CO2FIX for Windows:

a dynamic model of the CO_2-fixation in forests; Version 1.2

G.M.J. Mohren, J. F. Garza Caligaris, O. Masera, M. Kanninen, T. Karjalainen, A. Pussinen & G.J. Nabuurs

IBN RESEARCH REPORT XX

Institute for Forestry and Nature Research

Instituto de Ecología Universidad Nacional Autónoma de México (UNAM)

Centro Agronómico Tropical de Investigación y Enseñanza (CATIE)

European Forest Institute

1999

ACKNOWLEDGEMENT

The present document is a guide to the program CO2FIX for Windows, Version 1.2, a user friendly forest, forest soils, and wood products carbon accounting model. This report contains both a short description of the model as a manual on its use. A more detailed description of the technical characteristics of the model can be found in Mohren & Klein-Goldewijk 1990b.

This report and the user friendly windows version of CO2FIX have been made possible through funds provided by the EU under the INCO-DC programme (Contract Number: ERBIC18 CT98 0324). Additional funds were provided by the Climate Programme of the Dutch Ministry of Agriculture, Nature Management and Fisheries. We want to thank the Programme Manager and the Steering Committee.

Omar Masera and Jose Garza-Caligaris
Laboratorio de Bioenergía, Instituto de Ecología UNAM,
A.P. 27-3 (Xangari), 58089 Morelia, Michoacán. Mexico

Markku Kanninen, L. Pedroni, T. de Camino.
Centro Agronómico Tropical de Investigación y Enseñanza
7170 Turrialba, Costarica

Timo Karjalainen, Ari Pussinen, Tuija Lapvetelainen and Simo Varis
European Forest Institute
Torikatu 34
FIN-80100 Joensuu Finland

Frits Mohren and Gert-Jan Nabuurs
Institute for Forestry and Nature Research (IBN-DLO)
P.O. Box 23
NL-6700 AA Wageningen, The Netherlands

DISCLAIMER

This program can be downloaded from the World Wide Web free of charge and exclusively for the purpose of scientific research. It may not be distributed to third parties, other than by downloading the original software from the Web. If you use this program, the credit for both the model and the Windows program should be cited in papers, reports or books that result directly or indirectly from the utilisation of the program. We would greatly appreciate that reprints of articles citing the program be sent to the authors in The Netherlands, Mexico, Costa Rica, and Finland.

Neither the authors of the model, nor those of the Windows version assume responsibility for damages caused directly or indirectly from the use of the program or by the application of results derived from it. The accuracy of the predictions of carbon sequestration by CO2FIX is treated in paragraph 2.2 of this report.

Note that CO2FIX has never been approved for official crediting of carbon sequestration.

When using the model reference should always be made to the minimum of the following two publications:

Mohren, G.M.J. & C.G.M. Klein Goldewijk 1990. CO2FIX: A dynamic model of the CO2-fixation in forest stands. De Dorschkamp, Research Institute for Forestry and Urban Ecology. Report 624. 35 p. + app. Wageningen, The Netherlands.

Mohren, G.M.J., J.F. Garza Caligaris, O. Masera, M. Kanninen, T. Karjalainen & G.J. Nabuurs 1999. CO2FIX for Windows: a dynamic model of the CO2 fixation in forest stands. Institute for Forestry and Nature Research, Instituto de Ecologia, UNAM, Centro Agronomico Tropical de Investigación y Ensenanza (CATIE), European Forest Institute. Wageningen The Netherlands, Morelia, Mexico, Turrialba Costa Rica, Joensuu Finland. 27 p.

CONTENTS

1 INTRODUCTION: WHAT CAN I DO WITH CO2FIX?

Global forests play an important role in the global carbon cycle (Brown et al. 1996). Most likely the forests of the mid and high latitudes absorb 0.74 Gt C per year while deforestation mostly in the lower latitudes leads to an emission of carbon of around 1.65 Gt C per year (Brown et al. 1996). These dynamics of global forests, their potential contribution to curbing the increase of atmospheric carbon dioxide, and the acknowledgement of their role through the adoption of the Kyoto Protocol (UNFCCC 1997) have initiated many studies into the possibilities of enhancing and maintaining carbon sequestration of global forests. Options for enhancement and maintenance of the carbon sequestration are: stopping deforestation, expanding forest area, increasing the carbon stock in existing forests (including soils), increasing the use and life span of wood products, and using wood products as biofuels for substituting fossil fuels.

