is in motion. In 1979, IBDF approved reforestation projects totaling 360,950 hectares, but only 14 percent (50,000 hectares) represented projects initiated by iron and steel companies. If the iron and steel industry followed the government's Integrated Plan for Industrial Reforestation pointing toward charcoal self-sufficiency in 1995, it would have reforested 110,000 hectares in 1979.

Insufficiency in the planting program by the iron and steel industry sector can be explained in several ways. One explanation is in the sector's excessive optimism about expected yields from the plantations established. Another explanation is that reforestation has been undertaken only by the integrated steel companies. Virtually no reforestation has been done by the independent pig iron producers. Failure of the independent producers to establish plantations is sometimes explained by their lack of investment capital, but this explanation overlooks the fact that these companies can also take advantage of the government's fiscal incentive program. A third explanation is that reforestation is undertaken by the iron and steel mills only to the extent that it can be financed through fiscal incentives. In effect, the steel companies have been willing to reforest a little at no real cost to themselves, but if they are to achieve self-sufficiency in charcoal wood supply, they will have to make additional reforestation investments not subsidized by the government. Present costs to establish Eucalyptus plantations are about US$ 600/ha.

CHAPTER V

ECONOMIC EVALUATION OF CHARCOAL PLANTATIONS IN SOUTHERN BAHIA

Southern Bahia, the area on which this study focuses, contains 2 million hectares. Cattle raising and cacao plantations are the important economic activities, but the region is a promising one for tree plantations. Native forests have been heavily depleted for furniture wood and other products. Land is relatively cheap, and its average distance from the major charcoal-consuming centers in Minas Gerais -- some 600 kilometers -- is no more than the distance at which steel companies have established a number of the existing tree plantations within Minas Gerais. Interstate Highway BR-101 crosses the region from north to south. Secondary roads, which criss-cross the region, are reasonably passable during the rainy season. There are no railroads (Figure 4).

Reforestation projects which have been established aggregate 115,000 hectares -- 80,000 hectares of pine and 35,000 hectares of Eucalyptus. The steel industry of Minas Gerais is represented among the owners of these plantations, but the bulk of the plantation area is controlled by pulp and paper mills in Espirito Santo.

One of the large attractions of southern Bahia for reforestation projects by the iron and steel industry is the location of the region

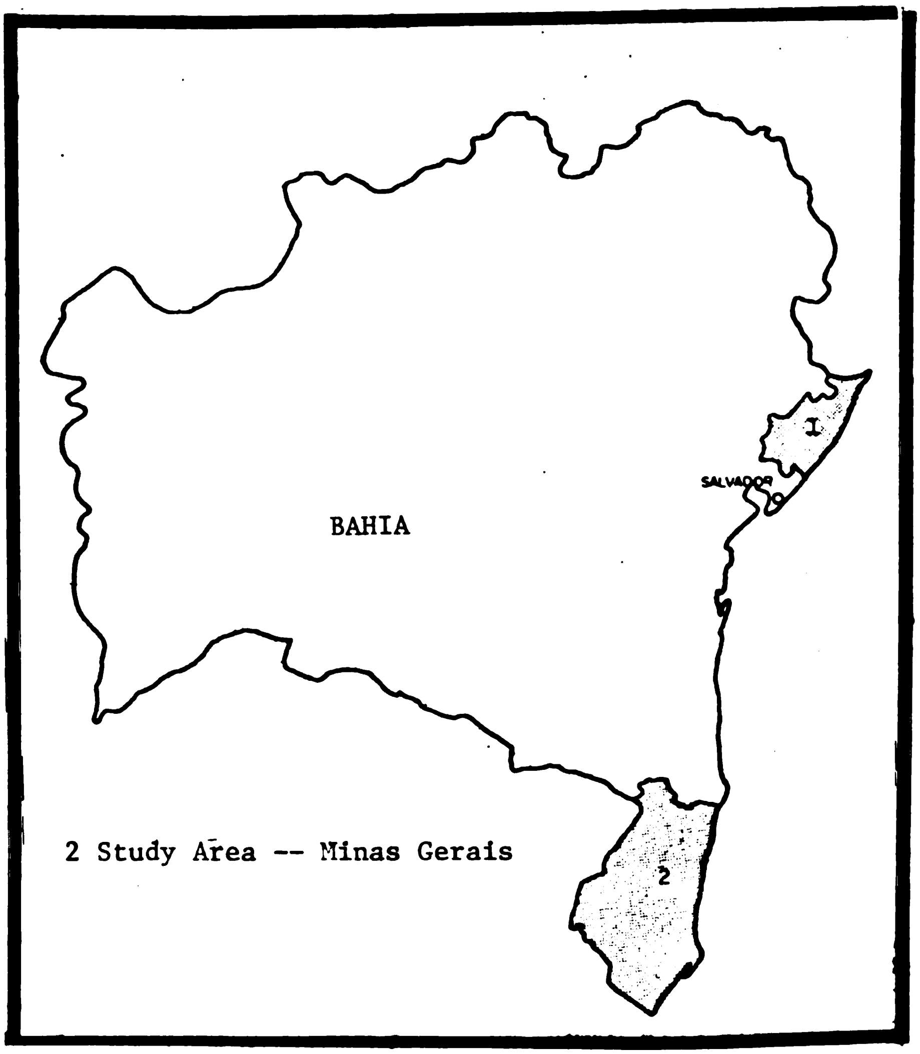

Figure 4 -- Location of the Study Area in Southern Bahia.

within SUDENE's geographic jurisdiction.[1] Within this jurisdiction, corporate tax credits for reforestation projects remain at 50 percent, which is much higher than in the areas close to the iron and steel centers. Financing for reforestation projects is also available from the regional development bank, Banco do Nordeste, and Banco do Brasil.

