Methodology

STUDY DESIGN

The initial task was to construct an appropriate database for data compilation and information management. A pre-test was conducted, definitions were developed, and input tables for data compilation were completed. A team of experts worked on a country-by-country basis through the latest available inventory reports to extract the data necessary to complete the country profiles in terms of forest area, growing stock volume, growth and removals, for the major industrial roundwood producers in Africa, Asia-Pacific, and Latin America and the Caribbean.

The analysts used Microsoft Access as the relational database management programme and Visual Basic as the programming language for supply forecasting. (Another forecast model was developed in FORTRAN, later converted to VBASIC, and it is described in more detail in GFSM Working Paper No. 5.)

In order to forecast to the year 2050, it is necessary to place the fibre supply projections into an appropriate policy context. Based on a thorough review of the policy issues addressed in previous supply studies, the major policy factors identified for consideration at this time are:

- sustainable forest management;
- land-use change – deforestation;
- land-use change – protected area;
- plantation afforestation rate;
- plantation development gains;
- non-wood and recovered fibre; and
- material efficiency and technological change.

The implications of these factors are described in more detail in Section 5. The study team recognizes that prices and costs are also important determinants in defining the economic supply but, due to the limited financial resources available for the project, these factors were not explicitly included. In particular, the definitions and classification were chosen to match those of the Forest Resources Assessment 2000. This will help the reader to follow upcoming FAO reports, assist the FRA and Outlook Studies teams with some of their information requirements and also improve the linkage of the GFSM study to some important current forest policy issues.

Table 1
List of countries included in the GFSM assessment

Africa (26)	North America (3)	Asia (22)	Europe (28)
Angola	Canada	Afghanistan	Albania
Botswana	Mexico	Bangladesh	Austria
Cameroon	United States of America	Bhutan	Belgium
Central African Republic		Brunei Darussalam	Bulgaria
Congo, Democratic Rep.	**Central America (9)**	Cambodia	Croatia
Congo, Republic of	Belize	China	Czech Republic
Côte d'Ivoire	Costa Rica	India	Denmark
Equatorial Guinea	Cuba	Indonesia	Estonia
Gabon	Dominican Republic	Iran	Finland
Ghana	El Salvador	Japan	France
Guinea	Guatemala	Korea,DPR	Germany
Guinea-Bissau	Honduras	Korea, Rep. of	Greece
Kenya	Nicaragua	Laos	Hungary
Liberia	Panama	Malaysia	Ireland
Madagascar		Myanmar	Italy
Malawi	**South America (13)**	Nepal	Latvia
Morocco	Argentina	Pakistan	Lithuania
Mozambique	Bolivia	Sri Lanka	Norway
Nigeria	Brazil	Thailand	Poland
Sierra Leone	Chile	Turkey	Portugal
Somalia	Colombia	Viet Nam	Romania
South Africa	Ecuador	Guyana	Slovakia
Tanzania, United Rep.	French Guiana		Slovenia
Uganda	Guyana	**Oceania (6)**	Spain
Zambia	Paraguay	Australia	Sweden
Zimbabwe	Peru	Fiji	Switzerland
	Suriname	New Zealand	United Kingdom
	Uruguay	Papua New Guinea	
	Venezuela	Solomon Islands	**USSR, former area (1)**
		Vanuatu	Russian Federation

Definitions

In conducting a study of this nature it is critical to have a clear set of terms for forest resources. The definitions must have at least the following characteristics to be useful for both consistency of the various statistical reports and for outlook work:

The definitions must be in general agreement with new terminology negotiated in international forums. For example, the definitions used must be compatible with the FAO Forest Resources Assessment 2000. Where definitions did not exist the terms used draw heavily on the forestry literature for description. The terms must be flexible enough to utilize old data sets. For example, the FAO Forest Resources Assessment 1980 contains very important data on forest volume utilized in building a country profile.

The major terms must be able to accommodate the country level data collected. For example, each country has its own unique way of classifying forest area and volumes and the standard definitions must be able to accommodate these differences.

The terms must be readily understandable to a wide audience of users. This ensures greater transparency in the presentation of data.

It is imperative for any long-term planning to establish standards that can be applied to a wide variety of circumstances. Annex 2 contains a complete list of definitions used in the study.

Classification of fibre resources

Figure 2 summarizes the classification of forest area for the natural forest (forest undisturbed and disturbed by man). In addition, there is fibre also available from industrial plantations, recovered fibre and non-wood fibre. Figure 3 summarizes the forest volume and growth classification. In addition to classifying from a fibre supply point of view, this classification scheme allows the study to maintain a high degree of consistency with other activities within the Forestry Department. In particular, the classification was chosen to be consistent with that of the Forest Resources Assessment 2000. This will help the reader to follow upcoming FAO reports, assist the FRA and Outlook Studies teams with some of their information requirements and improve the linkage of the GFSM work to some important current forest policy issues.

Figure 2
Land classification for the Global Fibre Supply Model

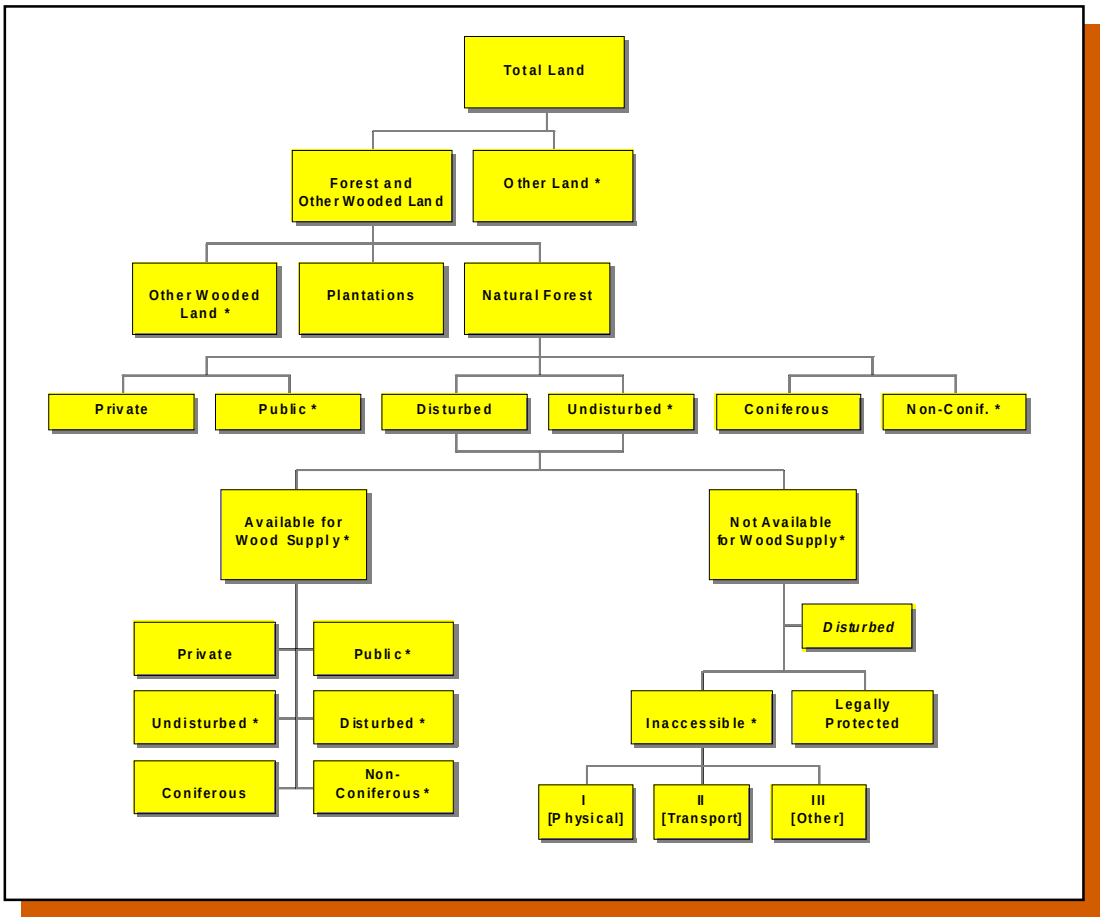
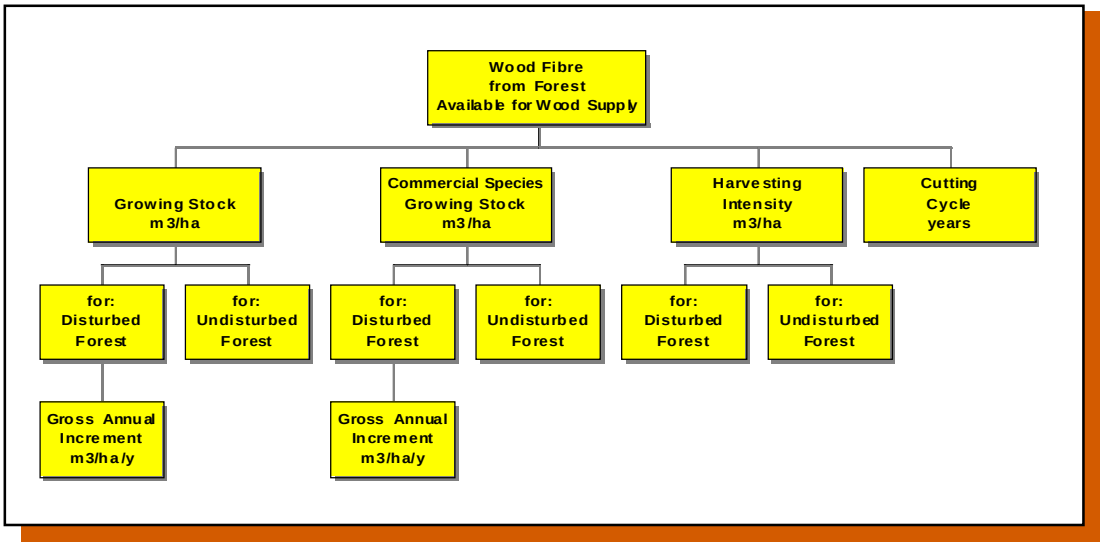


