National Model of Production, Distribution and Consumption of Biomass Energy*

By: Humberto V. Richter**
Reinaldo I. Adams***

SUMMARY

The general objective of this study is to develop an analytical model at national level, of the production and distribution of biomass liquid fuel and their economic relationship with the production and distribution of other agricultural products, whether for internal supply or for export. This model analysis seeks to obtain answers to the energy biomass production effects on:

a) biomass production trade-off, whether for energy or food and fiber;
b) the optimal production allocation among the different regions;
c) the incorporation of new areas for agricultural production;
d) costs and transportation systems in this production allocation;
e) agricultural products supply and price formation of these products;
f) production resource utilization and allocation, especially land and labor, and possible effects on their prices;
g) opportunity cost of alcohol production;
h) income generated by agricultural activities;
i) choice of raw materials for energy.

The interraltions of the various biomass producing regions in Brazil are analysed in this studuy, with production homogeneity criteria being adopted, as well as, resources availanility, means of transportation, etc.. On the other hand, agricultural production, biomass transportation to distillery, industrialization, transportation and distribution of energy products to consumer will be vertically integrated. The final product demand will be introduced in the model, in order to allow the evaluation of biomass production on prices.

It is hoped that this will be a contribution to the improvement of the development policy in the Brazilian energy plan, and that it may supply subsidies for research and investment resources allocation in the country.

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* Paper present at the U.N. Energy Conference, Nairobi, Kenya, Aug. 1981.

** Agricultural Economist, Ph.D, Coordinator of Biomass Area of EMBRAPA's Energy Program.
*** Agricultural Economist, Ph.D, Associate Professor - IEPE-RS.

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I CONCEPT AND OBJECTIVES:

The energy crisis calls for urgent steps in the substitution of imported oil. The external dependency weighs heavily on the balance of payments and generates constant uncertainties caused by the Middle East Crises.

One of the immediate sources for substitution of liquid fuels is biomass. Thus, in the present Brazilian economic conditions affected by the energy crisis, the incentive to agricultural production aims to:

a) supply the growing Brazilian internal market with cheaper food;
b) expand the production of exportable agricultural products in order to minimize the negative effects on the unfavorable balance of payments;
c) produce biomass for energy, and thus substitute for imported oil.

The production increase necessary to supply these needs should be available on a short term basis (1985), fundamentally from enlarging the agricultural frontier. Among the biomass production goals established by the government for 1985, the production of 10,5 billion liters of alcohol annually is foreseen. The Prooleo (Program to produce vegetable-oil in substitution of diesel-oil) is also planned - the present most important energy demand bottleneck in Brazil - aiming the substitution of 10% of diesel by vegetable oils. Finally, the production of ethanol from forestry elements is under study.

According to Homem de Mello[1], this represents an agricultural frontier average expansion rate around 7 to 8% a year during the period of 1977 to 1985. When this rate is compared to an average of 3,7% during 1968 to 1977, it is possible to see that an enormous effort is called for in order to reach the proposed goals.

Recent studies by Reinaldo Adams[2] and Juvir Mattuella[3] on the alcohol production in southern Brazil including São Paulo, showed that the implementation of the alcohol national plan will have important effects on the agricultural economy within the region, such as:

1) Energy biomass production must reallocate the agricultural production, since the competition for the use of resources such as transportation cost will modify: a) the comparative advantage of products spatial allocation; b) production concentration with possible changes for diversification; c) the technology used in the production sector;

2) Transportation weighs heavily on the alcohol final cost to the consumer, so it should be produced near the consumption centers.

3) The expansion of energy crops will take place by substituting already existing crops, reducing the food and/or fiber supply;

4) The demand pressure for production factors will raise prices, both of these factors and the products, also contributing to these crops substitution.

5) This however, will be accompanied by an income distribution effect among producers and among regions.

These studies nevertheless, were restricted to the country's southern region, including São Paulo. This region does not have new agricultural frontiers to be explored, neither are included some large consumption centers such as Rio de Janeiro and Belo Horizonte.

Reinaldo Adams's [2] study included some subregions of the states of São Paulo, Santa Catarina and Rio Grande do Sul only, but included nevertheless, transportation among the regions under study. It did not consider the demand functions for these regions.

Juvir Mattuella's [3] study developed the total programming of the southern region, including São Paulo, and analysed the total demand for all four states programmed, without considering transportation though.

These defficiencies limited the conclusions of the respective studies. Thus this study intended:

1. To enlarge the programmed region, including:
   - new consumption centers such as Rio de Janeiro and Belo Horizonte.
   - new agricultural frontiers such as Mato Grosso do Sul and part of the "cerrados", aiming the substitution and reallocation of crops in the new agricultural frontiers.

2. To program the area un-er study, considering:

- demand functions per consumption center;
- agricultural products and alcohol transportation among production regions and consumption centers.