Assumptions Underlying Financial Analysis

A harvest cycle for Eucalyptus plantations in Brazil assumes an average of 7 years from planting to first rotation harvest, 6 years to the second rotation harvest, and 6 years to the third rotation harvest. Average yields have been reported in a number of studies. Those selected for this analysis were determined by Berger and Engler (1975) as follows: 190 cubic meters at age 7; 100 cubic meters at age 13; and 80 cubic meters at age 19.

The management system used assumes complete site preparation (clearing, plowing, and harrowing), tree planting and fertilization in the first year; weed control in years 2, 3 and 4; and clearcutting harvest in year 7; thinning of sprouts in year 8; a clearcutting harvest in year 13; thinning of sprouts in year 14; and a final clearcutting harvest in year 19.

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[1]SUDENE (Superintendency for the Development of the Northeast), modeled after the United States TVA, was established within the Ministry of Interior to foster regional development of the impoverished Northeast. This area of jurisdiction includes Bahia, Sergipe, Alagoas, Pernanbuco, Paraiba, Rio Grande Norte, Ceara, Piaui, Maranhao and one-fifth of Minas Gerais.

Cost Assumptions

Cost assumptions were derived from IBDF files and records of steel company reforestation experience. Costs are expressed in terms of 1978 cruzeiros per hectare. Year 1 costs are Cr$ 13,600. Year 2 costs are Cr$ 2,985; year 3, Cr$ 2,285 and year 4, Cr$ 917. Thereafter, annual maintenance costs of Cr$ 450 apply except in years 8 and 14, when thinning of sprouts is necessary, and the annual cost is Cr$ 900.

A range of land values per hectare was assumed -- Cr$ 0, Cr$ 6,000, Cr$ 8,000, and Cr$ 15,000. This range of values covers most of the real possibilities facing iron and steel companies for reforestation projects. The zero value assumption is somewhat unreal, but it would reflect conditions where a company owns land with virtually no sale value or apparent alternative use.

Stumpage Price Assumptions

The 1978 value of Eucalyptus stumpage in Southern Bahia, based on limited transaction evidence, is Cr$ 120 per cubic meter. No attempt has been made to chart a real price increase that can be expected to apply when harvests are made 7, 13, and 19 years in the future. Under existing circumstances of rapid decline in the natural forests available for charcoal, it would be reasonable to project real price increases for plantation-grown charcoal wood. Since this has not been done, it should be understood that the financial analysis made may be understating the profitability of plantations.

Interest Rate Assumptions

Two interest or discount rates were selected for plantation analysis -- 8 percent and 15 percent. The lower rate has been selected by the major integrated steel companies as an appropriate rate to use in their analysis of reforestation projects. The higher rate is a commonly expected rate of return in the evaluation of investment alternatives in the Brazilian economy (Bacha, 1971).

Fiscal Incentive Assumptions

In Southern Bahia, full fiscal incentives apply. This means that a corporation may have its income taxes reduced by the full cost of site preparation, reforestation, and fertilization, and cultural work undertaken in years 2, 3 and 4 of a plantation cycle. The limitation on the extent to which income taxes can be waived for reforestation activity by a corporation is that the reforestation expenses cannot exceed 50 percent of the income tax due.[1] In four-fifths of Minas Gerais and in other states where the iron and steel industry has been established, the effective tax credit for reforestation has been reduced to 12.5 of the taxes due.

Financial Analysis

A number of economic parameters have been used to analyze long-term profitability of investments. In this study, the measures used to determine reforestation profitability are internal rate of return (IRR), present net worth (PNW), and benefit-cost ratio (B/C).

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[1]The fiscal incentive program for reforestation is described in detail by Beattie (1975) and Berger (1979).

IRR is defined as the compound rate of interest which equates the present value of expected future returns over the plantation cycle with the present value of expected future costs.

$$\Sigma \frac{R_n}{(1+i)^n} = \Sigma \frac{C_m}{(1+i)^m}$$

where R_n is a revenue item in year n

C_m is a cost item in year m

and i is the interest rate to be determined.

Expressed another way, IRR is the interest rate at which PNW is zero.

PNW is defined as the present value of expected future returns over the plantation cycle minus the present value of expected future costs, with costs and returns discounted at an appropriate rate of interest.

$$PNW = \Sigma \frac{R_n}{(1+i)^n} - \Sigma \frac{C_m}{(1+i)^m}$$

where R_n is a revenue item in year n

C_m is a cost item in year m

and i is the interest rate selected.

The benefit-cost ratio of an investment alternative is determined by dividing the present value of expected future returns (benefits) by the present value of expected future costs.

$$B/C = \frac{\Sigma \frac{R_n}{(1+i)^n}}{\Sigma \frac{C_m}{(1+i)^n}}$$

where the terms R_n, C_m and i are as defined by PNW.

A computer program was used to evaluate reforestation opportunities in Southern Bahia under the three investment criteria cited above -- IRR, PNW, and B/C ratio -- and the underlying assumptions described previously.[1] Results are summarized in Tables 5 and 6.

Under fiscal incentives, plantations are an attractive investment (Table 5). PNW shows a positive return under all assumptions of land costs using the 8 percent rate of return. Even at 15 percent, PNW is positive with land costs per hectare of Cr$ 6,000. B/C ratio is positive at the 8 percent rate with land costs of Cr$ 15,000 per hectare. At 15 percent, the B/C ratio is favorable even with land costs approaching Cr$ 10,000 per hectare. IRR is very high at low land costs and still exceeds 9 percent when land costs are Cr$ 15,000 per hectare.

