A GDR MODULE OF THE EUROPEAN FOREST SECTOR MODEL

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FOREWORD

The objective of the Forest Sector Project at IIASA is to study long-term development alternatives for the forest sector on a global basis. The emphasis in the Project is on issues of major relevance to industrial and governmental policy makers in different regions of the world who are responsible for forestry policy, forest industrial strategy, and related trade policies.

The key elements of structural change in the forest industry are related to a variety of issues concerning demand, supply, and international trade of wood products. Such issues include the development of the global economy and population, new wood products and substitutes for wood products, future supply of roundwood and alternative fiber sources, technology development for forestry and industry, pollution regulations, cost competitiveness, tariffs and non-tariff trade barriers, etc. The aim of the Project is to analyze the consequences of future expectations and assumptions concerning such substantive issues.

The research program of the Project includes an aggregated analysis of long-term development of international trade in wood products, and thereby analysis of the development of wood resources, forest industrial production and demand in different world regions. The analysis is carried out employing a global forest sector model for which this article represents the data of the German Democratic Republic.

Markku Kallio
Project Leader
Forest Sector Project

CONTENTS

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1. INTRODUCTION

The primary purpose of this paper is to suggest how to include a module representing the forest sector* of the German Democratic Republic (GDR) in a Global Trade Model (GTM) (Dykstra and Kallio 1984). In this connection I intend to discuss some current and prospective problems of the forest sector of the GDR. At the beginning let me briefly illustrate why research into long-term development of the forest sector of the GDR is very important. Then I shall describe an input-output model, illustrating the conversion of raw wood into final products, because this model is suitable for estimating the consumption levels of final products (sawnwood, panels, papers and boards) used in model runs with the GTM in the version by Dobrinsky and Kallio (1984). Then I shall discuss the connection between an optimization model of the GDR forest sector and the GTM.

Research into long-term development in the forest sector of the GDR is considerable from various points of view:

1. the development of consumption,
2. the development of the raw material base of the whole,
3. the development of forest resources and their utilization,
4. the international trade of forest products.

*According to the view of Andersson et al, the forest sector comprises two major components: forestry and the forest industry. The forest sector concept integrates all aspects connected with forests and their exploitation, i.e. activities ranging from timber growth to the use of end products. Ecological, environmental, and socio-economic factors are included in this definition (Andersson et al, 1984).

From the beginning of human production activities wood has been of great importance. Wood was needed for the production of 200 goods 2,000 years ago, 2,000 goods in 1919, 4,500 goods in 1930, 10,000 goods in 1960 (Offner 1961), and, in the GDR, 12,000 goods in 1980. In 1980 wood was allocated to the following so-called consumption complexes*:

- 20% to the consumption complex "housing",
- 17% to the consumption complex "transport and package",
- 16% to the consumption complex "education, information and science".

As the saturation level is not achieved, we expect rapid growth of these consumption complexes accompanied by increasing wood demand.

Wood is one of the important domestic raw materials of the GDR. A great number of other raw materials have to be imported. In connection with the price revolution for raw materials and energy sources at the beginning of the 1970s, we can observe a new economic approach to wood. The reactions focused on identifying strategies for an enlarged use of wood as an alternative raw material. The extension of wood use as a construction material, as chemical raw material, even as an alternative energy source (Langendorf 1981a) is under discussion. However, this is a controversial issue. A feature of the Industrial Revolution almost 200 years ago was the replacement of wood with so-called nonreproducible, depletable resources, e.g. steel, coal, concrete. In comparison with wood, which depends on a biological reproduction process, these raw materials were readily available. In this way it was possible to overcome the limits of economic growth set by the raw material base. To a certain extent we expect the opposite process in the distant future. Nonreproducible, depletable resources will be partly replaced with reproducible (i.e. biological) resources. However, the increased use of wood is very important for the future, when other raw material sources will be depleted.

In this connection we have to consider the following problem. On the one hand, biologically speaking, wood is exhaustible because it is reproducible. On the other hand, economically speaking, wood is exhaustible because it may be used up unless we give it the chance to reproduce. Avoidance of this effect implies long-term restraints in organic production in forestry. That was the case in the GDR. Especially from the beginning of the 1930s to the beginning of the 1950s the wood harvest exceeded the annual growth (Figure 1). The forest stock decreased rapidly. Hence it was necessary to restrain the annual cut (Figure 2). In this period ranging up to 1966 imports had to be increased rapidly to satisfy the need (Figure 3). Since 1966 the annual cuts have been increased parallel with the forest stock (Figure 4). In 1984 the growing stock is 179 m^3/ha (Rüthnick 1984). The annual cut per hectare is about 4 m^3 and the annual accumulation is over 2 m^3/ha (Kurth/Lucas 1980). The accumulation is necessary to improve the structure of forest stock, especially the age distribution. In Tables 1a and 1b we see the differences between the current and the optimum age distribution of trees resulting from the overcutting 35-50 years ago. The differences are significant for the main tree species, pine and spruce. The long-term consequence is to harvest large numbers of trees in young age classes.

In this connection the third aspect, the development of forest resources and their utilization, is discussed. In general, we have three possible ways to cover the increasing demand:

- increases in the degree of utilization of wood grown,

*By so-called "consumption complexes" we understand a network of similar consumption activities.

- increases in organic production per hectare and time unit,
- increase or decrease of exports.

Today only 50-55% of the grown forest biomass is used. In the forest industry only 50-60% of the used wood goes into final products. On the whole from the grown wood 25-35% is efficiently used (Langendorf 1981a). Up to 2000 we expect the closing of the cycle of wood utilization, so that increase in organized production per hectare and time unit is the only way to cover the increasing demand. To achieve a higher organic production, intensification measures (raising the fertility of soil and productivity of stands, optimization of tree structure, breed of new tree species etc.) have to be extended. On the whole, there will be an increase in increment amounting to 3 m^3/ha and within the time horizon of a doubling of the volume of timber cut per unit of area in 100 years (Figure 5). This amount considers lowered organic production at the expense of securing the social functions of forest (Kurth/Lucas 1980). To utilize these possibilities of increasing organic production we have to consider the time lag between expenditure and results revealed in increases in grown wood.

The third possible way to cover the increasing demand for wood is the extension of foreign trade. Since the beginning of the 1950s the import of wood and intermediate products has increased continuously (Figure 3), accompanied by an increasing export of forest final products, especially furniture. To investigate the prospective level of foreign trade of forest products we have to consider the development of international trade of products, trade barriers, market inertia, etc. This will be done in Chapter 3.4.