Objectives:

The program's general objective is to elaborate a study envolving the main socioeconomic aspects of biomass energy production. Along these lines, it is intended:

a) to develop an integrated interregional analysis model including the agricultural production; energy biomass transportation to the processing plants; the transportation of the other agricultural products to consumption centers; distillation of energy biomass; alcohol and other products transportation to consumption centers; and the agricultural products demand.

b) estimate the impact of the Alcohol National Plan on:

- the competition of energy biomass with other agricultural products in each region, through the use of resources;
- the optimal allocation at regional level, of agricultural resources, between energy and non-energy crops;
- the competition within and among regions which produce biomass and other crops;
- spatial allocation of biomass processing plants;
- the interregional distribution of alcohol and other crops;
- crops and resources prices, and income distribution;
- choice, for each region, of the best alternative sources of biomass.

Expected Results:

a) To supply information to the Alcohol National Plan, considering:

- Effects on the quantity and localization of food production;
- optimal allocation of alcohol production;
- Choice between raw materials (biomass) most recommended for energy production;
- subsidies for the government agricultural policy on food export, internal supply, agricultural and agroindustrial credit allocation;
- orientation to the States interests in the resources allocation for alcohol and food production vis-a-vis the national interests;
- orientation to businessmen in order to enable them to operate in in the best comparative advantage regions;
- subsidies for the socioeconomic evaluation of investment in energy and agricultural research.

b) To evaluate energy biomass production impacts on:

- the employment level and labor and land allocation;
- resources and crops prices;
- trade balance.

Beneficiaries:

a. Federal and State Planning Agencies.

b. Research institutions: technological level tests and guidance on its resource allocation; estimate of the new technologies potential and their feasibility in the presence of input and output new price structure.

c. Businessmen: knowledge of regions offering the best comparative advantage, products volume and price; compatibilization of social and private risks; instrument of decision making.

d. Agroindustries and cooperatives.

e. Consumers. The optimal allocation reduces production costs, and can reduce final prices.

II METHODOLOGY

This study aims to develop a "National Model of Production, Distribution and Consumption of Biomass Energy". Several work stages were programmed in order to make this study feasible. In first stage, the previous studies were enlarged to include besides the states of Rio Grande do Sul, Santa Catarina, Paranã and São Paulo, the states of Minas Gerais, Rio de Janeiro and Espírito Santo, Goiás, Mato Grosso do Sul e Mato Grosso (Figure 1). Thus, the options and repercussion of biomass production incorporating the new agricultural frontiers, as well as the new food and energy consumption centers studied. A second and third stages are programmed to complete the program for the whole country. The study was divided into: a) regions according to the production capacity, use of soil, climate, and present production structure; b) consumption regions; c) impor and export centers.

The agricultural production was divided into:

- agricultural products for internal supply, alloted to various consumption regions;
- export crops alloted to the export regions;
- energy biomass products, being considered initially: sugar cane, and cassava for alcohol production, aiming to substitute gasoline and diesel oil; forestry to substitute for fuel oil. Other crops can be included, depending on their technical suitability as an energy alternative source.

The definition of the methodology used was divided into three parts: a) the conceptual model; b) the analytical model; c) the mathematical formulation

Conceptual model. The analysis (figure 2) takes into consideration four levels of competition: the first level concerns the products competition at consumer level. This level is encouraged by government policies to production price control and marketing. At this level, the competition takes place, with final imported and/or exported products.