The favorable financial expectations from plantations established under fiscal incentives compare well with the results of other studies that have been made. The expectations are so favorable, in fact, that it is difficult to understand why some iron and steel companies based on charcoal use have not established plantations to the maximum extent permitted under fiscal incentive legislation.

Plantations established without fiscal incentives are not financially attractive enterprises. Table 6 shows that an IRR of 6 percent might be attained where land cost approaches zero. Under all other assumptions of higher land costs or higher interest rates, the investment will not appear financially attractive.

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[1]The computer program used was developed previously by Professor Daniel Chappelle, Departments of Forestry and Resource Development. The program required only slight modification for use here.

Table 6. Present Net Worth, Benefit-Cost Ratio and Internal Rate of Return for Eucalyptus Plantations in Southern Bahia, with the Use of Fiscal Incentives

	NPW / Ha		Benefit-Cost Ratio		
Land Cost/Ha	Interest Rate 8%	Interest Rate 15%	Interest Rate 8%	Interest Rate 15%	IRR
(Cruzeiros)	(Cruzeiros)	(Cruzeiros)			
0	16,710	9,481	6.18	6.53	> 40
$ 6,000	10,710	3,481	2.16	1.45	21.48
$10,000	6,713	-518.9	1.51	.96	14.29
$15,000	1,713	-5,519	1.09	.67	9.25

Table 7. Present Net Worth, Benefit-Cost Ratio and Internal Rate of Return for Eucalyptus Plantations in Southern Bahia, Without Use of Fiscal Incentives

Land Cost/Ha	NPW / Ha		Benefit-Cost Ratio		IRR
	Interest Rate 8%	Interest Rate 15%	Interest Rate 8%	Interest Rate 15%	
(Cruzeiros)	(Cruzeiros)	(Cruzeiros)			
0	-2,669	-9,303	.88	.55	6.26
$ 6,000	-8,669	-15,300	.70	.42	Negative
$10,000	-12,670	-19,300	.61	.37	Negative
$15,000	-17,670	-24,300	.53	.32	Negative

The conclusions that plantations established without fiscal incentives are not financially attractive enterprises needs a great deal of tempering. It should be understood that the yield assumptions underlying the financial analysis reflect existing average conditions. The average growth rate over a full cycle of 19.5 cubic meters/ha is at least 50 percent lower than the growth achieved by some companies on more productive sites with good management standards. The value assigned to stumpage, Cr$ 120 per cubic meter, is an average 1978 value, but there is good reason to expect that the real price of plantation-grown charcoal wood will increase substantially over the next few decades.

With an objective of maximizing net revenue, it can be expected that iron and steel companies will attempt to establish plantations as profitably as they can (or that they will minimize the losses that may be inherent in plantations established without fiscal incentives). However, the broader perspective requires that the industry establish plantations, not merely to meet government regulations, but to insure an adequate charcoal wood supply for pig iron production. Iron and steel companies need to be concerned with the overall profitability of their operation. Their profitability depends on many inputs. If charcoal is one of the inputs, then there needs to be a sufficient supply to insure uninterrupted production of pig iron. It is essential that iron and steel be produced profitably, not that plantations established to insure an adequate charcoal supply be grown profitably.

Job Creation and Income Distribution

From a social viewpoint, the growing of plantation forests which can sustain or expand the charcoal industry is a desirably objective. The charcoal industry is a medium for improving personal income distribution. Work provided for men who were previously unemployed and transfer of labor from subsistence farming to creative work are net benefits to Brazilian society as a whole due to the extra productivity obtained from the employment provided.

Wages obtained in the charcoal industry have a useful horizontal distributive effect upon national income which is usually weighted heavily in favor of the urban worker. There are signs that urbanization is occurring rapidly in Brazil with consequential problems of increase in crime and other undesirable anti-social trends which can be partly reduced by providing incentives for people to remain in the rural areas.

Employment in the charcoal industry improves the vertical distribution of money since there is a smaller income differential between the upper and lower echelons in a charcoal business than in industries which have to rely upon a top level of qualified local staff.

The estimates of the number of jobs generated per hectare planted are in general agreement with those found by other researchers. Despite the progressive reduction of labor-per-hectare over the years, the figures have leveled off at about 0.30 man/ha/year during plantation establishment and the following three years and 0.15 man/ha/year in the remaining years of the rotation cycle. These figures are relatively high, indicating the labor intensive nature of forestry. Assuming one million hectares of Eucalyptus tree plantations, an estimated 152,000 man-years of employment would be created from plantation establishment, management and harvesting. For charcoal manufacture and hauling based on the plantations, an estimated 353,000 jobs could be provided.

Regional Development

The establishment of Eucalyptus plantations in southern Bahia to provide a supply of charcoal for the iron and steel mills in Minas Gerais is, theoretically at least, a means to regional growth. As pointed out by Isard (1975):

> "It was clear that when the market lay outside the region, we were discussing the possibility of an export industry. Therefore, a basic concept in the literature relates to the set of export industries, or the export base of a region. The growth, development, and economic wellbeing of a region tend to increase, everything else being the same, when the number of outside (export) markets which the region's industries can profitably serve increases."

The establishment of charcoal manufacturing centers in southern Bahia might induce other industries to locate there. That is, there may be backward linkages via input requirements leading to additional growth. Similarly, the charcoal industry produces output which constitutes a source of supply of inputs for other kinds of industries, e.g., the use of charcoaling byproducts by the chemical industry. These industries may desire to save on the transportation cost of the good which they use as an input. They, too, might come to southern Bahia because of savings that are due to forward linkages in industrial interconnections.