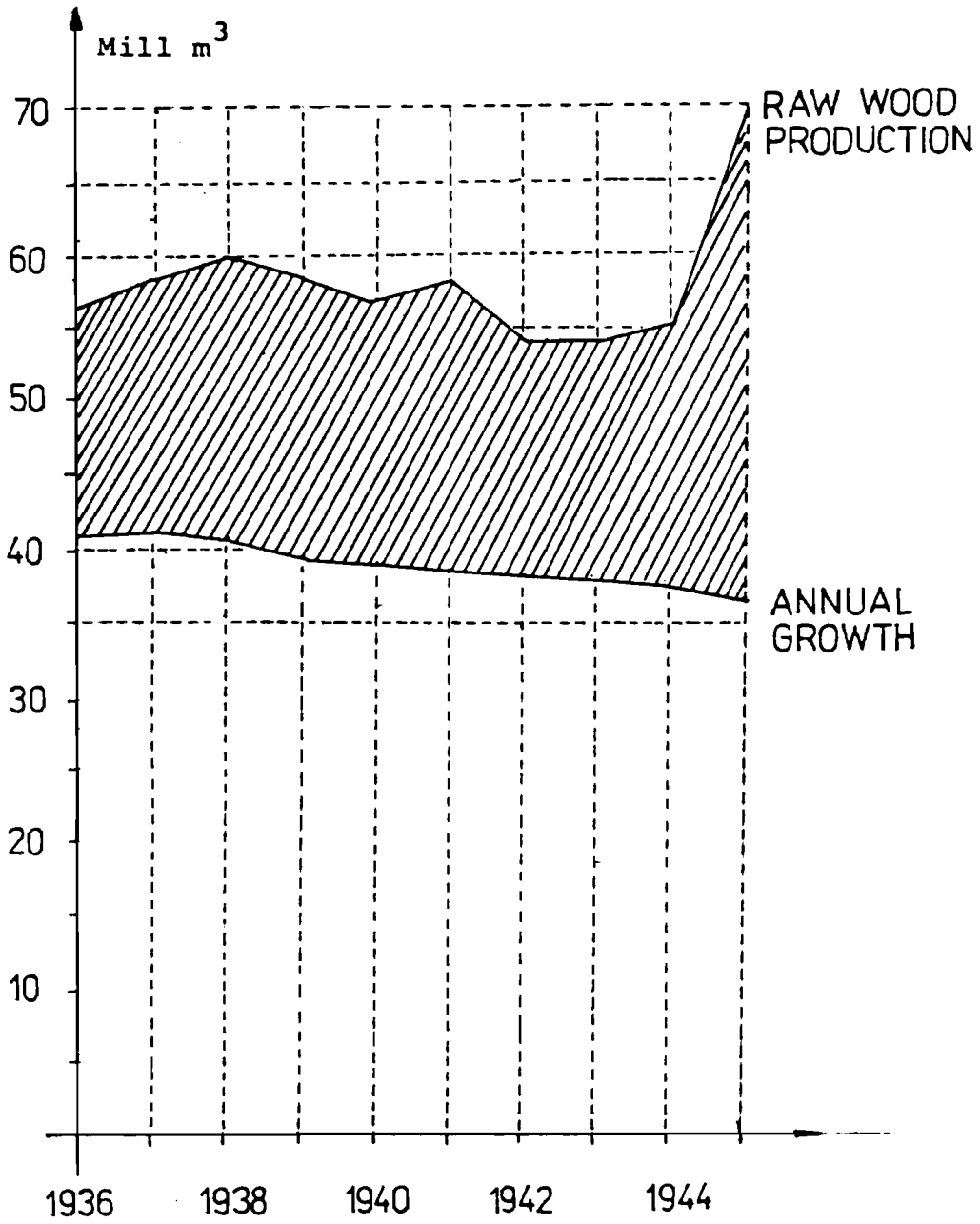


FIGURE 1. Development of raw wood production and annual growth in Germany between 1936 and 1945. (Source: Grottian 1948).

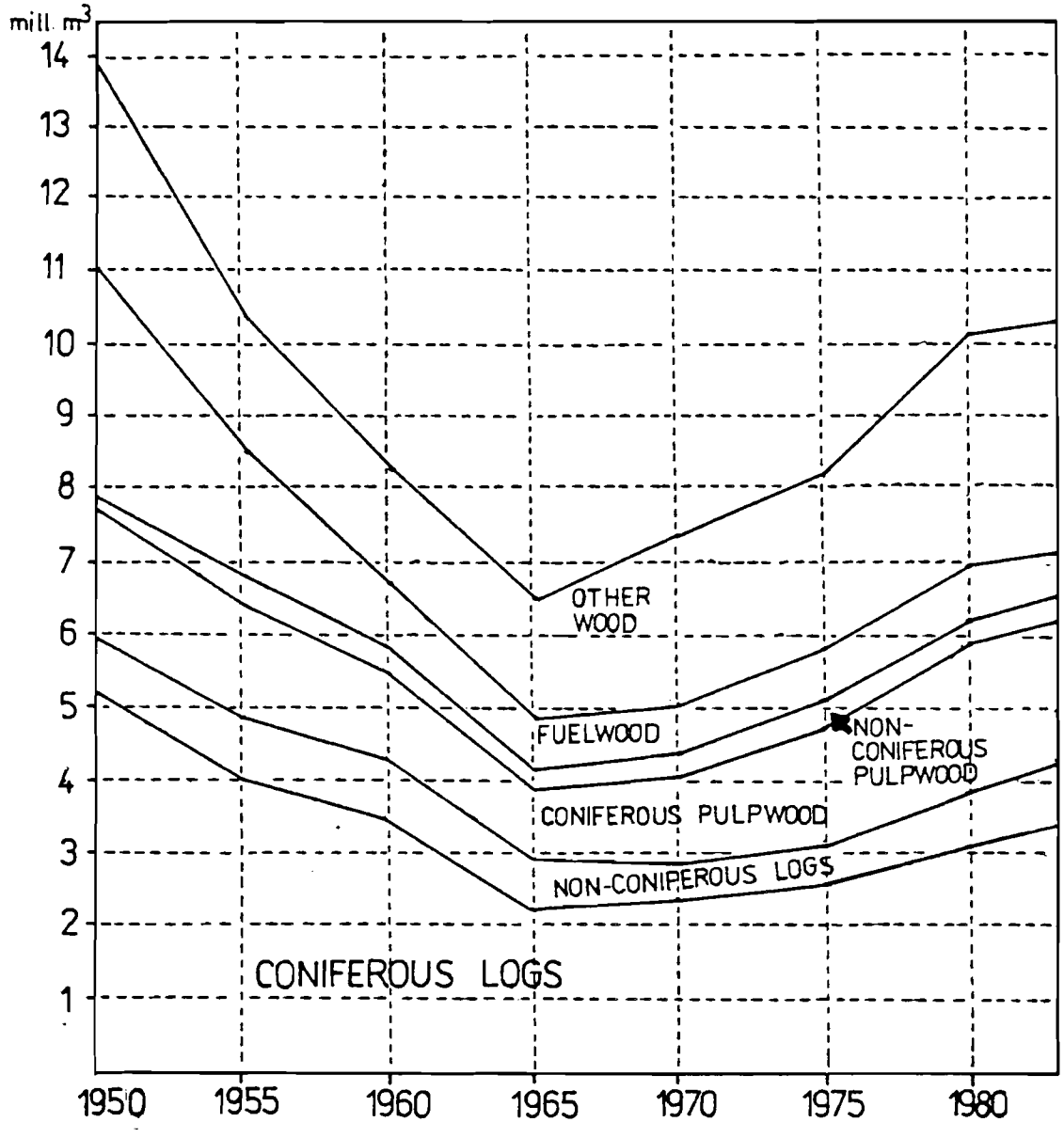
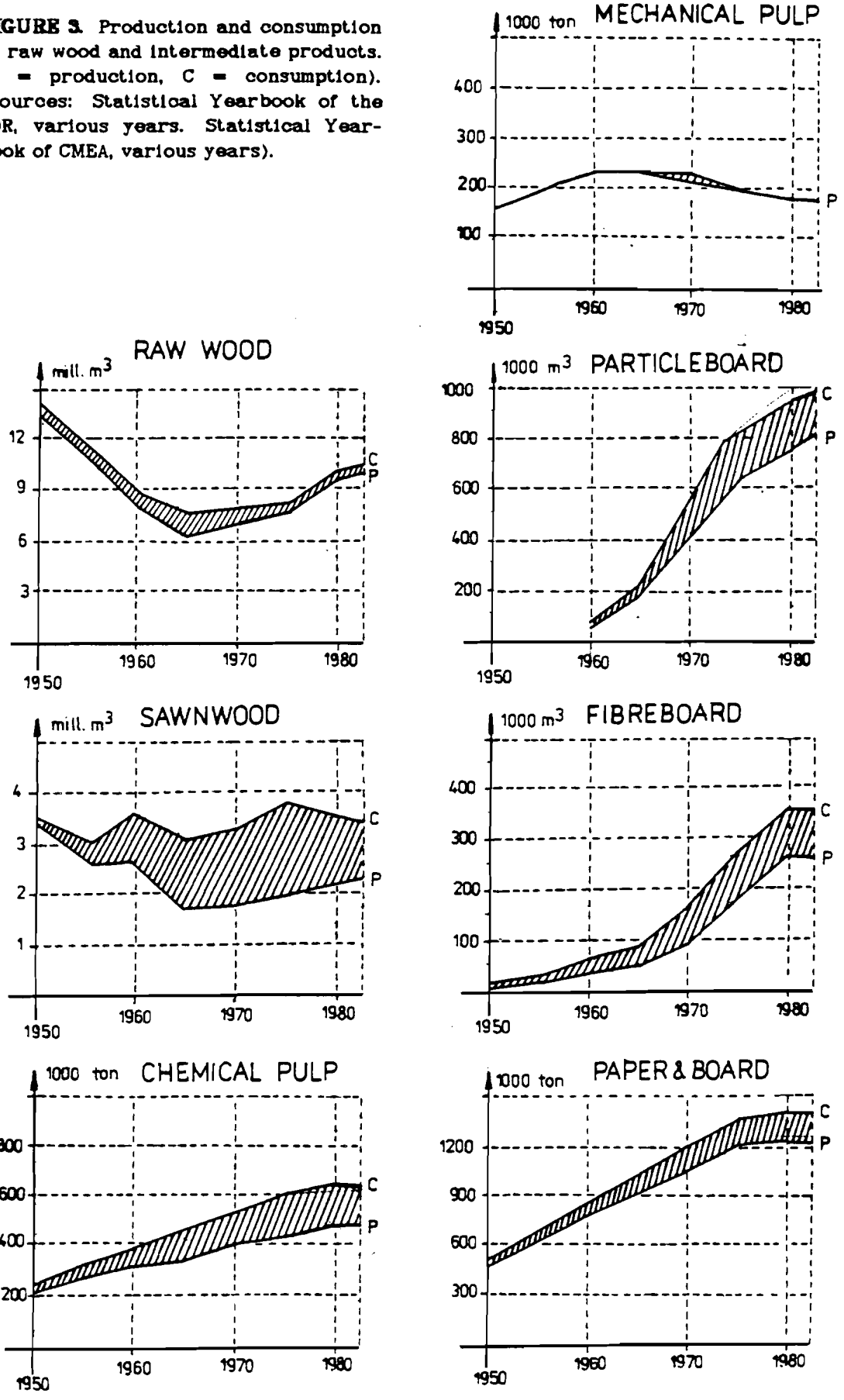