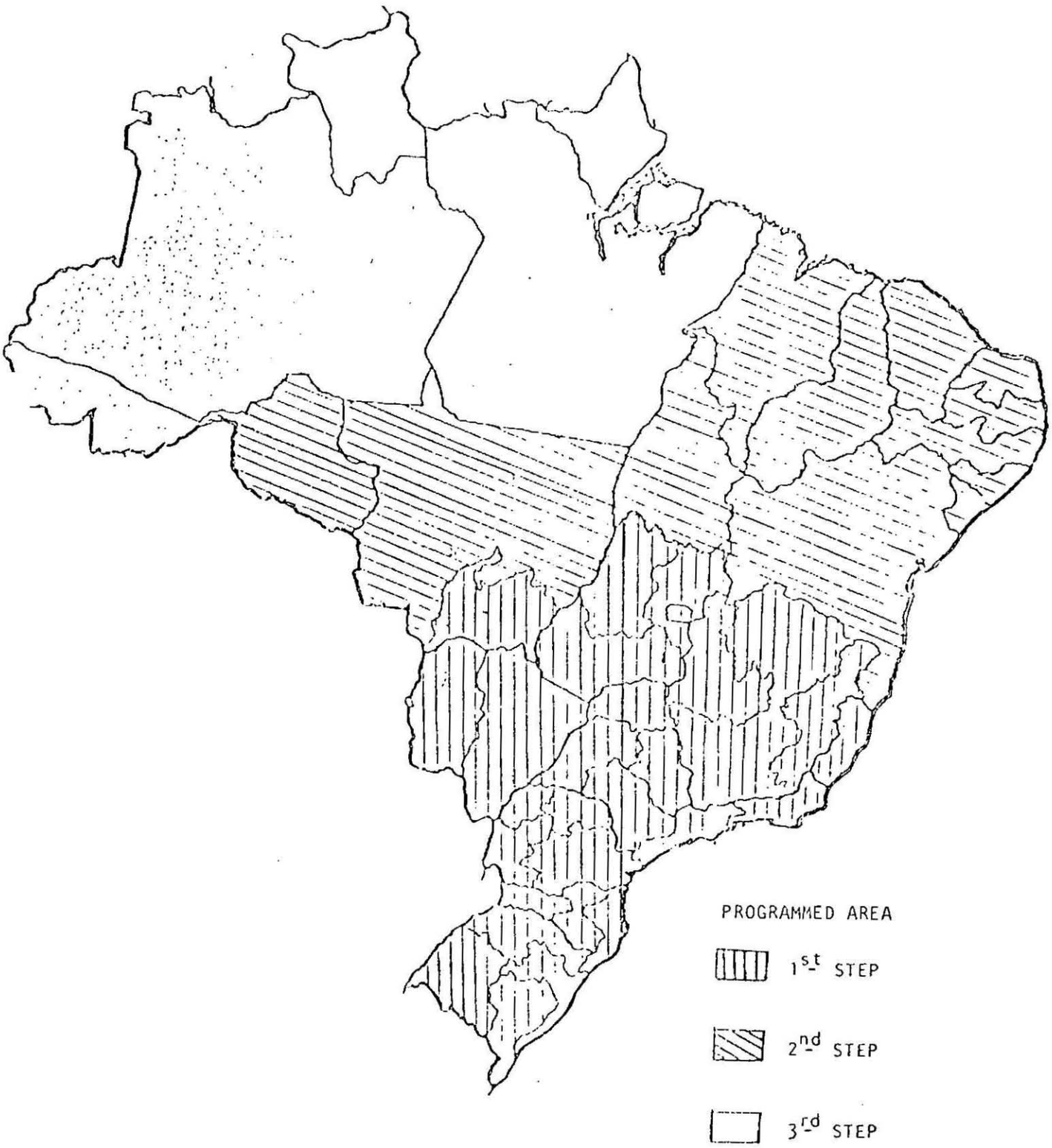
The second level involves imported or domestic petroleum refining. The competition between alcohol and gasoline as well as other oil products, and other energy sources is established. The government policies are expressed in price fixation, quotas, percentages of mixture of alcohol and gasoline, etc.

The third analysis level is established with alcohol distillation. At this level alcohol competes with sugar and other by-products.for resource use. The government intervenes at this level, establishing prices, quotas, production subsidies and agricultural credit.

Finally, the fourth level, which is of our interest in this analysis, studies the agricultural production sector in which sugar cane, cassava and eucaliptus used for energy production compete with other crops (for resource use). When energy production is raised, along with fixed land resource and technology, a food production decrease will occur. On the other hand, an expansion of the agricultural frontier is expected.

The analytical model. The main interest is on the diagnosis of the repercussions of energy biomass production increase, and of energy prices on the main variables involved in the agricultural production sector.