Figure 3
Forest volume and growth classification



Describing the current situation

The statistics chosen for collection are important because they serve as a basis for examining both the current and future conditions of the forests. The creation of possible futures requires the manipulation of critical variables in a set of equations that forecast changes in fibre sources over time. The critical statistics in the case of the GFSM are:

- area – i.e. current forest area available for wood supply;
- area – area change for natural and plantation forest;
- volume – both growing stock and commercial species growing stock;
- growth – gross annual increment and mortality;
- fellings/removals – harvesting intensity and cutting cycle;
- recovered and non-wood fibre – production capacity.

Constructing alternative futures

Modelling the future in today's forest policy context also requires the use of equations to manipulate the statistics or variables just described and which have at least some ability to express the sustainability of supply. Figure 4 is a summary of the formulae considered for use in the analysis of natural forests. Currently equations III and IV are being used in the modelling efforts and once better conversion factors are developed equations I, II and V will also be included to improve our analytical abilities.

Figure 4
Formulae for calculating fibre supply futures

I: $\frac{G_{ud}}{c} + (i \cdot A_d)$

II: $\frac{G_{ud}}{c} + (0.5 \cdot i \cdot A_d)$

III: $\frac{H_i \cdot A_{ud}}{c} + (i \cdot A_d)$

IV: $\frac{H_i \cdot A_{ud}}{c} + (0.5 \cdot i \cdot A_d)$

V: $2\frac{(G_{ud} + G_d)}{r}$

Symbol	Explanation
G_{ud}	Commercial Species Growing Stock – Forest undisturbed by man
G_d	Commercial Species Growing Stock – Forest disturbed by man
A_{ud}	Area available for wood supply – Forest undisturbed by man
A_d	Area available for wood supply – Forest disturbed by man
H_i	Harvest intensity
i	Increment
c	Cutting cycle
r	Rotation period

There are a wide range of equations used to calculate area of forest undisturbed by man and forest disturbed by man. Based on an extensive review of the literature on yield regulations, particularly as applied to tropical forest conditions[4], the GFSM identified five equations as useful.

Equations I and II rely on the growing stock statistics of

[4] Since the yield regulation formulae were originally developed in temperate and boreal forest conditions, a modification of the formulae presented can make them applicable to these forests as well. For example, in some forests the cutting cycle would be replaced with a rotation age and the harvest intensity replaced with merchantable volume.

commercial species in the forest undisturbed by man and allow for the gradual transition over time from an undisturbed forest to a disturbed forest. Equation II allows for the application of a reduction factor to the increment statistics. Since in many countries the increment statistics are very difficult to obtain, the ability to reduce increment because of uncertainty, mortality, bark and other factors is very important. The primary disadvantage of the use of these formulae relates directly to the inadequacy of forest inventory data which only report volumes for large-diameter trees, usually above 50 cm diameter at breast height (dbh). In calculating future potential supply this is simply not appropriate since all trees, and certainly all those above 10 cm dbh, are of significance and should be reported. Unfortunately, the needed conversion factors have not yet been developed, particularly to convert the inventories from, for example, a 50 cm class to a 20 cm class.

Equations III and IV focus on harvesting intensity statistics for the gradual conversion of the undisturbed forest to disturbed forest. Once the conversion has occurred, the formulae use the growth in the forest as the driving variable in calculating supply. A reduction factor to the growth of 0.5 is applied in the case of equation IV and this reflects the uncertainty over the growth statistics. For example, it is often unclear in the source of information if the growth includes a mortality factor or not.

Equation V is a barometer against which one can compare the results of the other four equations. It is useful to have a reasonable range of formulae for analysts to compare results and select the most appropriate equation for projecting futures.

Normally it is most appropriate to calculate the amount of fibre to be removed on the basis of the standing commercial forest and the growth of the forest, i.e. using equations I and II. However, since volumes are so difficult to determine from a supply point of view, the harvesting intensity applied to the area available for wood supply is a suitable surrogate for supply forecasting calculations.

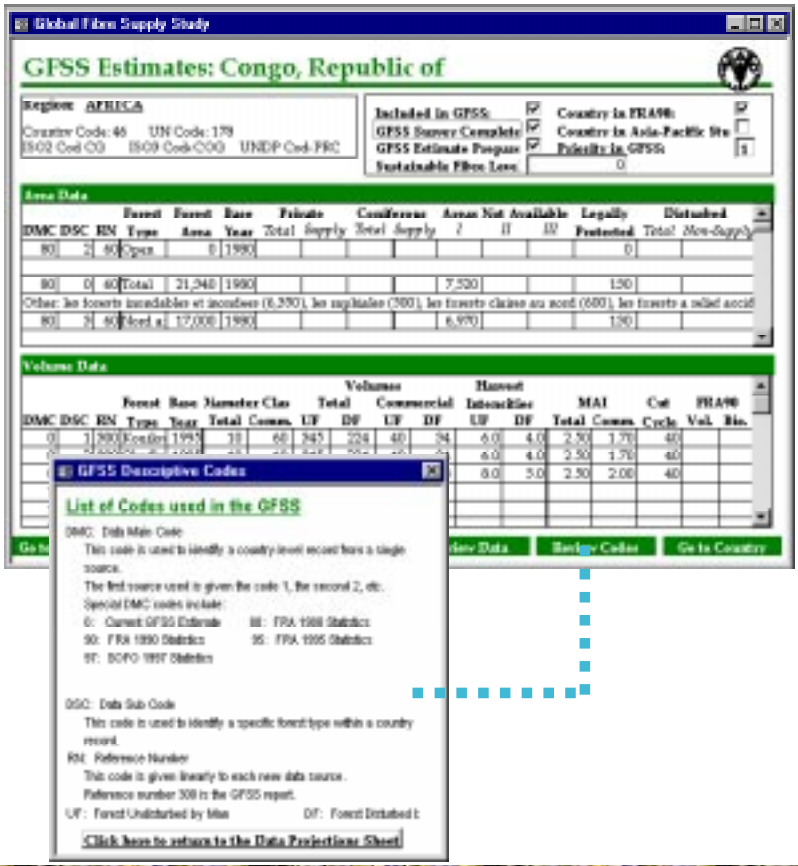
In determining the supply levels for industrial plantations, non-wood fibres and recovered fibres, the array of options are narrower than with forest undisturbed by man and forest disturbed by man. This is either because the data or information currently available are limited or the data can be handled in a more straightforward manner. The GFSM model identifies a single formula for the calculation of each of these components (see Working Paper No. 1 for details).