FIGURE 2. Structure of wood production in the GDR. (Source: *Statistical Yearbook of the GDR 1984*).

FIGURE 3. Production and consumption of raw wood and intermediate products. (P = production, C = consumption). (Sources: Statistical Yearbook of the GDR, various years. Statistical Yearbook of CMEA, various years).



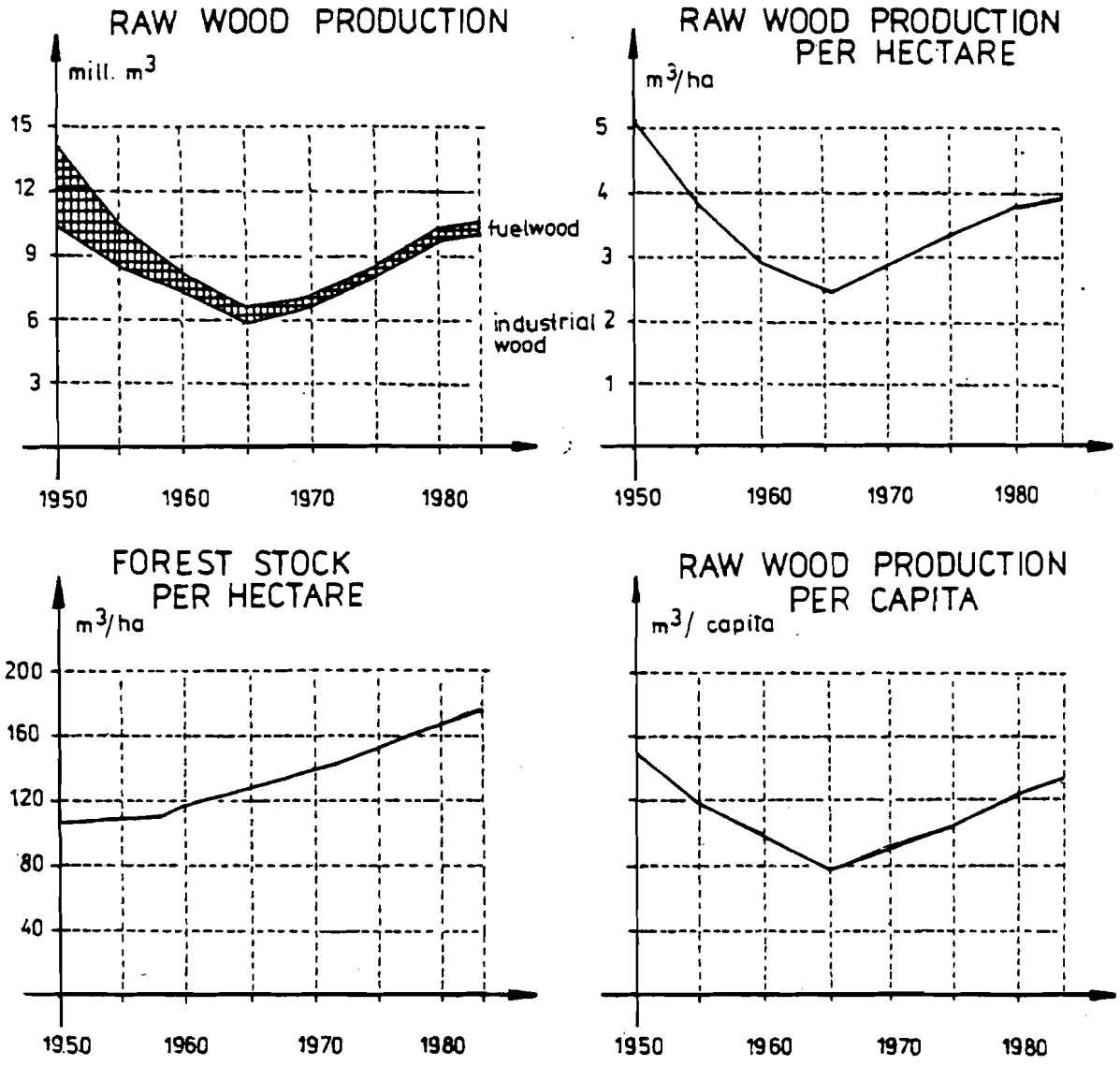


FIGURE 4. Development of raw wood production, and forest stock in the GDR. (Sources: Statistical Yearbooks of the GDR, various years. Ruethnick 1984.)

TABLE 1a. Structure of tree species. (Source: Langendorf 1982).

Conifers	77%		Deciduous trees	23%	
Pine		54%	Beech		7%
Spruce		21%	Oak		5%
Larch		1%	Other species		11%
Other species		1%			

TABLE 1b. Age distribution of trees. (In brackets: the optimal age distribution.) (Source: Langendorf 1982).