For this purpose, an aggregate model was formulated to describe and analyse the reality found in the study area. This implies a complete analysis of the production, transportation, energy transformation and consumption systems and their respective relationships, both vertical and horizontal, aiming the competition levels and material flow. According to the model, the net margin of production results and alcohol marketing are transferred to the farmer, competing with the production of non-alcohol crops. The energy input, both direct and indirect, are fed into the system and analysed among the whole process.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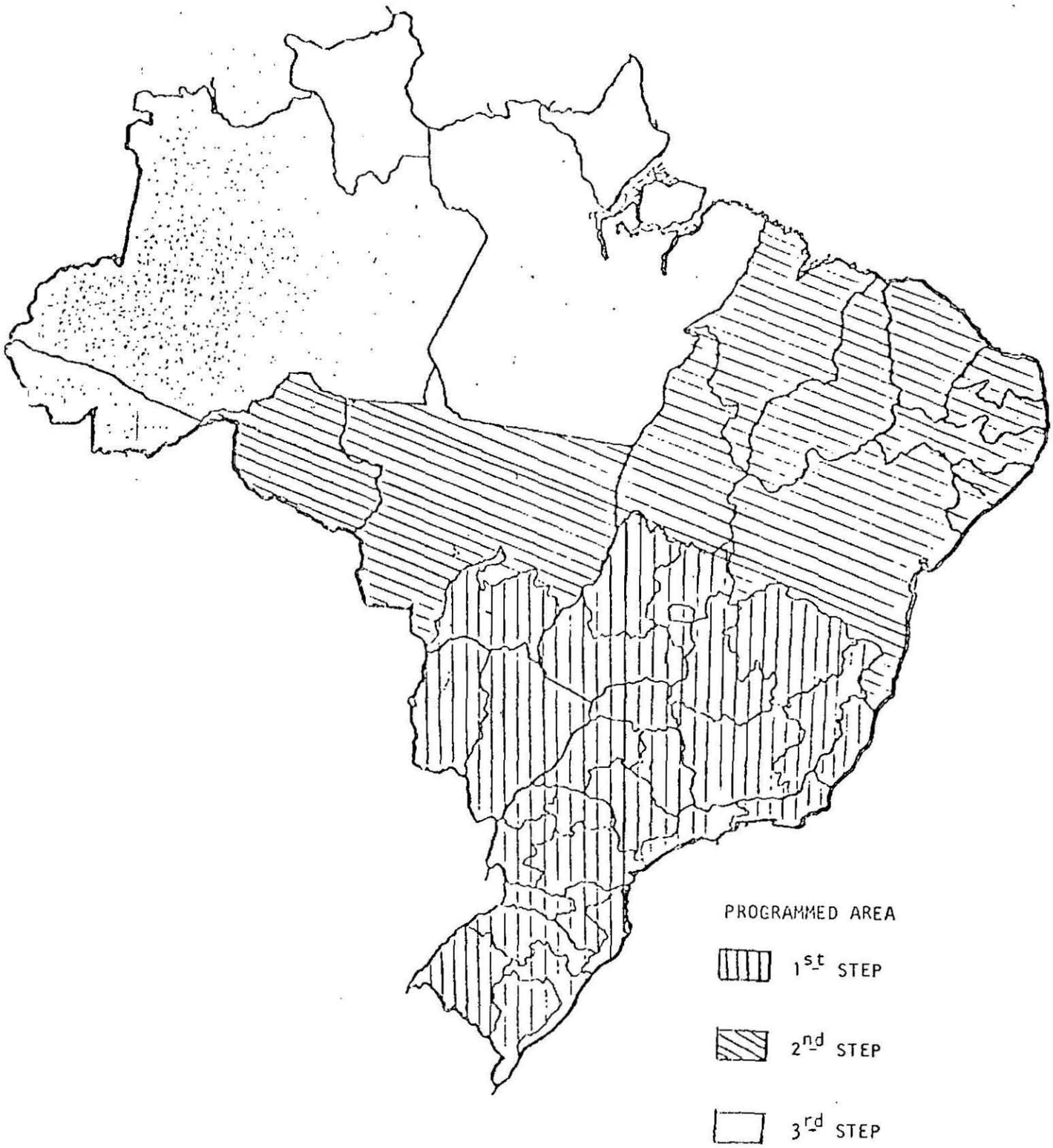
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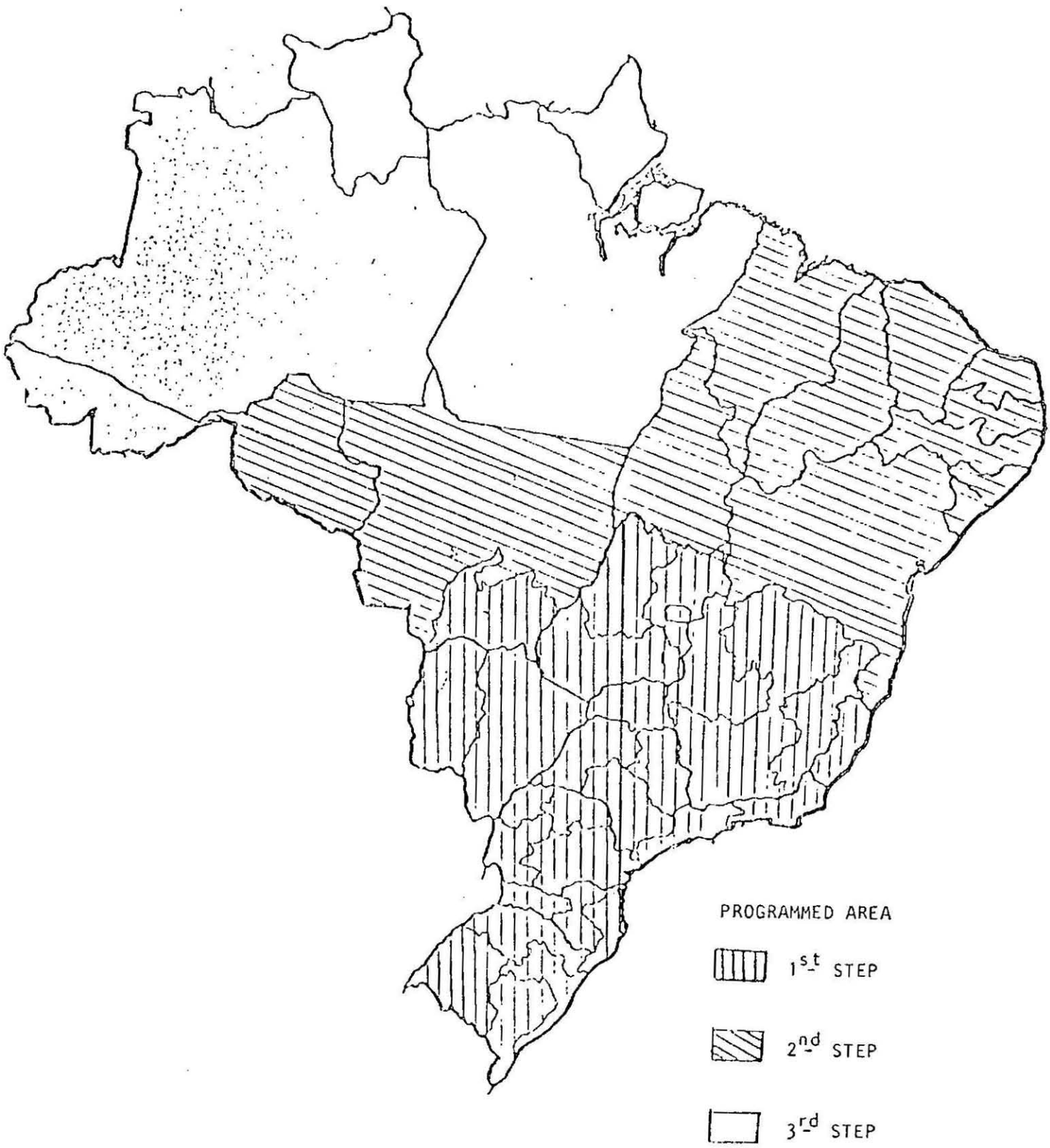
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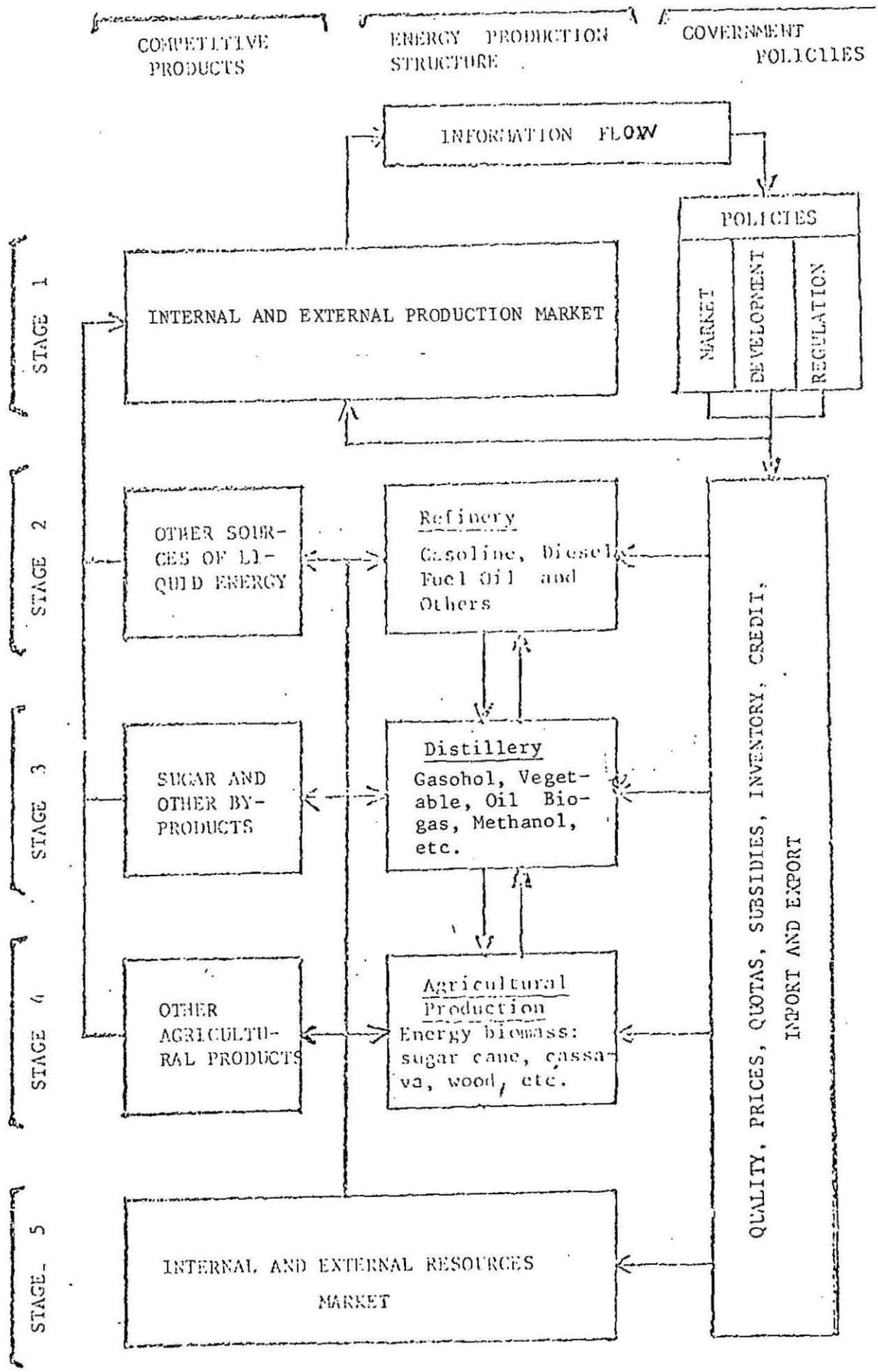