There are additional possible growth effects. The new charcoal manufacturing centers would provide jobs resulting in more wages for rural labor and other income to residents of the region. The added income increases the demands for products at the markets in the region, which in turn may lead other activities to locate there and contribute further to the round-by-round expansion.

There is some reason to believe that reforestation in areas of the South and Southeast of Brazil had an overall effect of increasing (or at least maintaining) the concentration of economic development in those areas. As stated by Berger (1979):

> "Industrial growth in Sao Paulo has also been favorably affected by reforestation. The increase in the pulp and paper sector (16 percent per year between 1967 and 1977) cannot be attributed entirely to reforestation, but it is clear that the establishment of tree plantations has been a great incentive to the expansion of the pulp and paper industry."

Still another factor in regional development is import substitution. In early stages of development in southern Bahia, the market in the region for numerous products is too small to justify locating plants producing those products. They must be imported from the industrialized South. However, as the markets in the region expand with its growth in industry, income, and population, the markets can grow to sufficient size to attract industries producing products hitherto imported.

In short, possibilities for import subsitution mount as a region grows, becoming another important source for generating new jobs and income. Moreover, as industries based on import substitution develop in the region, their presence attracts other industries. It is not improbable to visualize that the establishment of large-scale tree plantations and charcoal kilns in southern Bahia would induce the location of new iron and steel mills closer to the charcoal source.

CHAPTER VI

SUMMARY AND CONCLUSIONS

This analysis focuses on the Brazilian charcoal-based iron and steel industry in the State of Minas Gerais and its rapidly increasing problem of charcoal supply.

A survey of the major charcoal producers in Minas Gerais reveals that the native forests which supply wood for charcoal have steadily receded farther from the iron and steel mills. Distances from the producer centers to the consumer centers vary from 80 to 700 kilometers and are now commonly between 500 and 600 kilometers. Increasing transportation distances reflect the exhaustion of natural forests in areas closer to the consumer centers.

For the Brazilian pig iron producers, charcoal is the single most important cost item. It represents almost 60 percent of the total production cost of pig iron. As charcoal transportation increases, it becomes increasingly relevant to examine the economics of charcoal production from tree plantations established closer to the iron and steel centers. Firewood obtained from plantations represents a much greater cost than firewood obtained as a free gift of nature from natural stands, (although this greater cost is not necessarily true if plantations are established under fiscal incentives), but any greater cost that may be involved in plantations must be weighed against the increased transportation costs involved in reaching farther and farther for firewood from natural stands.

Charcoal Production in Minas Gerais

Apart from the larger well organized charcoal manufacturing centers operated by the integrated steel mills, charcoal for the independent pig iron producers is manufactured by hundreds of independent charcoal suppliers in thousands of beehive brick kilns. Their production is very primitive using heterogenous wood in remote places where supervision is impossible. As a result, the average operational practice is rudimentary and charcoal quality is not the best suited for blast furnace operation. According to some studies done by the IBDF, 60 percent of the tree's biomass is lost during the carbonization process using these beehive kilns.

The kilns which are operated widely in Minas Gerais by the large steel mills are internally heated, fixed, batch type. This type of kiln is referred to as a "beehive brick kiln." One advantage of such kilns is its relatively low cost, about $700 dollars (1978 price) inclusive of access roads for trucks.

Supply and Demand for Charcoal

Charcoal consumption in Brazil is large in absolute terms, but it does not appear large in terms of overall energy consumption. In 1978, charcoal consumption was 4,060,000 tons. This comprised 2.3 percent of the nation's total energy consumption. Projected consumption of charcoal will reach 5,723,000 tons in 1985, 2.2 percent of the national energy balance in that year. The modest projection for charcoal may be unrealistic in view of the strenuous government efforts to find domestic substitutes for petroleum and other fuel imports.

The alternative to charcoal in pig iron production is coke (90 percent of it is imported). For Brazil as a whole, as pig iron production increased, charcoal use increased relative to coke use until 1974 and then declined. In 1978, when pig iron production reached 10 million tons, only 38 percent of the tonnage was produced with charcoal.

In Minas Gerais, pig iron production rests more heavily on charcoal than on coke, although in this instance also, the percentage share of production depending on charcoal is diminishing. In 1970, 68.1 percent of total production in Minas Gerais was based on charcoal; by 1978, the percentage share dropped to 58.5 percent.

Natural Forest Base for Charcoal Production in Minas Gerais

A 1978 survey by CETEC of the charcoal woodlands in Minas Gerais confirmed that rapid reduction is occurring in each of the natural stand formations. The potential charcoal yield from the remaining natural stands -- assuming that these stands would be managed on a sustained-yield basis -- was estimated at 23 million steres annually. This converts to 7.8 million tons of charcoal, a yield capable of producing about 2.2 million tons of pig iron annually. Since 3.5 million tons of pig iron were produced in 1978 with charcoal, it is obvious that the current volume of charcoal production in Minas Gerais far exceeds the sustained-yield capability of the natural stands.

Overcutting in the natural stands is far greater than the above data imply. Fuelwood from the natural stands for household heating and cooking cannot be estimated with accuracy, but it is generally understood to be much greater than the volume removed for charcoal production. There is a further problem in that the charcoal operations do not follow an orderly management scheme, and this aggravates the effects of overcutting. Harvesting is concentrated where roads are present and passable and here large-scale land clearing for livestock projects is in progress. As a consequence, stand regeneration and growth will not occur to the extent visualized in the CETEC scenario where the yields of natural stands are predicated on a concept of orderly sustained-yield management.