	Pine	Spruce	Oak	Beech	Total
0 ... 19	21(18)	22(20)	10(15)	4(15)	21(18)
20 ... 39	23(18)	19(20)	13(14)	9(14)	22(18)
40 ... 59	17(18)	20(20)	11(14)	13(14)	17(18)
60 ... 79	16(18)	21(20)	15(14)	13(14)	16(18)
80 ... 99	14(18)	12(20)	17(14)	14(14)	12(18)
100 ... 119	6(10)	4(0)	15(14)	15(14)	6(8)
≥ 120	3(0)	2(0)	19(15)	32(15)	6(2)

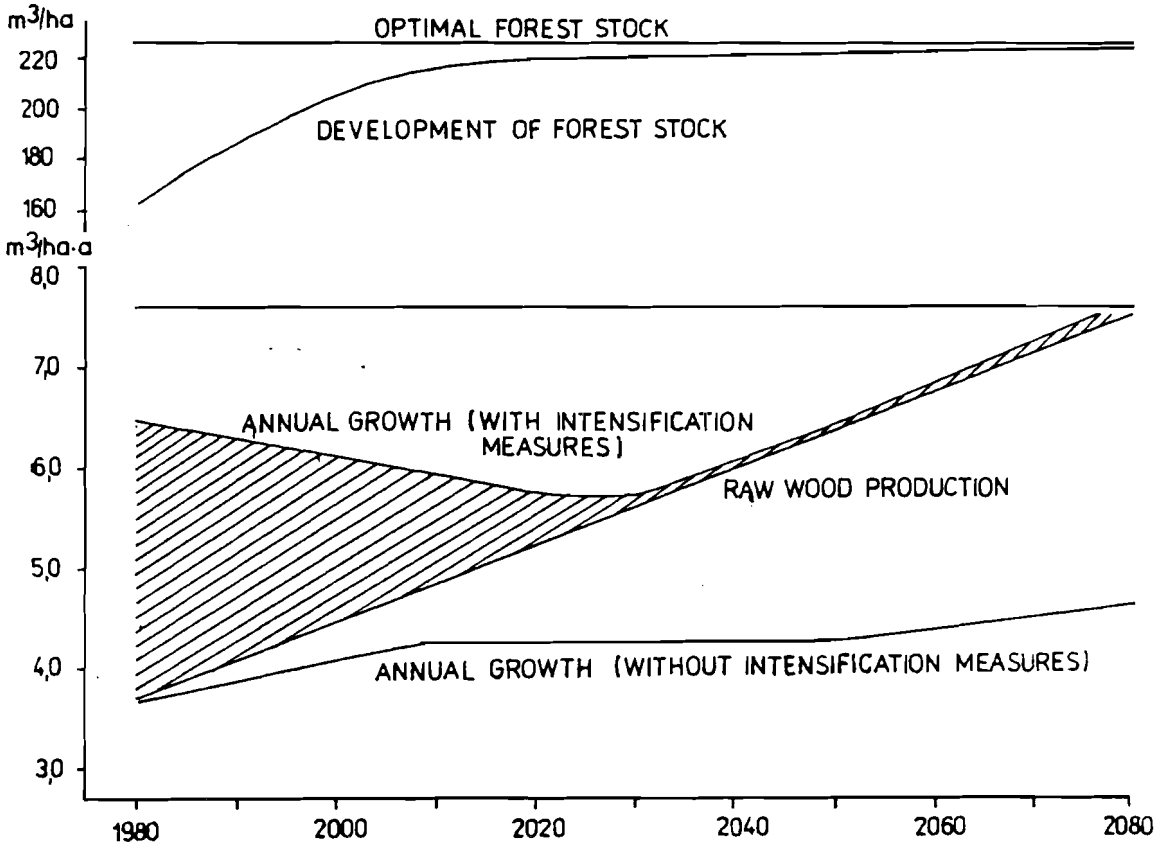


FIGURE 5. Development of annual growth, forest stock and raw wood production. (Source: Kurth/Lucas 1984)

2. THE INPUT-OUTPUT MODEL OF THE FOREST SECTOR

The input-output model of the wood and timber complex deals with part of the forest sector as defined by Andersson et al. It is concerned with the main lines of the wood flow within the national reproduction process, beginning with the raw wood production and ending with the production of final products such as furniture. The segregated input-output model has 69 sectors, the aggregated model has 14 sectors (Table 2).

Each sector is characterized by a technological input-output coefficient m_{ij} indicating the amount of commodity i that is required to produce one unit of commodity j. The set of such input-coefficients can be assembled into an input-output matrix

$$M = m_{ij} = \frac{M_{ij}}{P_j}$$

where P_j is the gross product of commodity j and M_{ij} is the required input of commodity j. Forming the static balance requirement for the forest sector we get

$$p = Mp + y$$

where $p = P_j$ and $y = Y_i$ is the final demand of the forestry and timber complex, defined to be exogenously determined final demand of individual consumer, government, investment, net export demand and demand for intermediate products for such industries, which are not in the product classification of the input-output model.

TABLE 2. Product classification in the input-output model. (Source: Brautzsch 1984c).

	I.-O.-T. 69 x 69	I.-O.-T. 14 x 14
Raw wood	11	1
Sawnwood	4	1
Chemical pulp	1	1
Mechanical pulp	1	1
Fibreboard	1	1
Particleboard	2	1
Veneer	1	1
Furniture	19	1
Wood-based package	4	1
Construction	5	2
Papers & Boards	2	1
Musical instruments/playthings/ sports kits/cultural articles	4	1
Other wood-based final products	14	1

The solution of the equilibrium structure p essentially amounts to the calculation

$$\begin{bmatrix} p \\ \tilde{m} \end{bmatrix} = \begin{bmatrix} (I - M)^{-1} \\ \tilde{M}(I - M)^{-1} \end{bmatrix} y$$

The vector $\tilde{m}$ represents the non-used wood residues as well as the whole input of waste paper.

$$\tilde{M} = \begin{bmatrix} m_{r1} - m_{s1}, & \cdots & , m_{rn} - m_{sn} \\ m_{t1} & , \cdots & , m_{tn} \end{bmatrix}$$

The model's importance is that it makes calculations with the aim of estimating effective variants of allocation of wood to cover the increasing demand for forest final products. In this sense model estimations can be used to create a better understanding of the interdependence between the activities from timber growth and the use of end products. Test calculations in the Central Planning Bureau show that the model is suitable as a means of fixing the proportions between production and final products. We can also obtain some analytical results:

1. If the main line of the flow of wood in the national economy is contained in the input-output table, it is possible to estimate which part of the gross product or the national income is based on wood. In 1980, 6% of the gross product of the GDR is based on wood.
2. We can estimate the degree of the utilization of wood residues. In $\tilde{M}$ one row represents the input and output of wood residues. The difference between the input and output of residues indicates the degree of closure of the cycle of wood utilization.
3. We can estimate the degree of finishing of the wood. This is the reciprocal number of the coefficients of the total expenditure of wood. The coefficient indicates the amount of commodity j that is produced per unit of wood used.

The input-output model of the forest sector is compatible with an input-output model for the national economy as a whole.

3. A GDR MODULE FOR THE EUROPEAN GLOBAL FOREST SECTOR MODEL

The preliminary GTM (and therefore also the GDR module) is a static model for which the parameters may be set to correspond to a specific point in time, but dynamic development is simulated by executing a stepwise series of runs.

3.1 Production

Table 3 summarizes the conversion factor data used in the GDR module.* Rows represent both intermediate and final products, and columns represent conversion activities from raw materials or intermediate products into final products.** Usually for a single commodity there are several production activities referring to alternative technologies.

*Input data for coniferous and nonconiferous white pulp must be considered tentative.

**In the fullest sense of the word we must understand by final forest products goods used for consumer, government, investment and export demand (e.g. furniture, wood-based musical instruments). In this sense sawnwood, panels, paper and boards are intermediate products. In the input-output model for the GDR, described in the first part of my paper, the terms "intermediate products" and "final products" are used in this sense. To connect the GDR module with the GTM we have to use a similar product classification and identical terms. In the following I consider sawnwood, panels, paper and boards as final products (Figure 6).