Tool for accessing and displaying the current situation and forecasts

In order to access readily available statistical information and to assist in quickly displaying possible scenarios a database and model that is directly linked were constructed. Figure 5 shows the front page of the database and

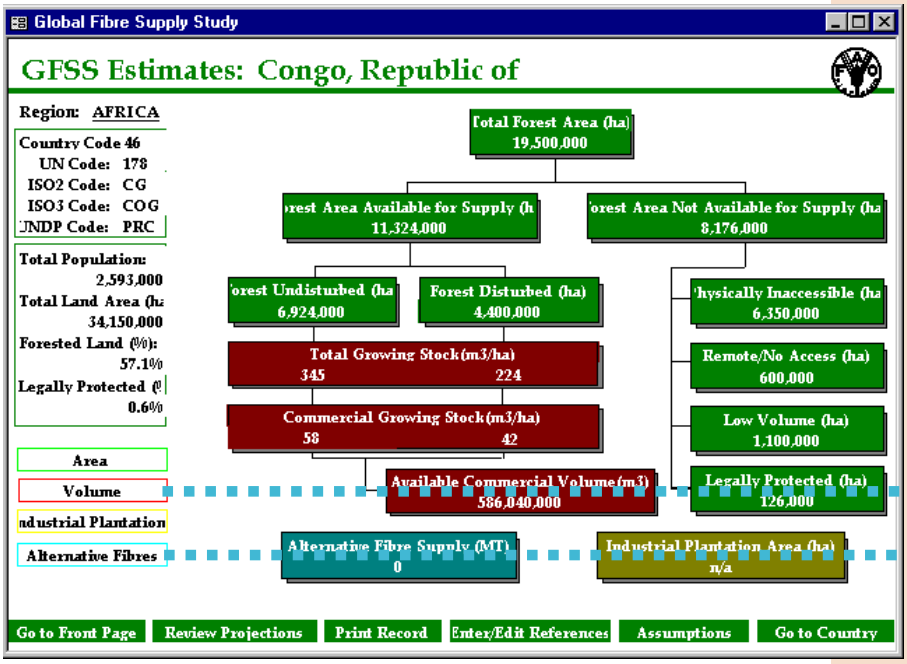
Figure 5
Front page of global fibre supply database and model

model. For each of the items mentioned in the right-hand column there are a number of activities that can be explored by the user.

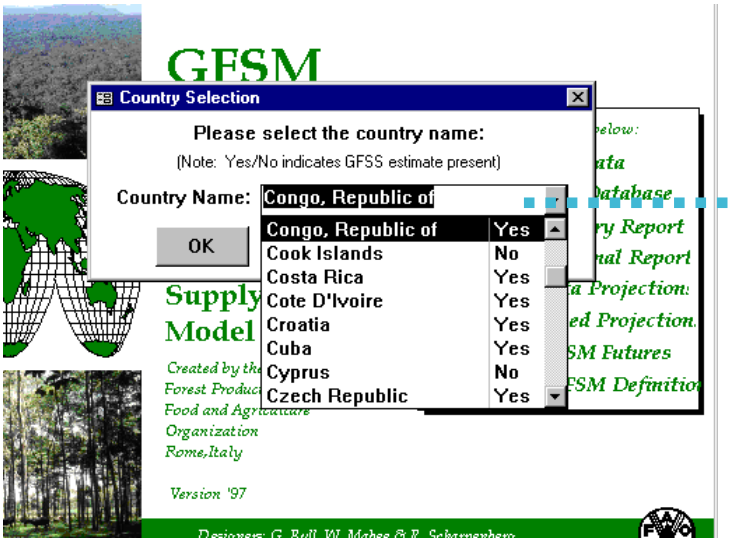


The first button ***Enter New Data*** allows the analyst to enter new data and reference material. It will only be accessible to designated analysts in charge of data entry and standardization.

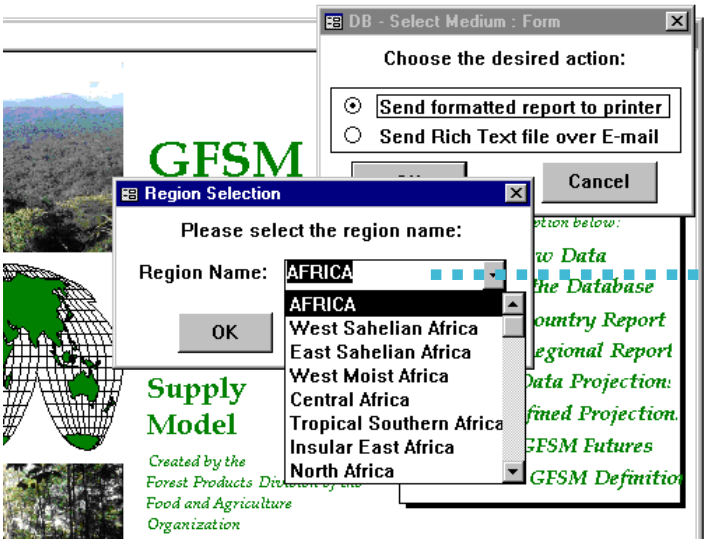
The second button ***Review the Data*** provides a quick snapshot view of the most important country statistics on forest area, volume, alternative fibres and plantation data. Other relevant statistics are provided along with a list of major assumptions made in creating the basic data (Section 2 – *Base data*)

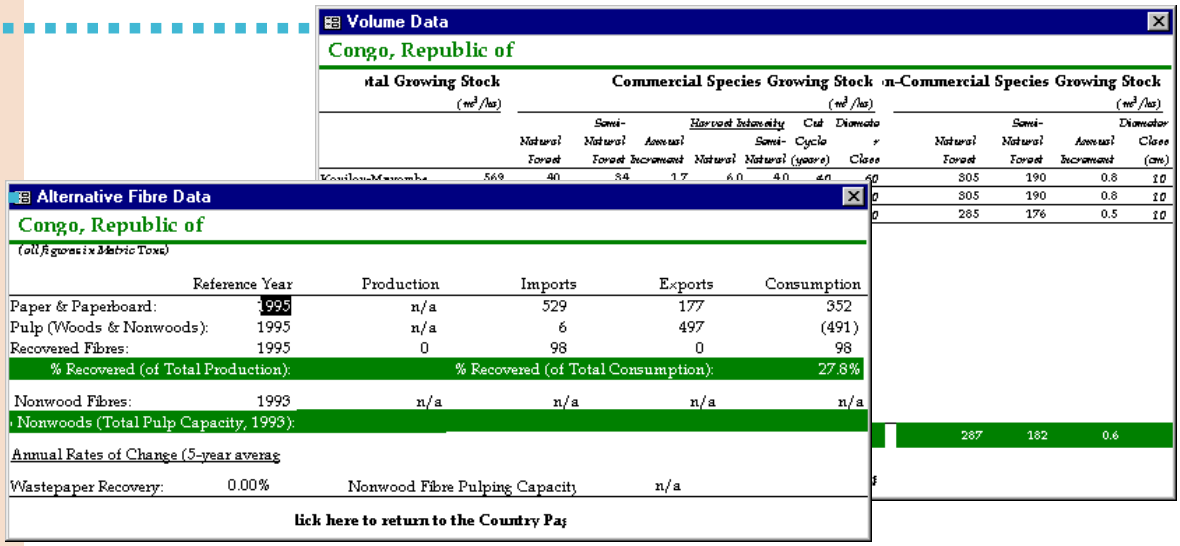


The third button ***Create Country Reports*** allows database users to generate reports which are automatically formatted and updated with the latest statistical information.