Even in the short run, the problems of charcoal supply for the iron and steel industry are serious. Transportation costs rise dramatically as natural stands are cutover and charcoalers must reach farther from the mills to obtain new supplies of charcoal wood.

Eucalyptus Plantation Base for Charcoal Production in Minas Gerais

Some 939,000 hectares of Eucalyptus plantations were established in Minas Gerais from 1966 until 1978. Thirty-nine percent of the plantation area (365,000 hectares) was under the direct control of the iron and steel industry. The remainder of the plantations, 574,000 hectares, are owned by individuals, independent reforestation companies, and pulp and paper companies.

Starting with the base figure of 939,000 hectares of plantations, a series of calculations were made to arrive at the expected charcoal wood yield in the year 1985. Some 65,700 hectares of Eucalyptus plantations will be available for charcoal wood harvest in 1985. The yield of approximately 2 million cubic meters of charcoal will allow a production of 642,000 tons of pig iron.

An analysis of the data concerning reforestation in Minas Gerais until 1978 by the iron and steel industry shows that not only is the rate of past reforestation by the industry totally inadequate for projected steel manufacture in 1985, but there is no evidence of increase in the current rate of reforestation to suggest that a reversal of the trend in charcoal wood supply is in progress.

Insufficiency in the planting programs by the iron and steel industry sector can be explained in several ways. One explanation is in the industry's excessive optimism about expected yields from the plantations established. Another explanation is that reforestation has been undertaken only by the integrated steel companies. A third explanation is that reforestation is undertaken by the iron and steel companies only to the extent that it can be financed through fiscal incentives. In effect the steel companies have been willing to reforest at little or no real cost to themselves, but if they are to achieve self-sufficiency in charcoal wood supply, they will have to make additional reforestation investments independent of government subsidies.

Charcoal Supply and Demand in Minas Gerais by 1985

Government's plans for the steel industry project Minas Gerais' production of pig iron to 6.1 million tons by 1985. In the light of the sustained-yield capacity of remaining natural woodlands in Minas Gerais -- a yield which can support only 2.2 million tons of pig iron production annually -- and the projected yield of existing plantations in 1985 which could support the production of 642,000 tons of pig iron, it is evident that the anticipated sustained yield of charcoal wood will be less than half of what is needed.

Even if the 1978 level of pig iron production (3.5 million tons) should be maintained without any expansion whatsoever, the sustained-yield capacity of natural woodlands and the anticipated yield of established plantations (a combined yield which may be sufficient for 2.8 million tons of pig iron) will pose serious problems of charcoal supply. The statistical data support the evidence that the industry's mandatory goals of charcoal self-sufficiency (50 percent in 1985 and 100 percent in 1995) cannot be reached under present programs. The iron and steel industry needs to engage in massive efforts of reforestation for charcoal supply far beyond the efforts visualized to the present date.

Financial Analysis of Charcoal Plantations in Southern Bahia

The financial analysis of Eucalyptus plantations in southern Bahia shows that with the use of the government's program of fiscal incentives, plantations are an attractive investment. PNW shows a positive return under all assumptions of land costs using the 8 percent rate of return. Even at 15 percent, PNW is positive with land costs per hectare of Cr$ 6,000, B/C ratio is positive at the 8 percent rate with land costs of Cr$ 15,000 per hectare. At 15 percent, the B/C ratio is favorable even with land costs approaching Cr$ 10,000 per hectare. IRR is very high at low land costs and still exceeds 9 percent when land costs are Cr$ 15,000 per hectare.

Plantations established without fiscal incentives are not financially attractive enterprises. An IRR of 6 percent might be attained where land cost approaches zero. Under all other assumptions of higher land costs or higher interest rates, the investment will not appear financially attractive.

With an objective of maximizing net revenue, it can be expected that iron and steel companies will attempt to establish plantations as profitably as they can (or that they will minimize the losses that may be inherent in plantations established without fiscal incentives). However, the broader perspective requires that the industry establish plantations, not merely to meet government regulations, but to insure an adequate charcoal wood supply for pig iron production. Iron and steel companies need to be concerned with the overall profitability of their operations. It is essential that iron and steel be produced profitably, not that plantations established to insure an adequate charcoal supply be grown profitably.

Social Benefits of Charcoal Plantations in Southern Bahia

Assuming one million hectares of Eucalyptus tree plantations, an estimated 152,000 man-years of employment would be created from plantation establishment, management and harvesting. For charcoal manufacture and hauling based on the plantations, an estimated 353,000 jobs could be created.

The establishment of Eucalyptus plantations in southern Bahia to provide a supply of charcoal for the iron and steel mills in Minas Gerais is a means to regional growth. It is not improbable that the establishment of large-scale tree and charcoal kilns plantations in southern Bahia would induce the location of new iron and steel mills closer to the charcoal source.

The establishment of charcoal manufacturing centers in southern Bahia might induce other industries to locate there. That is, there may be backward linkages via input requirements leading to additional growth. Similarly, the charcoal industry produces output which constitutes a source of supply of inputs for other kinds of industries, e.g., the use of charcoaling byproducts by the chemical industry. These industries may desire to save on the transportation cost of the good which they use as an input.

Recommendation for Future Research

In the course of conducting this dissertation program, it has become apparent that several areas of further research need to be pursued in the charcoal industry: (1) Cost analysis in charcoal manufacture to determine the most efficient method of manufacture; (2) Transportation cost analysis, with the purpose of determining locations where the added cost of growing charcoal wood in plantations is balanced by the increased transportation cost of reaching receding natural stands; and (3) Environmental effects of different methods of charcoal manufacture as well as the replacement of natural stands with plantations. Inevitably, Eucalyptus plantations and charcoal production centers make appreciable changes in the environment. Gases released during carbonization process are source of atmospheric pollution and, in some regions, reforestation sites with Eucalyptus tree species in place of original virgin forests could cause changes in wildlife habitat, soil erosion and flood control.