However, quantifying the likely results of the above-mentioned options is difficult because C sequestration in forests consists of stocks and fluxes in various compartments in the forest ecosystem as well as in the manufactured wood products. Management that focuses on enhancement of carbon in e.g. forest biomass therefore has an impact on soils and wood products as well. Also, study results are difficult to compare because of differences in the methodology used, or because parts of the carbon cycle of a forest ecosystem-wood products chain are regarded, or because different time scales are used.

CO2FIX is a tool which quantifies the C stocks and fluxes in the forest (whole tree), soil organic matter compartment and the resulting wood products at the hectare scale. It was originally designed for even-aged monospecies stands in The Netherlands (Mohren & Klein Goldewijk 1990a), but has also been used for a wide variety of (mostly even-aged) forest types from all over the world, including some selective logging systems (Nabuurs & Mohren 1993, Ordóñez, 1998) and agroforestry systems in the tropics (de Jong et al., 1998).). Some of the results of CO2FIX have been used in the IPCC 1995 climate change assessment (Brown et al. 1996).

Compared to the previous version of CO2FIX which was documented in Mohren and Klein Goldewijk 1990b, the present version:

- is a user friendly Windows-based version;
- is more precise in the allocation of harvested wood from thinnings and final fellings to wood product groups;
- has an option to choose for recycling;
- can directly sum the output of one forest type to larger areas;
- directly presents some of the output in a graph.

This report outlines the characteristics of CO2FIX (Ch 2) and then continues with the manual itself (Ch 3). The software including input files can be downloaded from the world wide web.

2 THE MODEL

2.1 Description of the model

CO2FIX quantifies the carbon budget of a forest-soil-wood products chain at the stand (i.e. hectare) level on an annual base and for multiple rotations. It also has a feature to scale up to the project level using the rotation length as the number of afforestations to be carried out.

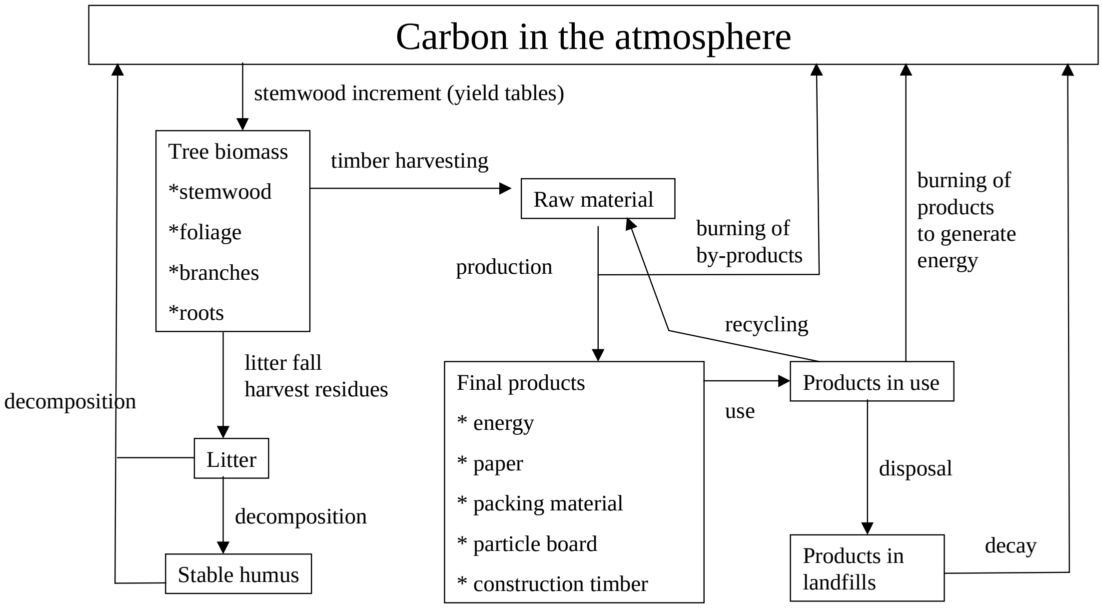


Figure 1. Carbon fluxes/processes (arrows) and carbon stocks (boxes) in a forest ecosystem and its wood products as distinguished in CO2FIX