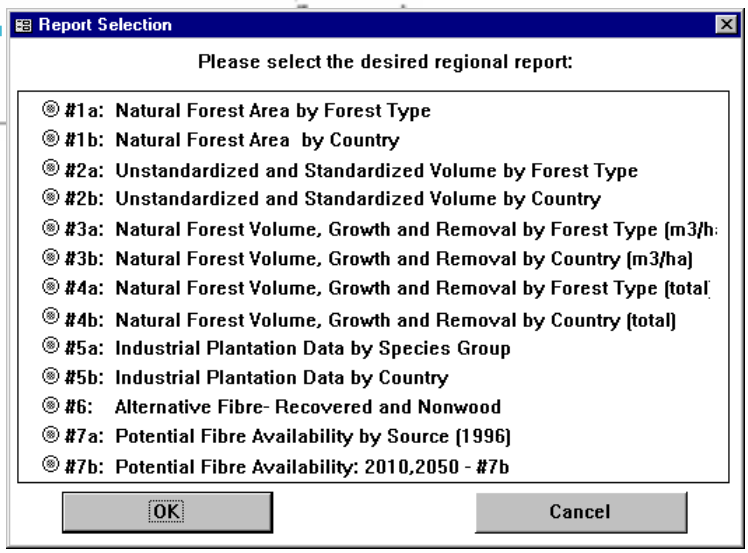


The fourth button ***Create Regional Reports*** allows users to generate a variety of regional reports to meet specific needs. For example, there are reports on forest area, volume, growth and removals by country at the forest type level or aggregated at the country level. There are also reports describing possible futures using the GFSM forecast model. Currently, the user has the ability to choose one of some 14 reports.

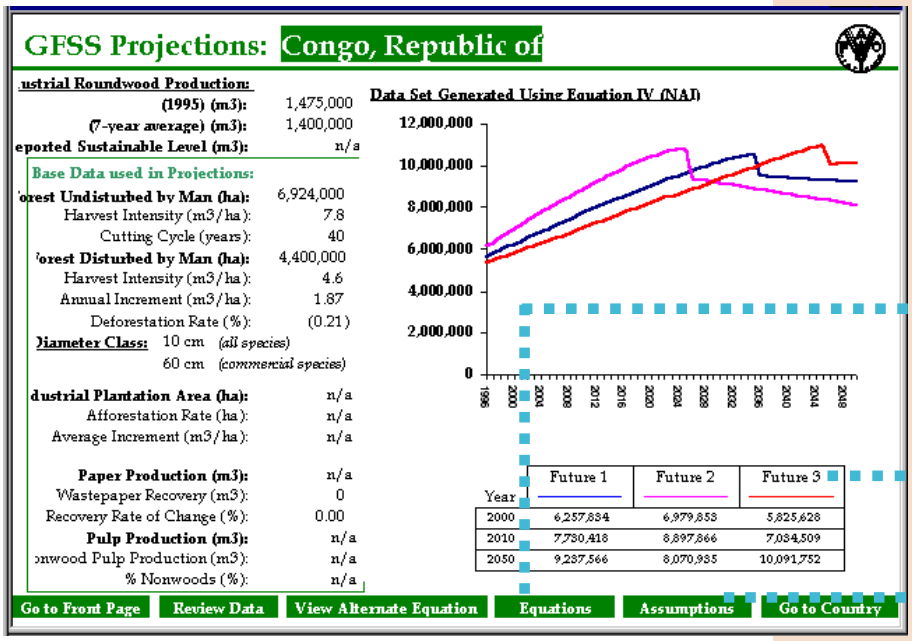



Volume Data
Congo, Republic of
Commercial Species Growing Stock
Natural Forest
Semi-Natural Forest
Annual Increment
Harvest Intensity
Natural
Semi-Natural
Cut Cycle (years)
Diameter Class
Non-Commercial Species Growing Stock
Natural Forest
Semi-Natural Forest
Annual Increment
Diameter Class (cm)
Alternative Fibre Data
Congo, Republic of
(all figures in Metric Tons)
Reference Year
Production
Imports
Exports
Consumption
Paper & Paperboard: 1995 n/a 529 177 352
Pulp (Woods & Nonwoods): 1995 n/a 6 497 (491)
Recovered Fibres: 1995 0 98 0 98
% Recovered (of Total Production): % Recovered (of Total Consumption): 27.8%
Nonwood Fibres: 1993 n/a n/a n/a n/a
Nonwoods (Total Pulp Capacity, 1993):
Annual Rates of Change (5-year averag
Wastepaper Recovery: 0.00% Nonwood Fibre Pulping Capacity n/a
lick here to return to the Country Pa

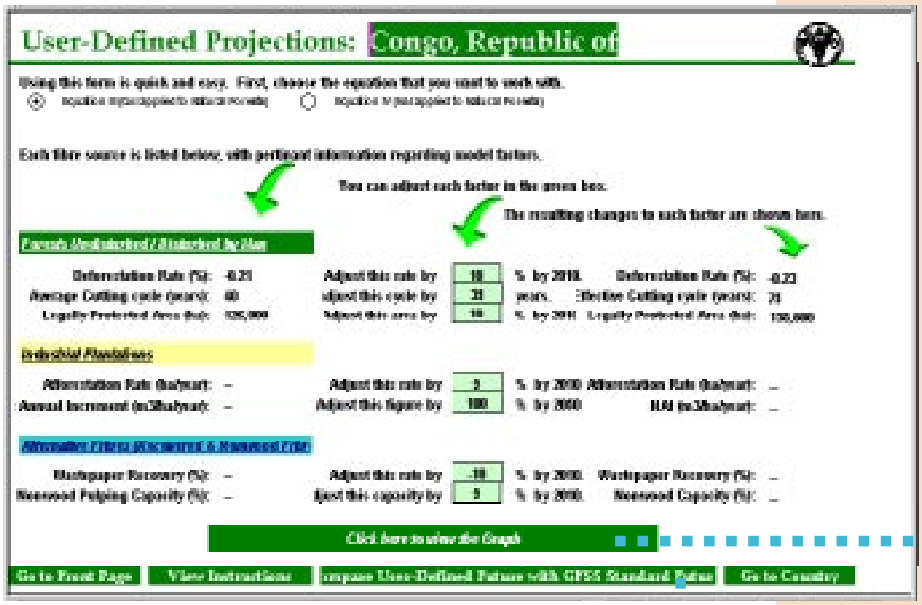

Country Summary : Congo, Republic of


Report Selection
Please select the desired regional report:
#1a: Natural Forest Area by Forest Type
#1b: Natural Forest Area by Country
#2a: Unstandardized and Standardized Volume by Forest Type
#2b: Unstandardized and Standardized Volume by Country
#3a: Natural Forest Volume, Growth and Removal by Forest Type (m3/h
#3b: Natural Forest Volume, Growth and Removal by Country (m3/ha)
#4a: Natural Forest Volume, Growth and Removal by Forest Type (total
#4b: Natural Forest Volume, Growth and Removal by Country (total)
#5a: Industrial Plantation Data by Species Group
#5b: Industrial Plantation Data by Country
#6: Alternative Fibre- Recovered and Nonwood
#7a: Potential Fibre Availability by Source (1996)
#7b: Potential Fibre Availability: 2010,2050 - #7b
OK
Cancel