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APPENDIX A

IBDF LEGISLATION ON FIREWOOD CONSUMPTION AND CHARCOAL MANUFACTURE

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IBDF LEGISLATION ON FIREWOOD

CONSUMPTION AND CHARCOAL MANUFACTURE

Article 8: The compulsory forest replacement for charcoal or firewood based industries, should be done on the basis of 4 trees per m^3 of extracted wood or 8 trees per m^3 of charcoal. These enterprises must present a reforestation project in a size that will be sufficient to cover wood material consumption in each year of the industries activities since 1968.

Article 9: New steel mills using charcoal will only be registered and the Forestry Permits furnished when these enterprises present projects duly approved by the Non-Ferrous and Siderurgic Council (CONSIDER) and assure wood self-sufficiency with a forest exploitation program independent of supply sources of other existing consumers. The program should indicate:

a) The possession of a private or bound forest reserve which ensures the necessary charcoal supply.

b) A reforestation program in which the replacement rate will be 1 ha for every 275 m^3 of charcoal consumed in the base year to assure self-supply in 22 years;

c) A forestry program approved by IBDF, which envisions the following levels of production for the respective forests;

    1. Cerrado areas: production - 30 m of charcoal per hectare - rotation 15 years.

    2. Tropical dense forest areas: production - 80 m of charcoal per Ha - rotation - 15 years.

    3. Eucalyptus plantations: production - 275 m of charcoal, 3 harvests - total rotation - 22 years.

Article 10: The forest replacement requirement will be reduced by half if the individual owns lands in the cerrado region, where sustained forest management assures raw material supply on a continuous and permanent basis.

In the case of natural dense forests, the replacement will also be halved if the individual submits for IBDF approval a project of sustained forest management, prepared by a qualified expert or enterprise.

Article 12: The burning of wood material from fellings is prohibited for any reason.

Article 15: The exploitation of virgin or naturally regnerated forests will only be allowed if a minimum of 20 to 50 percent of the area is preserved and if the exploitation of the remaining area follows the general rules of utilization;

a) For the Cerrado region, the minimum interval between cuttings will be 10 years unless a minimum basal area of 12 m^2/ha is reached. In the dense forest region the minimum rotation for successive cuttings will be 15 years or when a minimum basal area of 20 m^2/ha, is reached;

b) The cutting plan will be organized so as to yield 200 steres per ha in the dense forest and to obtain adequate rotation in the exploitation areas;

c) In any case, the responsible agent for the cutting permit will not authorize a cutting superior to 15 percent of the total area under management per year.

d) For the cerrado region the regeneration capacity will be determined as having the annual average increment of 7 steres per hectare;

e) For the jungle region, the regeneration capacity will be determined as having the average increment of 8 steres per hectare;

f) At the end of the cutting cycle, the owner of the management area will be able to begin cutting of the 20 - 50 percent reserve areas as long as he can show that the previously harvested areas are being completely regenerated naturally and the first area to be cut was harvested at least 5 years previously;

g) The above exemption will not be given to areas of permanent conservation.

Article 18: The individuals or companies who use raw material from tree fellings must carry out systematic plantation of appropriate species with the purpose of obtaining within 20 years a sufficient amount of charcoal capable of covering the consumption of wood deriving from existing natural forests or plantations.

Charcoal consuming steel mills are obligated to develop plantation or natural forestry programs, to reach 50 percent self-sufficiency in 10 years.

APPENDIX B

CHARCOAL-BASED IRON AND STEEL INDUSTRIES IN OTHER COUNTRIES

APPENDIX B

CHARCOAL-BASED IRON AND STEEL INDUSTRIES IN OTHER COUNTRIES

SWEDEN

Sweden was the dominant iron producer in Europe from the latter part of the XVII Century to the end of the XVIII Century. The only type of fuel which could be used in ironmaking was charcoal which was produced in large quantities from wood out of vast forests. In 1917 the Sweden's charcoal pig iron production reached its peak -- 719,000 tons -- which was nearly reattained in 1944. The last charcoal blast furnace was closed down in 1966.

The charcoal blast furnaces were small production units. In 1947 the average hearth diameter was 2.3 meters, total height 16.7 meters with a working volume of 81 cubic meters. The average production was 40 tons/day per furnace. The largest charcoal blast ever built in Sweden was a furnace at SKF, Hofors, closed down in 1953. Its daily output was 115 tons of pig iron. Charcoal was manufactured mostly with waste products of lumbering -- waste wood, branches and sawmill slabs. During World War II, 5,000 charcoal units were in operation, producing charcoal for iron and steel plants (30 percent) and for automobile gas generators (70 percent). All motor vehicles in Sweden were converted to use gas generated from charcoal.

In Sweden three types of carbonization furnaces or ovens existed: a) Retorts which used the reheated recirculated gases produced during the distillation process and which were totally or partially forced by fans through the wood being carbonized. These installations were very expensive and their operation proved economical only in large installations. b) Furnaces which used the heat generated by the partial combustion of the wood being carbonized for the carbonization process. These furnaces were of simple design, easy to operate, and therefore cheap. c) Furnaces using an outside source of heat for wood drying and carbonization. Some of these furnaces used the heat produced by the combustion of wood charcoal fines, in a separate combustion chamber, for wood drying and the carbonization process, thus increasing the yield of charcoal from wood.