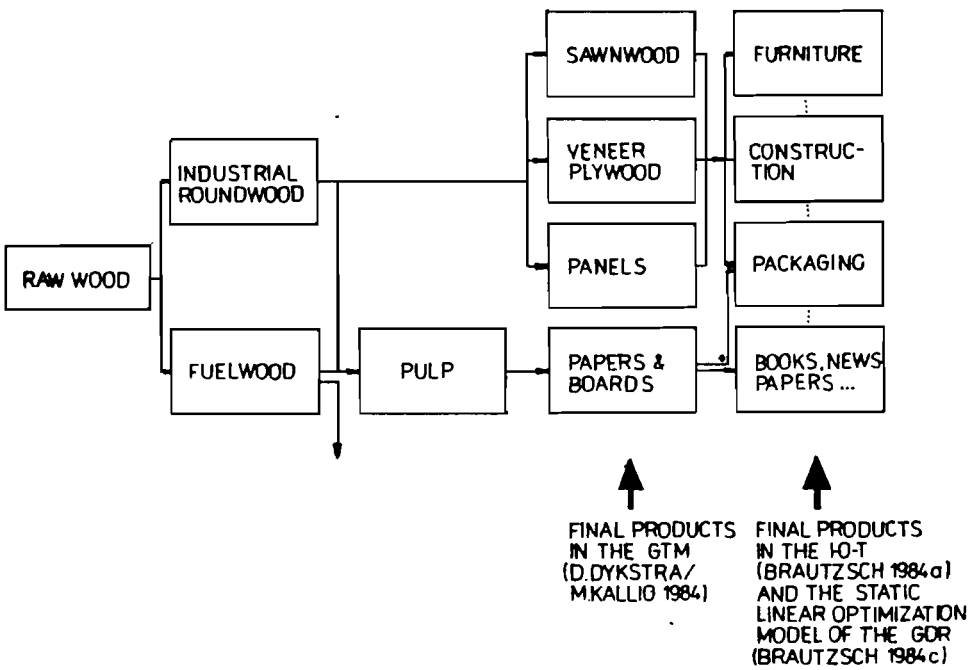


FIGURE 6. The definition of the term "final products".

TABLE 3. Conversion factor data of the GDR module.

	Coniferous logs	Nonconiferous logs	Coniferous pulpwood	Nonconiferous pulpwood	Fuelwood	Coniferous sawnwood	Nonconiferous sawnwood	Veneer and plywood	Particleboard/ fiberboard	Coniferous white pulp	Nonconiferous white pulp	Newsprint	Other printing and writing paper	Household and sanitary paper	Packaging paper and boards	Recycled paper
Coniferous logs	1.000					-1.400		-1.500								
Nonconiferous logs		1.000					-1.350	-0.500								
Coniferous pulpwood			1.000			0.250		0.400	-1.543	-5.173		-0.735	-0.378	-0.21	-0.241	
Nonconiferous pulpwood				1.000			0.200	0.100	-0.571		-4.138					
Fuelwood					1.000	0.100	0.100	0.150								
Coniferous sawnwood						1.000										
Nonconiferous sawnwood							1.000									
Veneer and plywood								1.000								
Particleboard/ fiberboard									1.000							
Coniferous white pulp										1.000		-0.250	-0.305	-0.400	-0.255	
Nonconiferous white pulp											1.000		-0.300	-0.050		
Newsprint												1.000				
Other printing and writing paper													1.000			
Household and sanitary paper														1.000		
Packaging paper and boards															1.000	
Recycled papers												-0.400	-0.220	-0.450	-0.630	1.000

It is necessary to refer to some special features of the GDR module:

1. In GTM a harvesting activity is assumed to yield logs and pulpwood in fixed proportions. If small trees are harvested the share of logs may be zero. No explicit upper limit may be needed for the harvesting volume, because increasing marginal costs are used as surrogates for explicit timber supply constraints. In the GDR module an upper bound equal to the exogenously estimated maximum annual timber removals must be set. These possible maximum annual timber removals have to be estimated by forest management, using a long-range forecast model of forest resources, in consideration of the development of forest stock and environmental issues. The scenario in Table 4 is assumed.

TABLE 4. Scenario 2000 (annual growth rate 1980-2000).

Coniferous logs	0.7%
Nonconiferous logs	1.1%
Pulpwood	1.8%
Fuelwood	0%

2. In GTM for a single commodity there are two or three production activities referring to alternative technologies. These are: the current technology, possibly divided into two efficiency categories, and a state-of-the-art technology to be employed in new investments.

   In the GDR module we segregate technologies in the following way:

   - We consider a technology representing the sawnwood processing of small conifers. In future the processing of small coniferous trees will gain importance because the age structure of coniferous trees is not optimal. This technology will have a share of up to 20% of the whole sawnwood production to 2000.
   - For the production of veneer and plywood, fiberboards and particleboards, coniferous and nonconiferous white pulp, newsprint, other printing and writing papers, household and sanitary papers, packaging papers and boards two technologies are considered for each, one referring to current technology and the other to a prospective technology. Generally we expect a higher wood residue input in pulp and panel production and an increase of the waste paper input in paper and board production*. It is to be considered that in future the processing of this wood or faulty wood will influence the technological input coefficients so that positive effects resulting from the use of technological progress could possibly be eliminated. We assumed that up to 2000 the increase of production will be achieved by using modern technology (Table 5).

*In this connection it is interesting to have a look at the input structure of the paper and board production (Figure 7). The share of waste paper has increased continuously. In comparison with advanced countries the share of waste paper input is high (Figure 8). In 1980 the input of waste paper for the production of papers and boards amounted to 600,000 tons. In the GDR the waste paper input is only limited by the maximal volume of the waste paper recycled. In 1980 it was possible to recycle 1,060,000 tons. Therefore the reserve was 460,000 tons (Arnold/Rahn 1981).

(Footnote continued.)

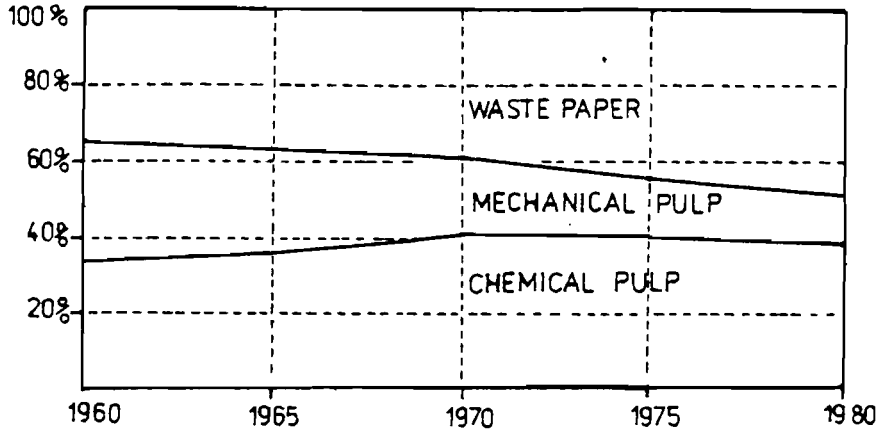


FIGURE 7. Input structure in % per ton of papers and boards.