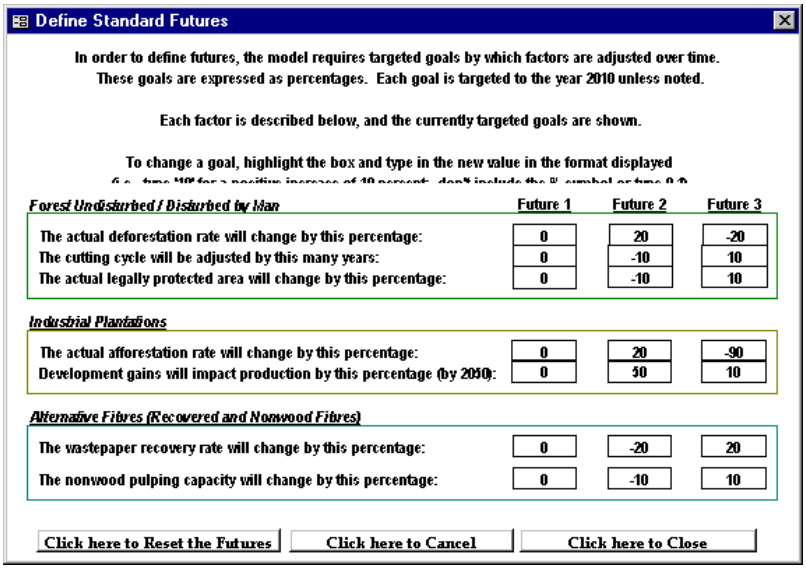
The fifth button ***GFSM Data Projections*** facilitates the exploration of three possible futures for each country and, most importantly, it describes the role each source of fibre could play in those futures. A list of major assumptions made in creating the futures is included (Section 2 – *Forecasting*).



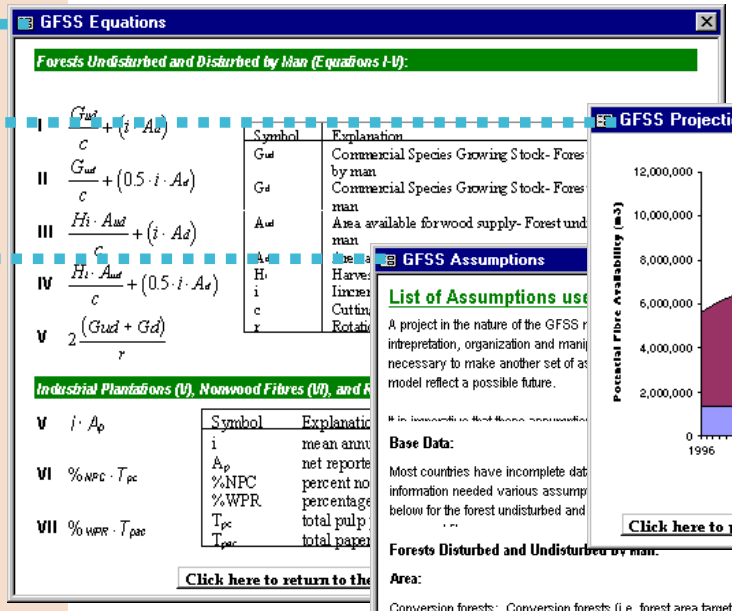
The sixth button ***User Defined Projections*** allows the user to explore a different future by manipulating variables as described in Section 5 and compare with the standard futures as set by the ***GFSM*** analyst. This is particularly useful for exploring country-specific policy issues affecting industrial wood supply. Instructions on how to use this feature are provided.

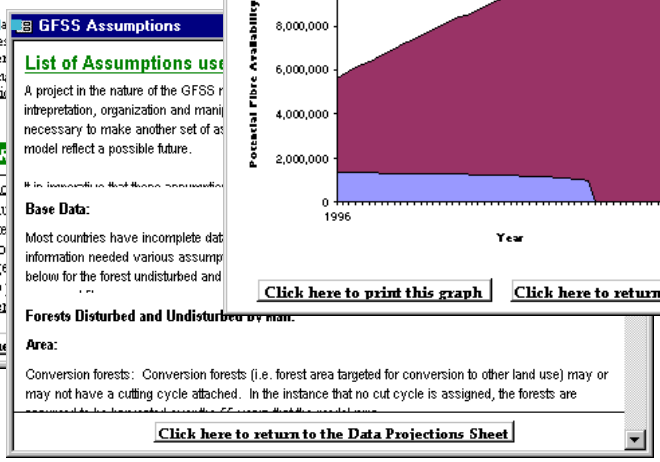


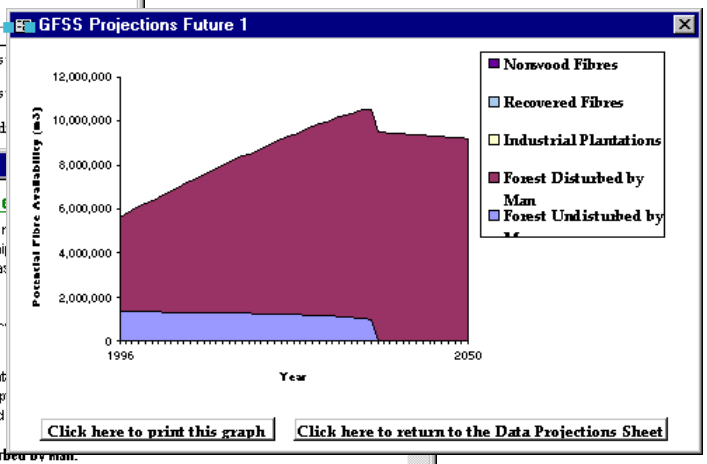
The seventh button ***Define GFSM Futures*** allows the analyst to set the standard variables as described in Section 5 for all countries. These variables can be reset at any time to help public policy makers, industry analysts and NGOs explore alternative futures.

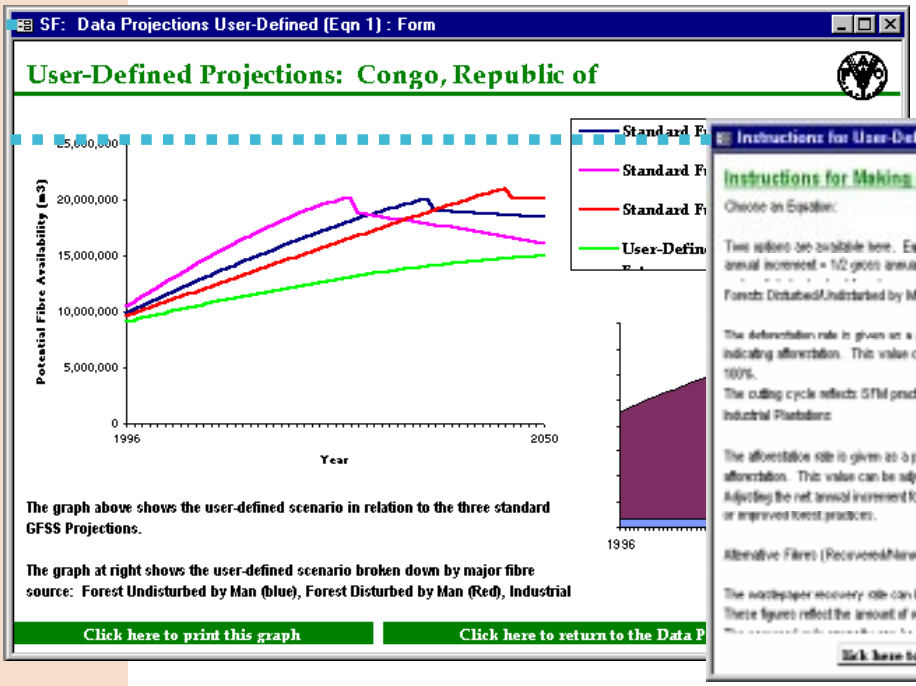


The eighth button ***Review GFSM Definitions*** contains a complete summary of the terms used in the database and model.