AUSTRALIA

Australia has one small charcoal-based iron and steel plant, the Wundowie Iron and Steel Company in Western Australia, producing 60,000 tons per year of pig iron. The Wundowie plant is characterized by the unique fact that the charcoal is manufactured at the iron plant site and not, as usual, in the forests. The wood used for carbonization comes from natural Eucalyptus forests which are located in the vicinity of the plant. Much of the land is privately owned and has been cleared for farming purposes under arrangements with the owners which resulted in the wood being reserved to the iron plant. The owner was compensated by having his bulldozing carried out at half cost. The cost of wood is a very important factor as it takes approximately 3.5 to 4 tons of wood with 25 percent moisture content to produce one ton of charcoal. Under the conditions at Wundowie, wood represents 75 percent of the total cost of charcoal.

Charcoal is produced in a central carbonizing plant located at the iron plant. The equipment consists of two different systems of retorts which use the combustion bases produced during the distillation process, besides some available blast furnace gas. The thermal efficiency of the carbonization process and the yields of charcoal to wood are high. Air pollution by the pyroligenous vapors is avoided. The operations are mechanized. Charcoal quality is reported to be good.

ARGENTINA

Since 1944 Argentina has operated one integrated charcoal-based iron and steel plant, Altos Hornos Zapla, owned by the government and operated by a department of the Defense Ministry. This was the first integrated plant in Argentina it was followed later by coke-based plants. The charcoal-based plant, situated 12 km from San Salvador de Jujuy, 1356 km North of Buenos Aires, produced 275,000 tons per year of pig iron. It uses charcoal as the principal fuel as well as a small amount of petroleum coke and metallurgical coke. Ninety percent of all the charcoal used is produced from "quebracho" bush forests. Besides the paramount supply from the Grand Charco area, the Zapla company has started to produce some of its own charcoal from Eucalyptus plantations planted in the work area. Two types of kilns are used: beehive brick kilns similar to those developed in Brazil by Cia. Siderurgica Belgo Mineira. The difference is that the Zapla kilns use steel doors, instead of brick doors.

INDIA

In Mysore a steel mill with a blast furnace produces an output of 80 tons of pig iron per day, together with a ferro-silicon plant, is supplied with 40,000 tons of charcoal per year from surrounding forests. Formerly the charcoal was made from distillation of fuelwood in the plant but in 1968 it was decided to stop this method of manufacture on economic grounds and to buy all charcoal from the Forest Department. Charcoal is made, on contract, in large earth kilns. The amount of charcoal per hectare is about 20-25 tons, i.e., 600-700 bags.

APPENDIX C

BRAZIL'S POLICY ON USE OF BIOMASS FOR FUEL PRODUCTION

APPENDIX C

BRAZIL'S POLICY ON USE OF BIOMASS FOR FUEL PRODUCTION

The Brazilian economy has been severely damaged by continuous increases in oil prices. The domestic production of fossil fuels is small, and this year oil imports will demand 40 percent of all of Brazil's export revenues. There has been a chronic deficit in the balance of payments. Spent resources are not recycled within Brazil, and other countries that traditionally import Brazilian goods tend to adopt protectionist trade policies since they also need to seek foreign trade balances.

Recognizing the adverse effects growing dependence on imported oil would have on the country's ambitious long-range economic development programs, the government launched a comprehensive program aimed at developing an alternative and renewable source of energy. The basic objective of the National Alcohol Program (PROALCOOL) is to indirectly harness solar energy by the utilization of plant materials formed through photosynthesis to produce fuel.

Initiated in 1975, PROALCOOL's first phase was to use an overall mixture of 20 percent of anhydric alcohol (ethanol) and 80 percent of gasoline. In the second phase, now being implemented, ethyl alcohol is being sold to the public at attractive prices to replace gasoline as a fuel for spark-ignition engines and to provide up to an 80 percent blend for diesel engines. Surgarcane is the basic raw material, since the technique of obtaining alcohol from sugarcane has been well developed.

Besides PROALCOOL, the Brazilian government has been searching for other renewable sources for energy production. According to a document from the Ministry of Mines and Energy (1979) "... the utilization of biomass energy, with the consequent production of fuel alcohol, vegetable oils, and the development of alcohol-chemistry, although not the ultimate solution for our problems, can be the solution for locations distant from the large systems of energy; it can solve a significant portion of the problem, and can be a transitory solution."

Use of Wood for Fuel Production

Under the government's sponsorship two projects aimed at fuel production using wood as raw material, are being implemented. The first project, partially financed by the Ministry of Mines and Energy, is being undertaken in Sao Paulo by CESP (Companhia Energetica de Sao Paulo). It calls for the use of a gasification system for methanol synthesis. The second project, a joint-venture between the government (represented by IBDF) and private companies under the name of COALBRA (Coque and Alcool da Madeira do Brasil S/A). It aims at ethanol production through wood treatment by acid hydrolysis.

CESP's Methanol Project

CESP's gasification system has a major drawback in the fact that no wood gasifier for large gas production is now available due to economic reasons. CESP decided to pursue two lines of research in the development of wood gasifiers: (1) To design a completely new wood gasifier, and (2) To adapt some existing coal gasifiers to operate with wood. After a survey of the available technologies, three options were selected: (1) To develop and build a wood gasifier using the experience from the present pilot plant (CESP pilot plant in Rio Claros produces 20 kg/hour of methanol using charcoal and has been designed to produce 1,000 kg/day of methanol). This will be a fixed bed unit, with recirculation of wood volatiles. The reaction heat will be partly obtained from electric power and partly through oxygen injection which permits good reaction control and avoids excess consumption of electricity;(2) To develop and build a wood gasifier and a gas cleaning system using a very traditional technology. Such gasifier (fixed bed, atmospheric pressure, counter-current) will actually be the result of updating some units which were built just after World War II for an ammonia plant in India; and (3) To adapt for wood an advanced lignite gasifier that operates at 10 atm in a fluidized bed in co-current.