The model comprises the compartments as given in Figure 1. CO2FIX can be parameterised by published data (often yield tables) on growth rates and amounts of biomass in the various forest types together with forest soil carbon data. Growth of foliage, branches, and roots is incorporated as an additional allocation of dry matter increment relative to the stem wood. This, together with expected life spans of those tree organs determines the biomass of those organs in the stand and determines the rate of litterfall.

The dynamics of the forest soils compartment are characterised by decomposition rates of litter and stable humus and humification rates of litter. Initial values for dead wood, litter, and soil stable humus can be based on current knowledge in literature. It is assumed that both litter and dead wood on top of the mineral soil and stable humus incorporated in the mineral soil, belong to the soil organic matter compartment.

The forest product compartment is incorporated in the model according to a specified harvesting regime. The harvested wood (in case of thinnings as a percentage of the standing volume) is allocated by the user to five product groups. Products are assumed to decay exponentially with the average residence times of carbon in energy wood, paper, packing wood, particle board, and construction wood usually being estimated at respectively 1, 2, 3, 20 and 35 years.

For wood products, a recycling option is also available. In case of recycling, the wood product does not decay exponentially, but the whole amount is, at the end of its life span, moved to a wood product of lower quality. Construction wood is e.g. recycled to particle board and then again particle board is used as energy wood. When the wood product has come to the end of the life span of its last use, all the carbon is emitted in one year. There is no land fill compartment in the present version of CO2FIX.

With basic wood density (dry matter weight per fresh volume) and carbon content data from literature, volume and dry matter are converted to carbon. For further details of the model see Mohren & Klein Goldewijk 1990b. The model produces an annual output of stocks and fluxes of carbon for different parts of the forest biomass, the wood product compartment, and the soil organic matter compartment.

2.2 Accuracy of predictions of carbon sequestration by CO2FIX

Errors in forest resource projections (and thus C balances) have two main sources (Kangas 1997):
a. the stochastic character of the estimated model coefficients;
b. measurement errors in the data or lack of data used for model construction;

Re a. In nature, an enormous variability occurs. This variability still exists within one clearly defined forest type and is the result of e.g. growth variation between years caused by weather circumstances, intra-species genetic differences, and site quality variation. This natural variability is not captured by CO2FIX because it very much relies on fixed input data from yield tables that can be seen as some sort of complete, and perfectly managed forests. Other stochastic events are management irregularity and risks caused by e.g. storm and fire. These events are not captured either. Furthermore natural variability occurs in carbon content of dry matter, basic wood density, litter and humus decomposition rates.

When parametrising CO2FIX this variability is usually dealt with by trying to find the average or median value of a parameter. Only when multiple runs are carried out in which the natural variability in e.g. growth rates, carbon content, and humus decomposition is captured, then CO2FIX provides insight in this type of uncertainty.

Re b. CO2FIX relies heavily on net annual increment data from yield tables[1]. These

[1] see http://www.efi.fi/projects/forsce/yield_tables.html for an overview of European yield tables.

tables are based on long-term measurement series in permanent plots and or forest inventories. In these measurement series, errors and/or bias can occur. However these errors are usually very small. Both forest inventories and yield tables are generally seen as very reliable. Tomppo (1996) gives standard errors of some characteristics of the National Forest Inventory in Finland: forest land area 0.4%, growing stock 0.7%, and increment 1.1%.

However, where input data for CO2FIX rely on few measurements or a single series, uncertainty in the predictions will increase very much. This type of uncertainty especially exists in the soil pools.