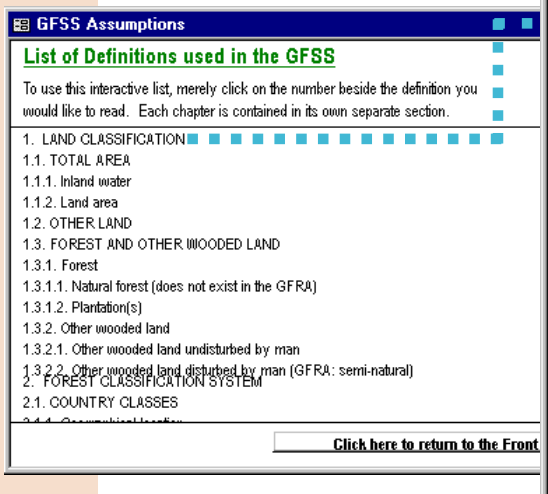

GFSS Equations
Forests Undisturbed and Disturbed by Man (Equations I-V):
Industrial Plantations (V), Nonwood Fibres (VI), and
Symbol
Explanation
Click here to return to the

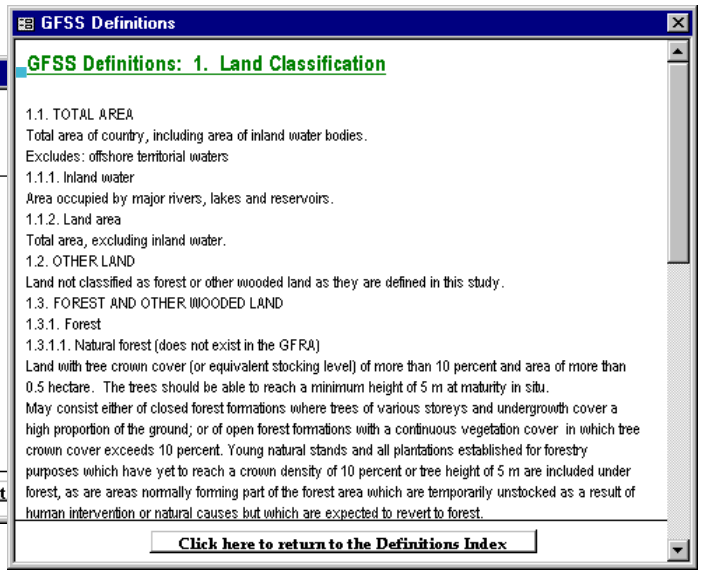

GFSS Assumptions
List of Assumptions use
A project in the nature of the GFSS
Base Data:
Most countries have incomplete dat
Forests Disturbed and Undisturbed by Man:
Area:
Conversion forests: Conversion forests (i.e. forest area targeted for conversion to other land use) may or may not have a cutting cycle attached. In the instance that no cut cycle is assigned, the forests are
Click here to return to the Data Projections Sheet


GFSS Projections Future 1
Nonwood Fibres
Recovered Fibres
Industrial Plantations
Forest Disturbed by Man
Forest Undisturbed by
Potential Fibre Availability (m3)
12,000,000
10,000,000
8,000,000
6,000,000
4,000,000
2,000,000
0
1996
2050
Year
Click here to print this graph
Click here to return to the Data Projections Sheet


SF: Data Projections User-Defined (Eqn 1) : Form
User-Defined Projections: Congo, Republic of
Potential Fibre Availability (m3)
20,000,000
15,000,000
10,000,000
5,000,000
0
1996
2050
Year
The graph above shows the user-defined scenario in relation to the three standard GFSS Projections.
The graph at right shows the user-defined scenario broken down by major fibre source: Forest Undisturbed by Man (blue), Forest Disturbed by Man (Red), Industrial
Click here to print this graph
Click here to return to the Data P


Instructions for User-Defined Projections
Instructions for Making a User-Defined Projection
Click here to return to the User-Defined Projections She


GFSS Assumptions
List of Definitions used in the GFSS
To use this interactive list, merely click on the number beside the definition you would like to read. Each chapter is contained in its own separate section.
1. LAND CLASSIFICATION
1.1. TOTAL AREA
1.1.1. Inland water
1.1.2. Land area
1.2. OTHER LAND
1.3. FOREST AND OTHER WOODED LAND
1.3.1. Forest
1.3.1.1. Natural forest (does not exist in the GFRA)
1.3.1.2. Plantation(s)
1.3.2. Other wooded land
1.3.2.1. Other wooded land undisturbed by man
1.3.2.2. Other wooded land disturbed by man (GFRA: semi-natural)
2. FOREST CLASSIFICATION SYSTEM
2.1. COUNTRY CLASSES
Click here to return to the Front


GFSS Definitions
GFSS Definitions: 1. Land Classification
1.1. TOTAL AREA
Total area of country, including area of inland water bodies.
Excludes: offshore territorial waters
1.1.1. Inland water
Area occupied by major rivers, lakes and reservoirs.
1.1.2. Land area
Total area, excluding inland water.
1.2. OTHER LAND
Land not classified as forest or other wooded land as they are defined in this study.
1.3. FOREST AND OTHER WOODED LAND
1.3.1. Forest
1.3.1.1. Natural forest (does not exist in the GFRA)
Land with tree crown cover (or equivalent stocking level) of more than 10 percent and area of more than 0.5 hectare. The trees should be able to reach a minimum height of 5 m at maturity in situ.
May consist either of closed forest formations where trees of various storeys and undergrowth cover a high proportion of the ground; or of open forest formations with a continuous vegetation cover in which tree crown cover exceeds 10 percent. Young natural stands and all plantations established for forestry purposes which have yet to reach a crown density of 10 percent or tree height of 5 m are included under forest, as are areas normally forming part of the forest area which are temporarily unstocked as a result of human intervention or natural causes but which are expected to revert to forest.
Click here to return to the Definitions Index

The emphasis of the database and model is transparency, flexibility and simplicity. In practical terms this means ease of access to forest standardized and unstandardized data, and ease of use of a simulation model which is relevant to some current forest policy issues.

SCOPE AND VALIDATION

Due to limited resources, and in order to keep the project to a more manageable size, it was decided that this project could not include at this time:

- fuelwood;
- trees outside of forests;
- non-industrial forest plantations;
- price and cost data;
- the geographic area of the Middle East;
- the geographic area of the republics of the former USSR;
- countries where industrial roundwood production is less than 100 000 m^3, unless the information was readily available.

In the future it will be necessary to collect the additional statistics to cover the fibre source of the regions/countries mentioned in order to present a more complete global picture of fibre supply for industrial and non-industrial uses (see Table 1). The price and cost information needs will also have to be addressed in order to bring market forces to bear on the supply analysis.