FIGURA 2: ANALYTICAL CONCEPTUAL MODEL

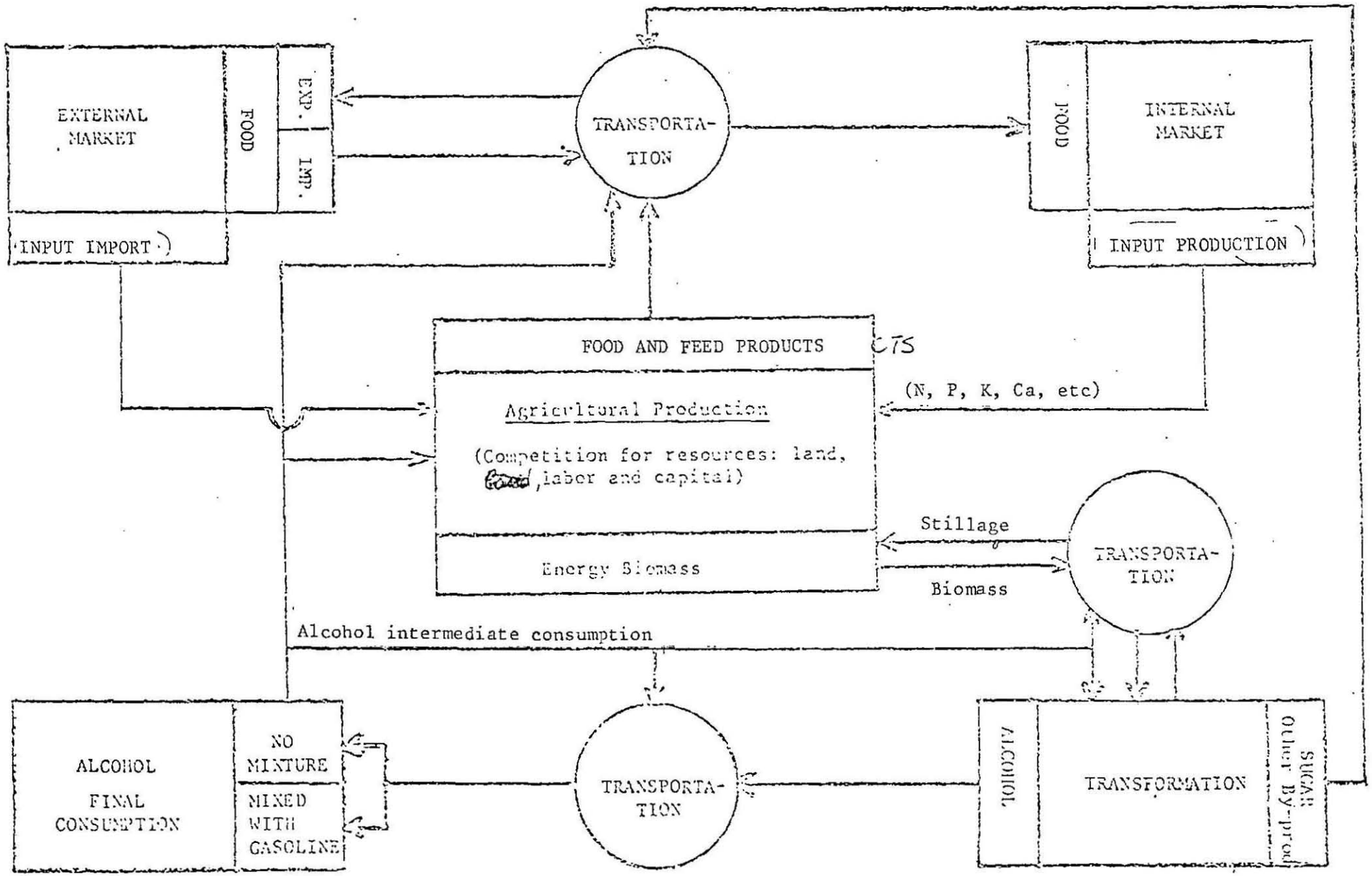

FIGURE 3: ANALYTICAL MODEL

Mathematical Formulation

The analitical model consists of the maximization of a non-linear objective function subject to linear restrictions. The objective function is made up of two parts: the first one, positive, represents the total area under several products demand curves; the second one, negative, represents the total cost, or the area under the supply curves of several products. Thus, the objective function is the addition of the consumer and the producer surpluses.

The addition of these surpluses is maximized subject to several restrictions, such as: fixed resources availability; technical limitations in product transformation; limits of transportation capacity; supply restrictions; demand restrictions; alcohol production limitations; and export and import limitations. The final products considered in the model are food, fiber and energy products. Food and fiber are classified as primary products (non processed) and secondary (the result of a primary product processing); they are also classified as domestic demand and exportables.