Van der Voet (in: Nabuurs & Mohren 1993) carried out an uncertainty analysis of the model CO2FIX. He specified input uncertainties in the form of simultaneous input distributions for an even-aged forest type. The 100 simulations with randomly chosen values of input gave an average CTOTAV of 316 Mg C ha^{-1}. The standard deviation was 12% and the 95% confidence interval was 254 - 403 Mg C ha^{-1}. He concluded that it was mainly the litter and humus coefficients and the carbon content that determined this uncertainty, but in general it was mainly the natural variability rather than a lack of data that determined the overall uncertainty.

3 MANUAL

3.1 Introduction: CO2FIX for windows

This model was originally developed by Frits Mohren in Fortran 77 to run on a VAX-3600. Due to the extensive use of personal computers and of graphic interfaces such as Windows, we found it necessary to update the data input system so that it could be used by a greater number of users who are less familiar with Fortran and VAX. Also, today's users commonly employ spreadsheets that allow them to generate high quality tables and graphs with their results, creating the need for a version that would provide a simple mechanism for data export to such tools.

As programming language, Borland C++ 4.5 was chosen due to the fact that C++ has become the standard programming language in graphic environments. Borland is one of the leading producers in development tools for programs used in personal computers and has been widely accepted in the academic and research sector.

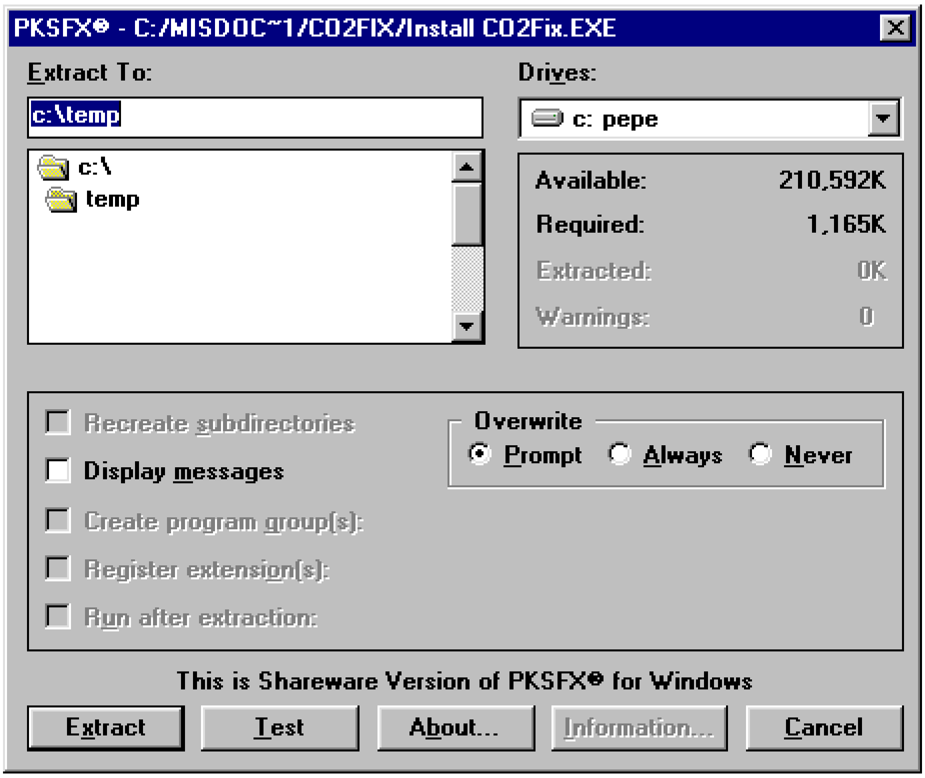
It was necessary in the first place to translate the Fortran code to C++ in order to encapsulate the model so that it would remain isolated from its interface. At the same time, dialogue boxes, viewing devices for result tables and a graph for the carbon balance were designed to facilitate the capture and modification of input data as well as the viewing of the results. An additional result file in a format limited by commas and apostrophes was generated to allow for easy export of results to spreadsheets.