Economic Parameters for Methanol Plants

According to CESP's studies, a methanol plant with a capacity of 1,000 tons/day would require fixed investments ranging from US$ 140 million to US$ 180 million under present conditions in Brazil. The fixed capital is between US$ 0.21 and US$ 0.35 per liter/year of installed capacity. This investment cost is similar to that needed for ethanol production in Brazil.

In a cost breakdown, CESP stresses that the amount to be paid in foreign currency is about 30 percent of the process equipment and engineering plus the licensing costs. The total importation will represent between 13 and 15 percent of total investment costs.

The wood cost per ton of methanol produced is between US$ 42.80 and US$ 64.20 (2.6 to 3.0 tons of wood per ton of methanol). It is assumed that a Eucalyptus plantation harvesting cycle of 7 years will yield a production of 5 to 7.7 tons of methanol/ha/year.

COALBRA's Project

According to Goldemberg (1980), the process of acid hydrolysis will obtain from one ton of dried wood: 6 kg of furfural, 110 kg of CO_2, 150 to 200 liters of ethanol, 350 to 700 kg of lignin, and 40 to 50 kg of animal feed. The lignin could be transformed in metallurgical coke for the iron and steel industry.

COALBRA's project resulted from a visit of Brazilian officials to the Soviet Union and Switzerland where plants producing some of the byproducts above are in operation.

There are no reasonable data available on fixed investment costs for plants producing ethanol. COALBRA claims that a plant with a capacity of 100,000 liters/day of ethanol would rquire an investment of US$ 23 million. The market value of coke and animal feed is equivalent to 70 percent of the value of alcohol produced. Furthermore, alcohol production cost is considerably decreased by the joint-production of coke (lignin) and animal feed. The approximate cost of alcohol would be US$ 0.71 per liter under the assumption of wood being bought in the market.

INT (Instituto Nacional de Techologia) is building an experimental industrial plant in Lorena able to process 3 tons of wood per day. It is hoped that this pilot plant will lead to a program in industrial scale.

The Resource Base for Wood Fuel

Central to any projection of future supply is the determination of whether the resource base of a commodity is adequate to support the uses contemplated for it, including energy supply. No fuel material, however valuable, has much of a future if it cannot be supported by a substantial resource base.

Brazil's forest resources are immense. Almost fifty-nine percent of the country is in some type of forest cover. The forest flora ranges from tropical rain forests in the North, with cerrado (woodland savannas) and caatinga (dry savannas with scrub wood vegetation) occurring to some extent thoughout the country.

The natural forest area covers 498 million hectares, and more than half of the entire forest area, including cerrado and caatinga, is in the tropical rain forest of the Amazon Basin. The timber volume (64.3 billion cubic meters) is huge, but almost 90 percent of the volume is in the Amazon Basin, composed of more than 400 species. Tree cover is being rapidly cleared from all categories of forest for agriculture and grazing.

Under the fiscal incentive program, established in 1966, Brazil planted an estimated area of 3 million hectares of Eucalyptus and Pinus plantations by 1978. However, these established plantations are committed to current programs being undertaken by pulp and paper, charcoal, and lumber and panel products industries. The current planting, about 300,000 hectares per year, is entirely inadequate for future needs of these industries.

The Wood Resource Base and Fuel Production

In Brazil, both CESP and COALBRA projects call for the use of plantations for fuel production. Whether or not the use of wood for fuel will succeed will depend on a number of factors: 1) As competition develops for the output plantations for charcoal, pulpwood, sawlogs, and panel products, it cannot be safely assumed that ethanol/methanol use will usually win out over competitive uses. 2) Some plantations have been established in remote places, where roads, trucks and other equipment and labor force needed to fully utilize plantations physically available for harvest may not be in place for full utilization of plantations. 3) The COALBRA ethanol plant presents a cost structure in which raw material represents 37.7 percent to 41.1 percent of total costs. CESP's projects indicate raw material costs of about 42 percent. However, under existing circumstances of rapid increase in plantation use by pulp and paper manufacture and the charcoal-based iron and steel industry, it would be reasonable to project real price increases for plantation-grown ethanol wood. The consequence of such real price increase in the raw material is to shift production costs upward and to diminish the competitive edge of ethanol/methanol from wood vis-a-vis ethanol from sugar cane or other renewable resource. 4) Recent optimistic forecasts of domestic oil production in the 1980's may or may not be realized. 5) The future availability and price of imported oil is highly uncertain. If the real price of oil continues to rise, the wood fuel alternative will become increasingly attractive.
6) The future world price for sugar will affect the outlook for wood fuel. High world prices would likely result in greater sugarcane production with less sugarcane being available for direct conversion to alcohol.

VITA

Uziel Batista Nogueira was born on May 17, 1950 in Sao Goncalo do Sapucai, Minas Gerais, Brazil. After being awarded a B.S. degree in economics from Faculdade Municipal de Ciencias Economicas e Administrativa de Santo Andre in 1975, he went to Michigan State University to begin studies toward a Masters in Natural Resource Economics. After two years at M.S.U., Mr. Nogueira received his Masters degree (August 1978). After completion of the M.S., Mr. Nogueira pursued further program for a Ph.D. in the same area of specialization. He received his Ph.D. in September 1980.

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