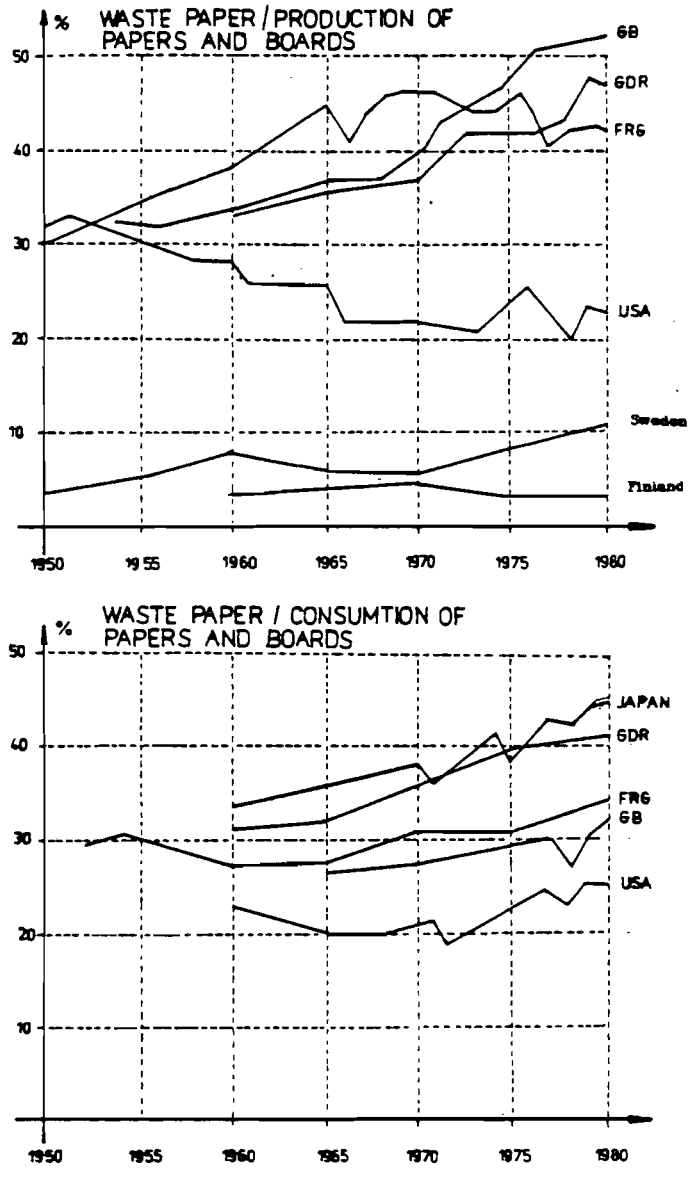


FIGURE 8. The development of the relation between waste paper input and production and consumption of paper and boards in several countries.

TABLE 5. Development of the Capacity up to 2000 (Scenario).

	T1	T2
Coniferous sawnwood (mill m^3)	2,440	0,240
Nonconiferous sawnwood (mill m^3)	0,490	0,490
Veneer and plywood (mill m^3)	0,490	0,490
Panels (mill m^3)	1,03	0,600
Coniferous white pulp (mill 0,33)	0,33	0,1
Nonconiferous white pulp (mill ton)	0,07	0,04
Newsprint (mill ton)	0,116	0,02
Other printing papers (mill ton)	0,182	0,031
Household and sanitary papers (mill ton)	0,060	0,010
Packaging paper and board (mill ton)	0,894	0,154

3. For raw wood allocation the following substitution activities have been included:
   - the conversion of coniferous logs into coniferous pulpwood,
   - the conversion of nonconiferous logs into nonconiferous pulpwood,
   - the conversion of coniferous pulpwood into fuelwood, and
   - the conversion of nonconiferous pulpwood into fuelwood.

3.2 Consumption

In the GTM consumption refers to the use of forest products outside the forest sector. Consumption of intermediate products (e.g. sawnwood, pulp) outside the forest sector is assumed to be negligible compared with the production of these commodities. Consumption of each of the final products (sawnwood, panels, papers and boards) is given by the demand outside the forest sector.

At first I am concerned with the estimation of the prospective level of consumption of sawnwood and panels. Then I shall discuss the prospective paper and board consumption. To estimate the prospective level of sawnwood and panel consumption we must

- consider the actual allocation of sawnwood and panels,
- analyze the development of industries consuming sawnwood and panels,
- deduce conclusions for the definition of scenarios describing the prospective level of sawnwood and panel consumption.

Relevant data for the allocation of raw wood and intermediate products and of so-called final forest products are summarized in Table 6. This shows that an important part of sawnwood and panel consumption is used for

a) furniture,

b) packages,

c) building industry.

First it is concerned in *furniture* production and consumption. In Figure 9 we illustrate the development of

- production,

TABLE 6. The allocation of wood and intermediate products in the GDR in 1980. (Source: Brautzsch 1984d).

Distribution of Raw wood (Consumption[a] of raw wood=100%)		Distribution of intermediate products (Consumption[a] of intermediate products = 100%)					
		Furniture	Wood-based package	Paper & boards	Construction	Musical instrument etc.[b]	Other final products[c]
31.8%	Sawnwood	9.4%	18.6%		21.2%	3.2%	47.6%
2.2%	Fiberbd	36.3%	3.2%		36.2%	1.8%	22.5%
10.9%	Particlebd	86.6%				3.2%	10.2%
24.1%	Chemical pulp			69.6%			30.4%
4.6%	Mechanical pulp			100.0%			0
0.8%	Veneer[d]	96.1%			2.4%	1.5%	0
25.6%	Other						

a) Consumption = Production + Import - Export
b) Playthings, sports kits, cultural articles
c) Not for plywood
d) Inclusive of remedy

- share of export,*
- regional export patterns,
- input of sawnwood and panels per 1000 M furniture production.

The production of furniture has rapidly increased since 1955. Primarily, this is because furniture export has expanded quickly. The export has been concentrated on the USSR and Western Europe. The rapid growth of the production of furniture has been accompanied by increasing substitution of sawnwood for panels. Today sawnwood is used in no small measure for the production of upholstered furniture and seat furniture. It is expected that domestic consumption as well as the export of furniture will increase. On the basis of the past development of annual growth rates of furniture export and furniture domestic consumption we have made the following scenarios up to 2000 (Table 7).** In the first scenario a high annual growth rate of furniture export is assumed. The second scenario considers possible trade and market inertia and a higher annual growth rate of domestic consumption. The consequences of the demand for sawnwood and panels are given in Table 7. It is assumed that the input of sawnwood and panels per 1000 M furniture production will decrease by one per cent per year.

*The import of furniture is assumed to be negligible compared with export of furniture.
**In this connection we have to consider the following problem: in future a high level of sawnwood and panel consumption will be determined by a high level of furniture exports. Hence on the one hand the high level of sawnwood and panel consumption determines, potentially, a negative solution in the optimization model, maximizing net exports. On the other hand furniture can only be exported if sawnwood and panels are imported. Therefore when we analyze the solution comprehensively (Chapter 3.4) we have to consider the net exports of furniture and other wood-based final products as well.