3.2 Program installation

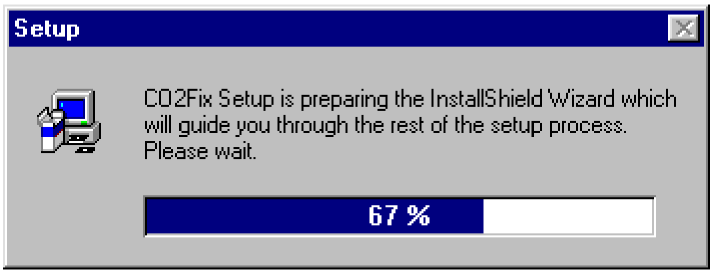
The minimum requirements for installing the program on your personal computer are: Intel 80386 processor, 4 MB RAM memory, 4 MB free space on the hard disk, and Microsoft Windows 3.1 (or higher) previously installed. The software can be found on the world wide web on the site: http://www.efi.fi/projects/casfor/

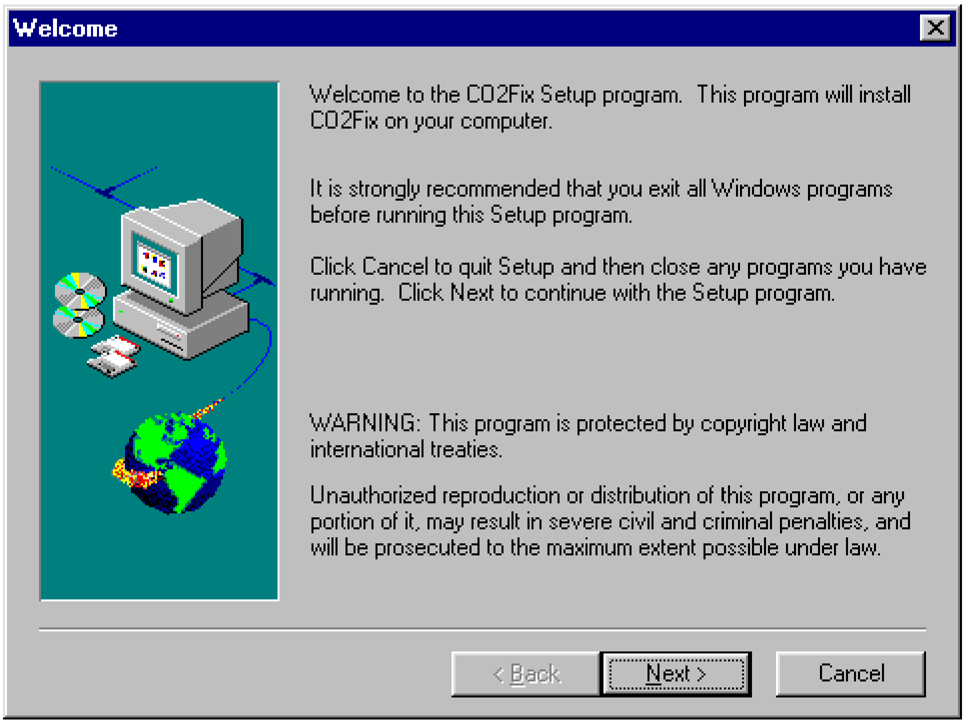
Go to ‘CO2FIX-model’ and after reading the disclaimer and completely filling out the registration (including your email address) two emails are automatically send to you. The first confirms that you have been registered, the second gives the URL where you can download the software. Start the download and save the file (Co2fix.exe) to e.g. C:\temp.

When the download process has finished, execute it by a double click in the Windows Explorer. The next screen will appear:



Select a temporary directory (e.g. c:\temp) and press the "Extract" button. A set of standard windows installation files has been created in the temporary directory. To initiate it execute the "setup.exe" file.