Formally, the model can be expressed in this manner:

$$\text{Max } W = \sum_f \sum_j \left[\int_0^{q_{fj}} p(q_{fj})\, dq_{fj} \right] + \sum_j P_{1j}\, q_{1j} -$$

$$- \sum_f \sum_i C_{fi}\, X_{fi} - \sum_e \sum_i C_{ei}\, X_{ei} - \sum_{f=F-N+1}^{F} \sum_i G_{fi}\, S_{fi} -$$

$$- \sum_e \sum_i G_{ei}\, L_{ei} - \sum_f \sum_j \sum_j \sum_v t_{fijv}\, T_{fijv} -$$

$$- \sum_i \sum_j \sum_v t_{ijv}\, T_{ijv} -$$

$$- \sum_f \sum_k \sum_j \sum_v (t_{fkjv} + M_{fk})\, T_{fkjv}$$

Subject to the following restrictions:

1) $\sum_f a_{rfi}\, X_{fi} + \sum_e a_{rei}\, X_{ei} \leq B_{ri} \quad r = 1 \ldots\ldots R \quad i = 1 \ldots\ldots I$

2) $\vartheta_{fi}\, Y_{fi}\, X_{fi} = S_{fi} \quad f = F-N+1 \ldots\ldots F \quad i = 1 \ldots\ldots\ldots I$

3) $\sum_{e} g_{ei} Y_{ei} X_{ei} \leq L_i \quad (i = 1.....I)$

4) $\sum_{f} T_{fijv} + T_{ijv} \leq B_{ijv} \quad \begin{pmatrix} i = 1.....I \\ j = 1.....J \\ v = 1.....V \end{pmatrix}$

5) $Y_{fi} X_{fi} \geq \sum_{j} \sum_{v} T_{fijv} \quad \begin{pmatrix} f = 1.....F-N \\ i = 1.....I \end{pmatrix}$

6) $S_{fi} \geq \sum_{j} \sum_{v} T_{fijv} \quad \begin{pmatrix} f = F-N+1...F \\ i = 1.....I \end{pmatrix}$

7) $L_i \geq \sum_{j} \sum_{v} T_{ijv} \quad (i = 1.....I)$

8) $q_{fj} \leq \sum_{i} \sum_{v} T_{fijv} \quad \begin{pmatrix} f = 1.....F \\ j = 1.....J \end{pmatrix}$

9) $L_j \leq \sum_{i} \sum_{v} T_{ijv} \quad (j = 1.....J)$

10) $\sum_{i} L_i \leq B$

11) $\sum_{k \in f} q_{fk} \leq B_f \quad (f = 1.....F)$

12) $\sum_{k} \sum_{j} \sum_{v} T_{fkjv} \leq BM_f \quad (f = 1.....F)$

Where:

W = the sum of consumer and producer's surpluses

P_{fj} = $D(q_{fj})$ is the demand function, indicating that the f-th product price, in the consumption region j, is a function of the demanded quantity of the same, in this consumption region.

q_{lj} = alcohol demanded quantity in consumption region j.

P_{lj} = is the price of alcohol in consumption region j.

X_{fi} = cultivated area with the f-th product in production region i.

X_{ei} = cultivated area with the e-th energy product in production region i.

c_{ei} = variable cost of production, per area unity, of the e-th energy product in production region i.

S_{fi} = quantity of the f-th food or fiber produced offered in region i.

C_{fi} = production variable cost, per area unity, of the f-th product in region i.

G_{fi} = processing cost of the f-th food or fiber in region i.

L_{ei} = quantity of alcohol produced, starling with the e-th energy product in production region i.

G_{ei} = transformation cost of the e-th energy product into alcohol in region i.

T_{fijv} (T_{ijv}) = quantity of the f-th food or fiber (alcohol), transported from production region i to consumption region j, through transportation route v.

T_{fkjv} = quantity of the f-th product transported from point k to consumption region j, through route v.

t_{fijv}, t_{ijv}, t_{fkjv} = the respective costs of transportation per product unity.

M_{fk} = import price of f-th food in point k.

a_{rfi} (a_{rei}) = coefficient indicating necessary amount of r-th fixed resource, per area unity, for the production of food f (primary product e) in producing region i.

B_{ri} = availability of r-th fixed resource in production region i.

g_{fi} = coefficient indicating quantity of secondary product f-th to be obtained from one unity of primary product in region i.

g_{ei} = coefficient indicating quantity of alcohol to be obtained from one unity of the e-th energy product in region i.

L_i = total amount of alcohol produced in production region i.

L_j = total amount of alcohol demanded in consumption region j.

Y_{ei} (Y_{fi}) = productivity per area unity, of the e-th energy product (f-th food) in production region i.

B_{ijv} = transportation capacity of v-th route between agricultural production region i and consumption region j.

q_{fk} = quantity of product f produced in production region k (KEI) to be exported.

B = alcohol quantity to be produced by all production regions together.

B_f = quantity of f-th food or fiber to be exported by the complex of ports K.