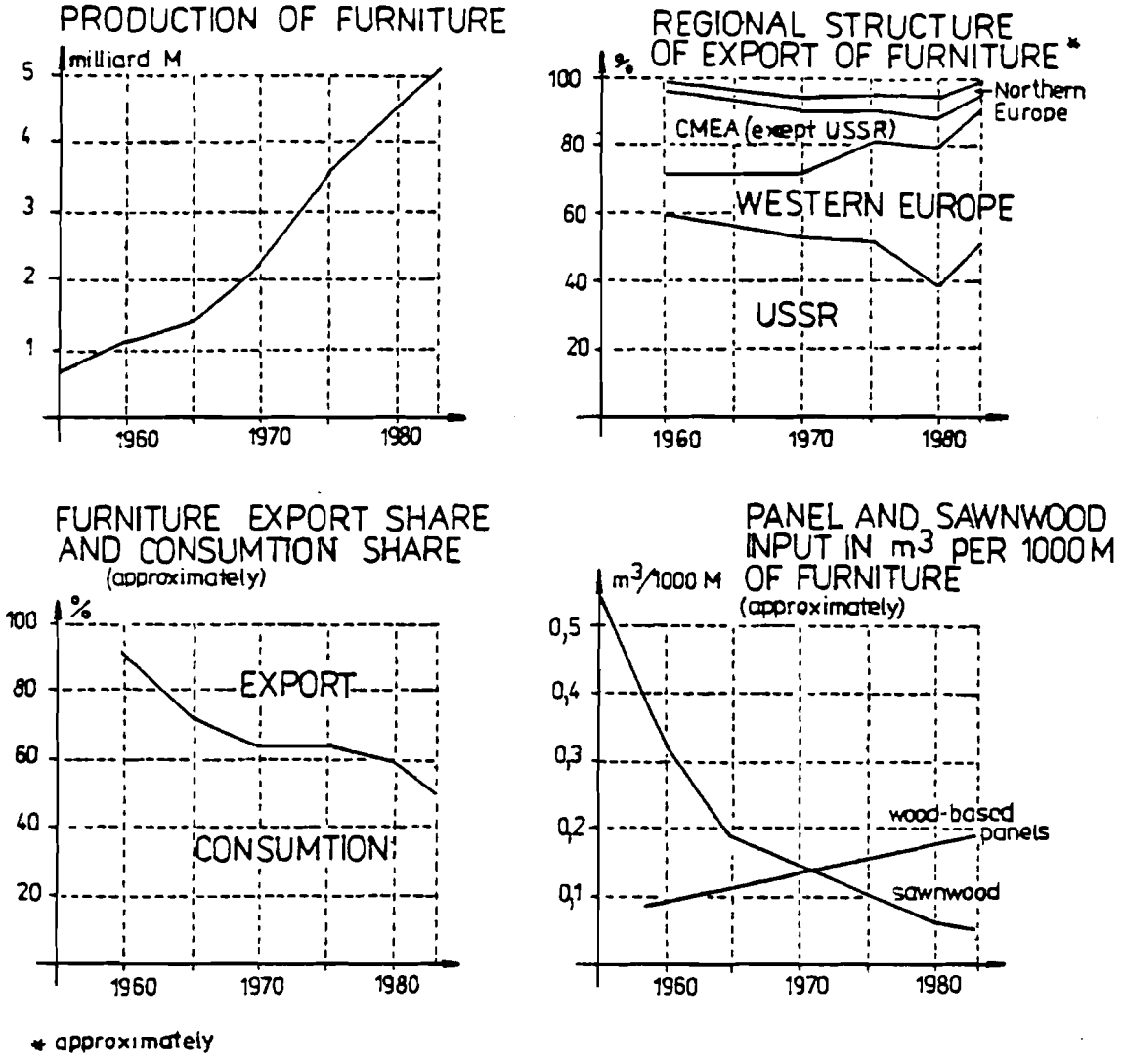


FIGURE 9. Furniture production, export, and input structure. (Sources: *Statistical Yearbook of the GDR*, Various Years).

Figure 10 shows the development of ***packaging intensity*** and the ***structure of packaging materials*** in the GDR. The packaging intensity is the relation between the gross national product and the production of packages. If production and consumption of packages are equal, this coefficient shows how many units of gross national product can be packaged with one unit of packages.

Paper and boards and sawnwood are the main packaging materials in the GDR. In comparison with advanced countries in the GDR the share of wood-based packages is high (Figure 11). This is due, among other things, to the fact that wood is one of the important domestic raw materials. Other raw materials used for the production of packages (metal, oil for the production of plastics) have to be imported. It is expected that

TABLE 7. Scenario 2000 – Production of furniture. (Source: *Statistical Yearbook of the GDR*, various years.)

	1960-70	1970-80	1980-83	2000 I	2000 II
Rate of Annual Growth (%)					
- Export	18.9	9.1	12.0	10	8
- Domestic consumption	3.5	6.3	-2.5	1.5	2
Demand of					
- sawnwood (1000 m^3)				710	590
- panels (1000 m^3)				2210	1820

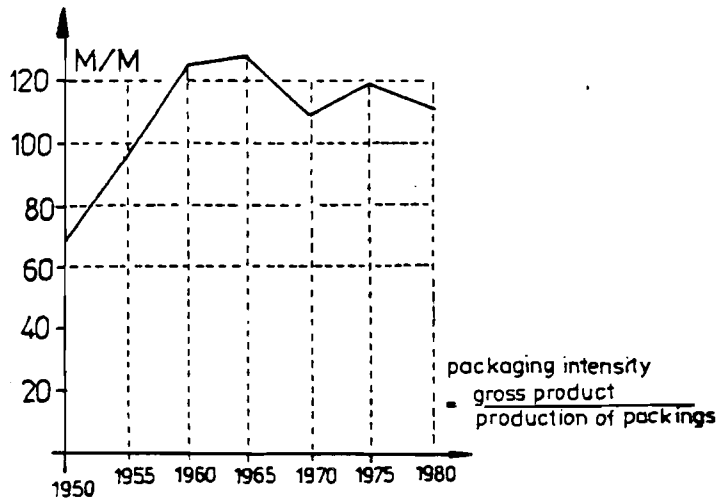


FIGURE 10. Packaging intensity in the GDR (Source: Brautzsch 1984b).

- the packaging intensity will stay constant or decrease in future,
- wood-based packages will be the main packages in the GDR in future,
- the volume of sawnwood used for the production of packages will increase slightly up to 2000 (0,5% per year).

A great part of sawnwood and panel consumption is used in the ***building industry***. In Germany the share of wood consumption in construction decreased continuously in the past (Breithaupt et al):

1907 – 1913 52,8%
1931 33,0%

Today the share is approximately 11%. In the past sawnwood was substituted through other materials, e.g. concrete, aluminum, steel. An increasing demand for sawnwood and panels in construction is not expected. We assume that the demand will be constant.

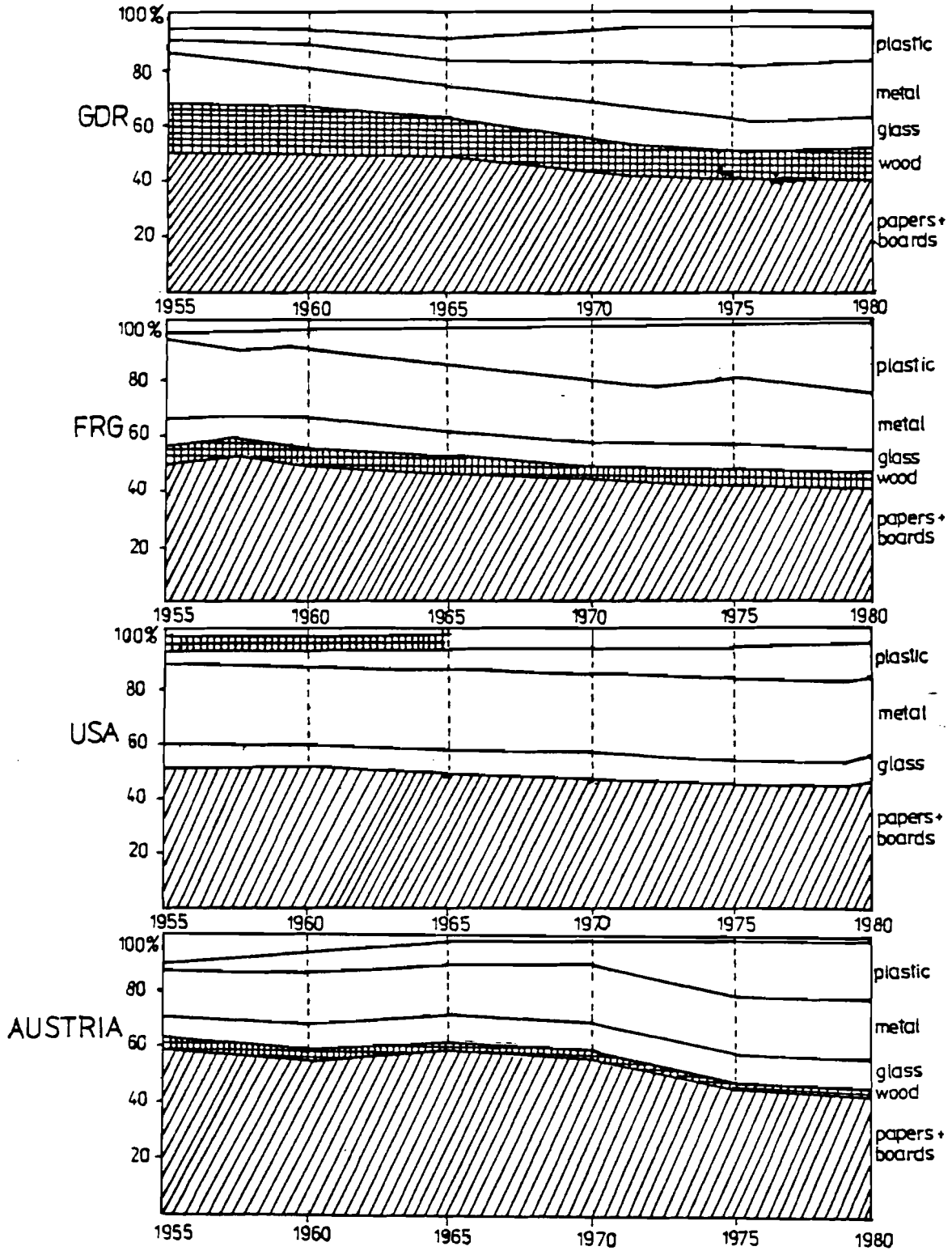


FIGURE 11. Structure of packaging materials. (Source: Brautzsch 1984b)

In order to estimate the whole level of consumption of sawnwood and panels we assume that in future the demand of sawnwood and panels for the production of so-called "other final products" (including remedies*) will be constant. In this way we are able to fix the following scenarios of sawnwood and panel consumption on the whole (Table 8).