Press the "Next" button to begin the process. The setup program will guide you to install the CO2Fix program in your computer. Be prepared to answer the following questions:

- Software licence agreement: Read carefully the conditions for using the program. Press the "Yes" button if you agree

- Destination directory: Accept the default directory C:\CO2Fix or "Browse" to select another folder for your convenience

- Setup type: Accept the "Typical" to install all software (about 1.35Mb). Select "Compact" to install only the application file, no help file or samples will be provided. Choose "Custom" to manually specify which components are to be installed.

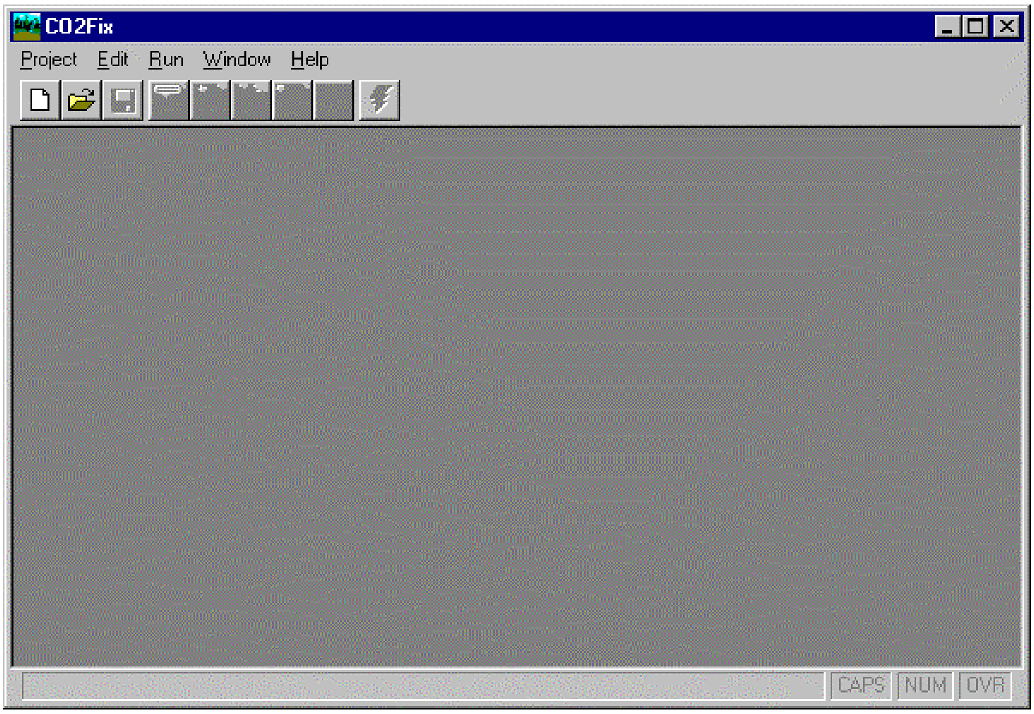
- Program folder: Accept the default CO2Fix folder or select another one. That folder will be created in the "Programs" section of the "Start" menu.

- Start copying files: Check that all options are correct and press "Next" to initiate the copy proccess.

- Setup complete: The software was successfully installed in your computer. Press "Finish" to end the setup program.

3.3 Getting started

To call CO2Fix for Windows give a double click on the CO2Fix icon. This has a bar menu that gives shortcuts for the most commonly used options. Navigating through the menus you will note that the majority of the options are deactivated (in grey).



The first step consists of the creation of a new project (with the Project-New option), opening an already existing project (Project-Open option) or importing a project from the files of Mohren's original version (Project-Import). Each of these will be discussed in detail.

Once a project file is in use, the deactivated options will be activated, allowing for the capture or modification of input data in the project by calling up each one of the five dialogue boxes (Comments, Stands, Thinning & Harvest, Trees Species, Growth). Each input field within the dialogue box includes a brief description of its meaning as well as the acronym used by Mohren. If you desire more information on the specific meaning of one of these fields, consult the list of acronyms included in this manual in Annex 1 (and available with the Help-Acronyms option). To obtain more information consult the documentation on the CO2Fix model (Mohren & Goldewijk, 1990b).