BM_f = maximum quantity of f-th food to be imported by group of consumption regions j.

Restriction 1 indicates that the fixed use of resources in a production region cannot excede the availability.

Restrictions 2 and 3 indicate that the quantity of a secondary product (alcohol) produced in one region cannot excede the volume technically possible to obtain from its primary products (energy products) produced within the region. It is considered that the products will be processed within the production region.

Restriction 4 concerns the transportation capacity limits of the serveral routes.

Restrictions 5, 6 and 7 concern supply. They indicate that the quantity of food, fiber or alcohol sent from one production region to all consumption regions cannot excede the volume produced in this production region.

Restrictions 8 and 9 concern demand. They indicate that the quantity of food, fiber or alcohol demanded in one consumption region cannot excede the sum of the quantities that it receives from all production regions.

Restriction 1o to 12 establish limits in the alcohol production as well as food and fiber import and export.

VARIABLE DEFINITIONS

Consumption and Production Regions

The area of the study has been divided into nine consumption regions. Each of the following states constitutes one consumption region: Rio Grande do Sul, Santa Catarina, Paraná, São Paulo, Rio de Janeiro, Espirito Santo, Minas Gerais and Goias. The states of Mato Grosso do Sul and Mato Grosso farm both one consumption region. The area of the study has been divided into 28 production regions, as indicated in the following table.

Table Nº - Number of production regions considered in each state.

S T A T E	Nº of Production Regions
Rio Grande do Sul	4
Santa Catarina	3
Paraná	4
São Paulo	4
Rio de Janeiro	1
Espirito Santo	1
Minas Gerais	5
Goias	3
Mato Grosso do Sul	2
Mato Grosso	1
T O T A L	28

Besides the consumption and production regions six harbours (Rio Grande do Sul, Itajai, Paranagua, Santos, Rio de Janeiro and Vitoria) were considered, as points of exportation or importation of agricultural products. The area of Brazil (North and Northeast) not directly included in the first phase of the study has been considered as one consumption region and as one production region, with a fixed supply and demand of agricultural products.

Crop and Livestock Production

The crop production processes (activities) of each product differ mainly in two aspects: being or not mechanized and using or not fertilizer. For rice still another characteristic, irrigation, has been considered. The livestock activities include cattle, dairy cattle, hogs and chicken.

The restrictions imposed on the production activities are land, labor, tractors, combines, and animal power. There are upper limits on cropland, pastureland and land for forestry. There are upper and lower limits for each crop and livestock, based on historical data and flexibility coefficients.

Two types of labor, family and hired, are included in the model. Each of these is divided into especialized and non-especialized labor. Three sizes of tractor were considered, small, medium size and large. But the small and large were transformed into a medium size equivalent. The model includes six periods (of two months each) for the availability and use of labor, tractor, combine and animal honrs. Closely related to the production activities are the transformation, hiring, buying and transfering activities.

Alcohol production

Alcohol can be produced from sugar-cane, cassava, sorghum, sweet potatoes and others. Also wood can be used to produce eather alcohol, methanol or coal as energy products. A transportation system is programmed to carry energy products to the transformation plants, and from there to the final consumption centers.

Products

The final products considered in the model are cattle, hog and chicken meat, eggs, milk, alcohol, bananas, beans, cassava, cotton, corn, coffe, oil, oranges, peanuts, potatoes, rice, soybeans, sugar and wheat. These products are produced in the production regions and transported to the consumption regions or to the harbours for exportation. On the other hand the possibility has been considered, to import certaim agricultural products, like corn, wheat, etc. Connecting the production regions to the consumption regions or to the harbours, and the harbours to the consumption regions, there is a transportation system.

Transportation system

The model consideres transportation by truck railroad and ship, between whatever regions these alternatives exist. The cost/ton of transportation the products was estimated as being in part a function of the distance and a fixed charge corresponding to the cost of loading and unloading. The cost of transportation by truck has been calculated, based on truck's depreciation and maintenance, wages, fuel, lubricants, etc. To estimate the transportation cost by railroad and ship the tariffs charged by Rede Ferroviaria Federal and Loid Brasileiro were used as a proxy. Upper limits were included in the model for transportation by railroad and ship, based on there capacity restrictions.

Final Consumption

The model includes the final consumption of products. Demand functions have been estimated, regarding each product in each consumption region. Product own price elasticity, income elasticity and population have been used to define prices and quantities for final products within consumption regions. A markup for each product between production and consumption was calculated to equate price differentials. Finally, international demand functions for several products were established to aproximate export decisions.

Table Nº . - Final Demand Commodities

01. Wheat	13. Beef (carcass)
02. Rice	14. Pork (carcass)
03. Corn	15. Poultry
04. Sorghum	16. Eggs
05. Soybeans	17. Milk
06. Peanuts	18. Coffee
07. Vegetable oils	19. Cocoa
08. Soyneal, Cottonmeal	20. Alcohol
09. Sugar	21. Coal
10. Potatoes	22. Cotton
11. Beans	23. Tobacco
12. Citrus	

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