It is important in an exercise of this manner to validate the data used on basic area and volume of fibre available. Due to time and budgetary limitations and at the instruction of the Steering Committee, the data compiled was screened in two ways: First, it was examined by forestry experts and consultants who have knowledge of the particular country. Second, it was taken to regional workshops in Malaysia, Ghana and Brazil for an examination by government, private sector and non-governmental representatives.

MAJOR ASSUMPTIONS

A project of this nature requires the analysts to make key assumptions in data collection, interpretation, organization and manipulation. In addition, for any fibre supply modelling exercise, it is necessary to make a set of assumptions in model construction and development in order to describe possible futures. To gain more widespread acceptance of the information and the forecasts it is imperative that assumptions are made transparent and therefore considerable effort is made below to describe them fully. It should be noted that the assumptions described below are generic in nature and therefore used in the countries to which they apply. Naturally, the data collected from each country requires that additional unique assumptions are applied in order to standardize the data fully. In a report of this nature it is not appropriate to present an exhaustive description but the intention is to establish a continual dialogue with country analysts whereby all assumptions will be developed through a workshop participation process, a process which has already been initiated with over 25 countries for this report and now is still ongoing in the outlook study and FRA processes.

Base data

Most countries have incomplete data sets for natural and plantation forests. In order to fill in the essential information needed various assumptions were made in developing the base data. These are described below for the forest undisturbed and disturbed by man, the industrial plantation forest and the non-wood and recovered fibre.

Forest Undisturbed and Disturbed by Man

Forest Area

Area estimates contain three major assumptions.

1. The collection of total forest area statistics has a long history. It is now possible to calculate forest area with remote sensing information along with ground checks and it is assumed that this is the best possible method for area statistics for many countries in the absence of detailed inventory reports. The FAO Forest Resources Assessment 1990 forms an important part of the ***GFSM*** area assessment in developing countries.
2. It is also assumed that other wooded land will not yield a significant amount of industrial roundwood. Thus it is excluded from the current ***GFSM*** assessment.
3. There are distinctly different points of view on the issue of what area is available for fibre supply at a point in time and these are legitimate differences since our knowledge is imperfect[5]. While the precise boundary of the area available for wood supply cannot be defined, it is necessary for an industrial fibre outlook study to assess the area which is available under current market conditions, with current technology and infrastructure. Therefore assumptions were made using country experts and other data sources to deduct the forest area not available for wood supply. Forest area not available for wood supply was placed into the following classes and subclasses:
    a) legally protected according to IUCN classes 1 and 2;
    b) economically inaccessible;
        i) physically inaccessible due to factors such as steepness of terrain.
        ii) far from industrial sites due to transportation distance or lack of infrastructure.
        iii) too low in commercial volume, degraded forest or some other legitimate reason specific to each country.

It is worth noting that a similar evaluation procedure was used in the 1980 Forest Resources Assessment for the tropical forest.

[5] For example, there is sometimes a different view between governments and industry over area available for wood supply. From a government's point of view an area could be available for wood supply if there is no official policy, regulation or legislation which precludes its inclusion in a concession agreement. Industry may take a different view since it will assess the likelihood of an area of the concession being included in, say, protected area, or an area being physically inaccessible due to restrictions on permissible harvesting systems. This naturally leads to a divergence of opinion but neither policy actor can be considered unreasonable.

Forest Volume and Growth

Growing stock volume in cubic metres per hectare (m^3/ha)is reported at the diameter class which is standardized to 10 cm. It is also possible to indicate the unstandardized volumes if the information is requested. It is important to note that these statistics are not necessarily a reflection of the forest volume available for future wood supply.

Commercial species volumes are based on the tree species considered commercial under current market conditions for a particular country. The commercial or potentially commercial volume in the natural forest of tropical countries is normally far lower than the total growing stock. It is very important to pay special attention to the reported diameter class of the growing stock. In many cases the statistics are not a reflection of the commercial growing stock available today for industrial uses but of all age classes of commercial species greater than 10 cm.

Forest undisturbed by man in the tropical forest areas will not, in general, have any net growth since mortality is an offsetting factor to any annual growth. This is not the case in the forest disturbed by man and estimates of increment by forest type are included. There is a paucity of good data in this area.

For the temperate and boreal forests the study relies on the estimation procedures already made in statistical reports from the countries, research institutes or the ECE/FAO reports, all of which are mentioned in Section 6. Naturally the assumptions are different and the reader should refer to the relevant documentation.

Forest Removals

Harvesting intensity estimates for the tropics will change with the transition from forest undisturbed by man to forest disturbed by man under the historical and future forms of management. Working Paper No. 6, which is an annotated bibliography on this subject, strongly supports this assumption.

Under sustainable forest management practices harvesting intensity should remain fairly constant in a forest disturbed by man with each cutting cycle. The cutting cycles' statistics attempt to reflect the common silvicultural and harvesting prescriptions used most commonly in a country by each forest type.

In boreal and temperate regions the removal is expressed on an annual basis since the harvesting systems are generally different from the tropical regions and it is the total volume divided by the rotation age for each forest type.

Industrial Plantations

The plantation area includes all plantations whose primary objective is to produce industrial roundwood – that is sawlogs, veneer logs, pulpwood and other industrial wood. They include areas of "non-forest" species, such as rubber and coconut and, to a lesser extent, oil palm. Presently relatively few countries are using these species for forest products but more use is anticipated in the future. They exclude all plantation areas where it was

possible to identify, or in some cases infer, that the objective was non-industrial – that is mainly fuelwood but also poles, tan-bark and areas managed exclusively for other non-timber products. If, however, an area is managed for a non-timber product such as naval stores (e.g. some of the pines in Sri Lanka) they are included since they will eventually produce industrial roundwood.

The gross annual increment is an estimate by species and by country of the increment in m^3/ha/a continued over the commercial rotation of the crop. Once more is known about mortality, reduction factors can be applied to yield a net annual increment.

Recovered Fibres

The percentage of wastepaper recovered is a fraction of total paper and paperboard production. For a few countries, particularly those with political turmoil, figures were either unreliable or unavailable. In such cases estimated values were used to fill data gaps. Working Paper No. 4 describes the background of wastepaper statistics in detail.

All available recovered fibre is provided by wastepaper recovery. While this is not always the case, as there are viable operations concerned with recovering solid timber and engineered wood products, the use of recovered fibre is still predominantly in the pulp and paper industry with the recovery and recycling of wastepaper.

Non-wood Fibres

Most non-wood fibre produced is used towards the production of pulp for paper. Non-wood fibre usage is significant in a limited number of countries. In some cases estimates were made to fill data gaps and these are also described more fully in Working Paper No. 4.

Forecasting

Forests Undisturbed and Disturbed by Man

Forest Area

Conversion forests. These forests (i.e. forest area targeted for conversion to other land use) may or may not have a cutting cycle attached. In the instance that no cutting cycle is assigned, the forests are assumed to be harvested over the 55 years that the model runs.

Adjusting the legally protected forest areas. Targets for legally protected forest areas are expressed as a percentage of the current legally protected area (i.e. 1995 base year). Therefore, the total legally protected area can be said to increase or decrease by the target percentage. The target date is fixed at 2010. It is also assumed that increases or decreases in the legally protected forest area will be applied evenly over forests both undisturbed and disturbed by man.

Transformation from undisturbed forest. All undisturbed forests are assumed to transform to disturbed forests after a single harvest.

Transformed areas are assumed to still contribute to the overall productive capability although in many forest types the sustainable productivity will be at a lower level under existing management.