The first dialogue box allows you to write comments on the location and species used as well as to register the premises used in the project.

The second dialogue box contains information on stand management, length of harvest cycle, number of cycles to be used in the model, factors of adjustment to the specific conditions of the location, initial content of biomass, re-use of products, etc. The surface per stand, not taken into consideration by Mohren, has been added to this dialogue box. This will allow you to calculate the total fixation in a plantation that has as many stands of the same size as years in a harvest cycle.

The third dialogue box contains information with reference to thinning and harvest. It consists of a table in which for each year of thinning, the total fraction of stem wood extracted, as well as its distribution in different products, are specified. The total of the row should sum to 1. Each line should be listed in chronological order by year of thinning. You may specify up to 25 thinnings per harvest cycle. If you desire to register fewer than 25, simply input a large number in the year column (larger than the duration of a cycle, e.g. 999) in the extra lines, the rest of the columns may contain zeros. The last line of the table will be used to specify the distribution in terms of the different uses of the wood extracted during the final harvest.

The fourth dialogue box is used to introduce information relative to the tree species being cultivated. This includes the name of the species, basic wood density, carbon content, decay, mortality and humification rates, etc.

The last dialogue box contains a table in which the year column represents the upper limit of a growth stage. It is associated with a determined annual growth rate. You may define up to 25 growth stages that should be ordered chronologically. If you wish to define fewer than 25, you must specify for each of the left-over lines a large number in the year column (larger than the duration of a cycle, e.g. 999) and associate this with the estimated growth for older trees. Tables for leaf, branch and root growth are provided to relate this to stem growth. In each growth stage, the growth factor is expressed relative to dry weight increment of the stem. The tables allow for up to 10 different stages that should be ordered from the first to the last. If you desire to use fewer stages, specify a large year number and a long-term growth factor for each line left.

Once you have completed the data capture phase you must save the project (Project-Save or Project-Save As). If you have input illogical data leading to results the program cannot manage, an error message will appear along with the results generated up to the point in which the problem occurred, so that you will be able to locate and correct the problem. However, at times the error may cause the program to suddenly shut off with a consequent loss of information if the project was not saved.

When the program is run (Run) a bar will appear which indicates the advance of the calculations. Once the process has been completed two graphs, one with the Carbon balance at the stand level and another with the Carbon balance at the plantation level will appear. To view the results tables select the option "Run-View Results". You may choose one of 12 results tables or open all at once (All Tables, see also annex 3).

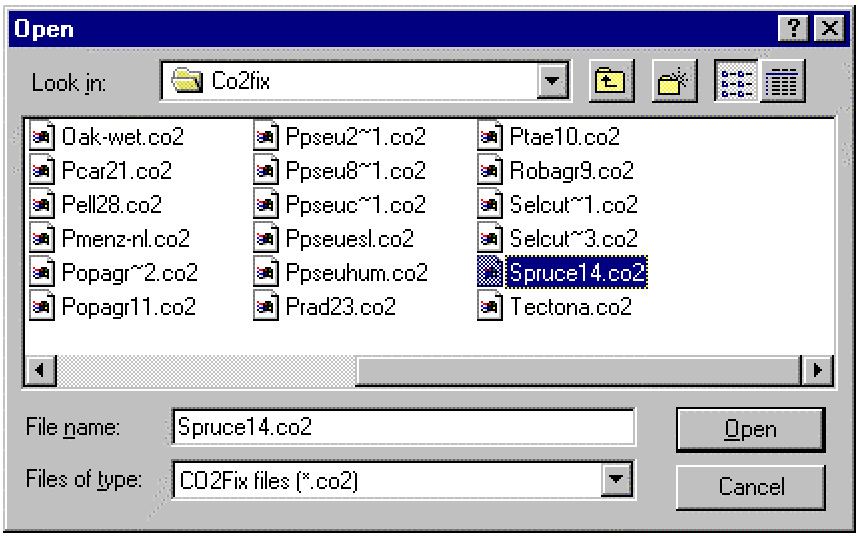
The meaning of each column in the table is described in the list of acronyms. Eleven of the twelve tables are described in the documentation of the model (Mohren & Goldewijk 1990a). The twelfth table, TOTBAL.OUT is an extrapolation of the results for a plantation that has a number of stands equal to that of the years in the harvest cycle. Each stand has a surface equal to that which is specified in the dialogue box of Stand Parameters. When the model is executed, the file EXPORT.TXT is produced (not visible in the program window, but created in directory c:\CO2FIX\ ). This allows the project to be imported for use with the majority of spreadsheets or databases since it formats the file with commas and apostrophes as limits.