In order to estimate the prospective level of the consumption of panels and boards we have to consider the following facts:

- According to the paper and board consumption per capita the GDR is among the 20 leading countries.
- The produced area of paper and boards (i.e. the amount expressed in m^2) will increase more rapidly than the produced mass of paper and boards (i.e. the amount expressed in tons) (Figure 12). The main feature of the production structure is the high share of high quality technical papers so that the total export of papers and boards has the same value as the total import of papers and boards (Arnold/Rahn 1981).

Two scenarios are assumed: the annual growth rate of paper and board consumption is 1% and 0.5% (Table 8).

TABLE 8. Development of the Consumption Scenario 2000.

	I	II
Coniferous sawnwood (mill. m^3)	3.110	2.990
Nonconiferous sawnwood (mill. m^3)	0.600	0.600
Veneer and plywood (mill. m^3)	0.060	0.060
Panels (fiberboard/particleboard) (mill m^3)	2.475	2.085
Newsprint (mill ton)	0.184	0.166
Other printing and writing papers (mill ton)	0.250	0.226
Household and sanitary papers (mill ton)	0.079	0.072
Packaging papers and boards (mill ton)	10.194	1.082

*I am referring to additional materials for the production processes.

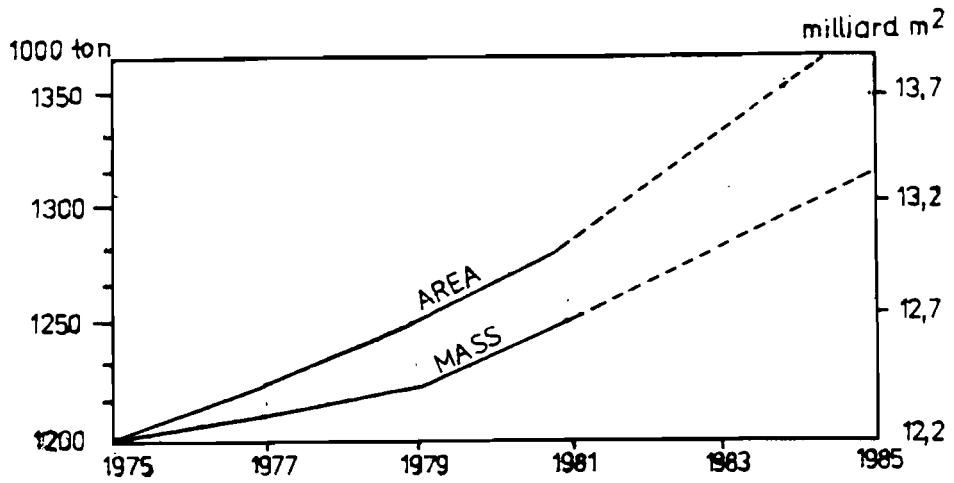


FIGURE 12. Production of papers and boards: mass-area-relation. (Sources: Arnold and Rahn 1981a, Müller and Wolf 1980).

3.3 International Trade and Market Inertia

To represent market inertia in the GTM we may set upper and lower limits on trade flows. Such bounds may account for certain types of trade policies as well.

In the GDR module we have to consider that the GDR is a member of the COMECON. According to the view of Dobrinsky/Kallio (1984) we assume that to satisfy the domestic needs most socialist countries encourage domestic production and trade within the COMECON and would only import from other world markets if domestic or COMECON capacities were insufficient. It is also important to increase trade with other regions in order to acquire, among other things, technological know-how. Foreign trade in forest products is concentrated on Western Europe and Northern Europe, except COMECON. Imports from and exports of forest products to other regions are negligible.

In general foreign trade in forest products is required to meet three main constraints:

- total exports have to equal or exceed an exogenously given budget,
- total imports of forest products have to be equal to or smaller than an exogenously given budget,
- the net export or the net import have to be limited to capitalist countries as well as to COMECON countries.

3.4 Model Formulation

The initial assumptions in the GTM treat producers and trade agencies within a region as separate entities, each one of which tries to maximize profit. Dobrinsky/Kallio (1984) suggest that from the point of view of a centrally planned economy, the total profit of all producers and foreign trade agencies in the

country has to be maximized.

Another possible objective function is to maximize the net export to capitalist and developing countries under the constraints that

- target levels of consumption have to be guaranteed on the one hand and saturation levels of consumption, which identify the maximum possible levels of consumption, have to be considered on the other hand,
- production capacities are limited,
- the net export to socialist countries equals or exceeds an exogenously given budget.

From various points of view this objective function* is very important:

1. A feature of the GDR forest sector is the high net import of raw wood, sawnwood, panels, papers and boards (in physical terms) and the high net export of furniture and other wood-based end products.
2. The pulp and paper production is especially energy intensive and except brown coal and gas all other energy sources have to be imported.
3. Equipment used in wood processing has to be imported partly from capitalist countries as well as from socialist counties.
4. In foreign trade between COMECON countries multilateral clearing in transferable rubles (TR) is used. To guarantee an overall balance for imports and exports (in value terms) from the GDR to all other COMECON countries, we need to develop an exogenous budget specifying minimum net exports to and maximum net imports from other COMECON members.
5. The maximization of net export to capitalist countries (in hard currency) is very important because if exports exceed imports, hard currency is available and from the point of view of a centrally planned economy this is a flexible and useful resource.

The following formulation can be suggested for modeling the GDR forest sector in the GTM:

$$\max \sum_{j,k} [(\Pi_{jk} - D_{r \cdot jk})\, e_{r \cdot jk} - (\Pi_{jk} + D_{jr \cdot k})\, e_{jr \cdot k}]$$

$$\text{for all } j \text{ and } k \qquad j \neq r \tag{1}$$

$$C_{r \cdot} - A_{r \cdot}\, Y_{r \cdot} + \sum_{j} (e_{r \cdot j} - e_{jr \cdot}) + \sum_{r} (e_{r \cdot r} - e_{rr \cdot}) = 0$$

$$\text{for all } j \qquad j \neq r \tag{2}$$

$$C_{r \cdot} \geq C^{o}_{r \cdot} \tag{3}$$

$$Y^{o}_{r \cdot k} \leq Y_{r \cdot k} \leq K_{r \cdot k} \qquad \text{for all } k \tag{4}$$

$$\sum_{r,k} (e_{r \cdot rk} - e_{rr \cdot k})\, \Pi^{*}_{rk} \geq S^{*} \tag{5}$$

where

*The product classification for paper and boards used in the GTM and the GDR module is not suitable to reflect that the total exports of papers and boards have the same value as the total imports of paper and boards (Arnold/Rahn 1981). Therefore the solution of model runs must be considered tentative.

r^* is the index of the GDR

r is the index of the ESC region (including USSR)

j is the index of other regions, except ESC and USSR

k is the index of commodity K

S^* is the exogenously given budget of net export to socialist countries

$C_r^{0^*}$ is the vector of minimum target levels of consumption in the GDR

$y_{r^*k}^0 = \min(C_{r^*k}^0, K_{r^*k})$

Π_{jk} for all j, $j \neq r$ are the import or export prices in region j endogenously estimated

Π_{rk}^* are the internal CMEA prices exogenously given.

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