Deforestation. The annual deforestation is applied to a percentage of the area available for wood supply. The original rate is provided by the *State of the World's Forests* (FAO 1997). One year of deforestation reduces the overall area available for wood supply, which is reflected in the next year's calculation. Thus, the actual area being deforested and, as a result, the area available changes from year to year. The deforestation rate itself is applied evenly over every year of the cutting cycle. The deforestation rate is applied evenly over the entire undisturbed and disturbed forest area available for supply.

Adjusting the deforestation rate. Changes to the overall deforestation rate are expressed as a percentage of the current deforestation rate. Thus, the deforestation rate can be said to increase or decrease by the target percentage. This target percentage is applied as an even reduction or gain in the overall deforestation rate over each year of the cutting cycle. Changes in the deforestation rate are applied evenly to both the disturbed and undisturbed forest areas.

Forest Volume

Potential commercial growing stock. It is the portion of the actual commercial growing stock that will be potentially utilized and includes all age classes of commercial value.

Inventory diameter class. One of the most critical factors in compiling forest inventory data is establishing the diameter class of the inventory. Each country compiles data at different classes and the challenge is to find the forest volume at the 10 cm class. Crude conversions, described in Working Paper No. 1, have been used for reporting purposes.

Forest Growth and Removals

Growth. It is assumed that the forest undisturbed by man has little or no growth in terms of a net increase in the potential commercial growing stock.

Removals. For the undisturbed forest the removals are assumed to be the forest volume distributed over the cutting cycle for a particular forest type. Removals should not exceed the net growth of forest once the forest is disturbed.

Yield Calculations

Sustainable supply. Sustainable supply as a concept has now been broadened in many regions expanding from the traditional tenets of sustained yield[6] to include the concepts of biological diversity and ecosystem management (see Working Paper No. 3). This means broadening the analysis to include spatial as well as aspatial possibilities in forest yield regulation and, despite the increased complexity, quantify the long-term supply. Several formulae are used in an attempt to reflect supply levels which might be deemed ‘’sustainable”, at least from a productive capacity point of view (one criterion in the Montreal and other processes).

Yield regulation diameter class. Supply calculations require the specification of the diameter class. Since different countries choose different diameter classes for yield regulation calculations, it is important to compare the diameter classes used before comparing modelling results.

Adjusting the cutting cycle. Increased reliance on practices regarded as contributing to forest sustainability is reflected in an increase in the cutting cycle. Conversely, abandoning the principles of SFM is reflected by a decrease in the cutting cycle. Target changes in the cutting cycle are applied at the beginning of the cycle. Therefore, implementing a management plan which entails improved SFM would have an immediate effect upon the model output.

Industrial Plantations

Afforestation rate. The afforestation rate is derived from various government sources and other published information. Where no information is available the estimates are made by plantation experts with knowledge of the region. It is assumed to be an annual planting rate. However, to offset the effects of replanting a currently existing plantation or changes in government initiatives, the afforestation rate is reduced by 7 percent annually and thus is brought to 0 percent by the year 2010.

Adjusting the afforestation rate. Changes to the afforestation rate are expressed as a percentage of the overall afforestation rate. Thus, the rate may be increased or decreased by a target percentage. This rate only refers to additional area planted.

Industrial plantation area available for supply. The plantation area that is available for supply is variable. It is assumed that 5 percent of a country's industrial plantation area was available in 1995. (Notable exceptions are countries with long-standing plantation programmes where the area available for current wood supply is assumed to be 50 percent.) This percentage rises linearly until the year 2015, when it is assumed that 80 percent of a country's plantation area is available for supply. However, where reliable information on the area currently available exists, it will be used in the simulations.

Development gains. There is provision in the model for gains from improved plantation development, such as better silvicultural practices or improved genetic stock. The development gains factor is expressed as a target percentage. Essentially, it represents a percent increase in the production capacity of industrial plantations. The target percentage is evenly applied over 55 years until the year 2050. The default is set at 30 percent but Working Paper No. 2 gives a more detailed review of other percentages that could be used for simulation modelling purposes.

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[6] This report does not review the merits and shortcomings of sustained yield or any modification of the concept. However, as a well respected forest economist once said:

> *The concept of sustained yield should not have followed the crosscut saw into oblivion, nor is it likely to. Divergence between industrial and social rate of time preferences, different attitudes towards risk, and the implications of forest ownership patterns all seem likely to inhibit experimentation with other objectives. Also sustained yield management does create benefits which are not always noted (Nautiyal 1988).*

Actual increment. The industrial plantation increment values are commonly very high. The model reduces the increment value by 25 percent in order to take into account bark, age class distribution, inadequate management practices, environmental restrictions, losses incurred in harvesting and transport or possible over-estimations of plantation growth.

Recovered Fibres

Conversion of metric tons to cubic metres. The conversion factor to convert metric tons to cubic metres is assumed to be 2.5 m^3/t. This factor is an estimate taken from an amalgamation of various sources.

Existing recovered paper usage rate of change. The rate of change in recovered fibre use as estimated (see Working Paper No. 4) is applied on a linear basis over the 55 years of the model run. The existing rate of change is derived from historic wastepaper recovery statistics and paper and paperboard production figures, as published by FAO (FAOStat 1997).

Maximum recovered paper. The wastepaper recovered will not exceed twice the 1995 level (i.e. if they recovered 100 tons in 1995, nowhere in the forecast will they recover more than 200 tons).

Maximum recovered paper usage rate. The wastepaper recovered will not exceed 70 percent of the overall paper production, based on current trends of paper production. This prevents any unreasonable amounts of wastepaper recovery.

Adjusting the recovered fibre usage rate of change. The rate of change in wastepaper recovery can be adjusted by setting a target percentage and then adjusting the rate of change up or down by this percentage. The target date is 2010. This allows the pattern of wastepaper recovery usage to be adjusted over the course of the model run.

Non-wood Fibres

Conversion of metric tons to cubic metres. The conversion factor to convert metric tons to cubic metres is assumed to be 2.5 m^3/t. This factor is a rough figure taken from an amalgamation of various figures compiled by different sources.

Existing non-wood fibre usage rate of change. The rate of change in non-wood fibre use is estimated (see Working Paper No. 4) and applied on a linear basis over the 55 years of the model run. The existing rate of change is derived from historic non-wood fibre usage statistics and pulp production figures as published by FAO (FAOStat 1997).

Adjusting the non-wood fibre usage rate of change. This adjustment is made by establishing a target percentage (i.e. non-wood fibre use might increase or decrease by a percentage over the next 15 years) and then applying this change to the existing non-wood fibre usage rate of change. Thus, the pattern of non-wood fibre usage could change over the course of the model. The target date for this factor is 2010 (15 years into the model).

DATA AND STATISTICAL ISSUES

Data quality and resolution

Data quality is very mixed, inconsistent or missing altogether. For example, in a few countries there is recent forest inventory data of outstanding quality while in most countries inventory information is poor or is very old.

Data resolution means the spatial scale at which the forest inventory data was collected and the intensity of the survey conducted. It is difficult to aggregate data from the field level to the country level. Often forest inventory projects are small scale with a much narrower purpose and it is difficult to take the information and apply it to the country level. For example, the field project may estimate that the average growth of the forest in a particular forest type is 1.8 m^3/ha/a. Given that there is no other information on other forest types in the country, does it mean we should apply it? Experts had to make judgement calls and then the data was reviewed by people in the most important countries.

Statistical inconsistencies

Many countries do not declare their statistical assumptions in defining their forest inventories. The critical factors include definition of commercial species, appropriate volume expansion factors to standardize forest volumes, definition of accessible forest area, and tree growth increments in both open and closed forest formations.

It is also difficult to get a standard definition of land area, forest area, and protected areas. In many cases there are different numbers for the same area or volume from different reports for the same country. Deciphering the best estimate required extensive effort by our country assessment team.