3.4 Input dialogue boxes

MAIN MENU 'PROJECT'

New: Create a new project from zero

Open: Open an existing project. A standard Windows file dialogue box appears, in which you select the file to be opened.



Import: Information contained in data files created for use with Mohren's Fortran version is imported. Two dialogue boxes will appear one after the other, requesting the stand file name and the tree file name. Due to the design of the C++ input/output libraries, commas used to delimit fields in the original files must be replaced by spaces. This may be done using the MS-DOS editor (EDIT.EXE).

Save: Save changes made in data files. If the project file has just been created (New option) or it was imported (Import option) a dialogue box will request a name for the file.

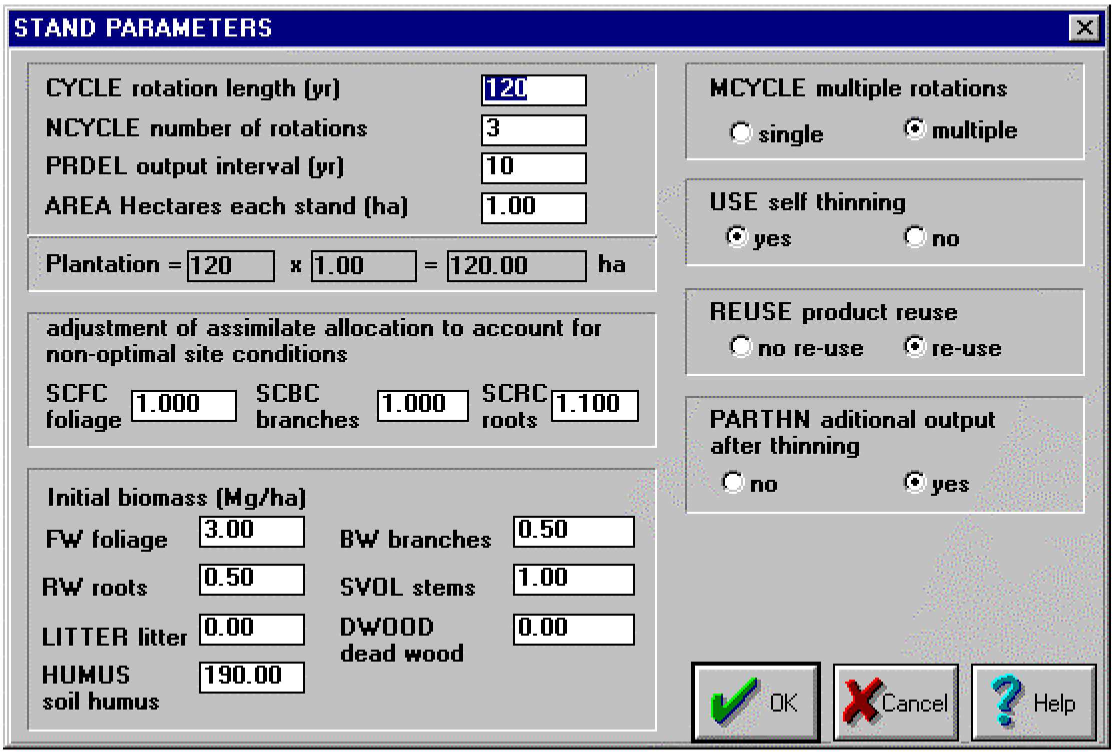
Save as: Save the data file with a different name. A dialogue box will appear requesting the name of the new file.

Exit: End the CO2Fix session.

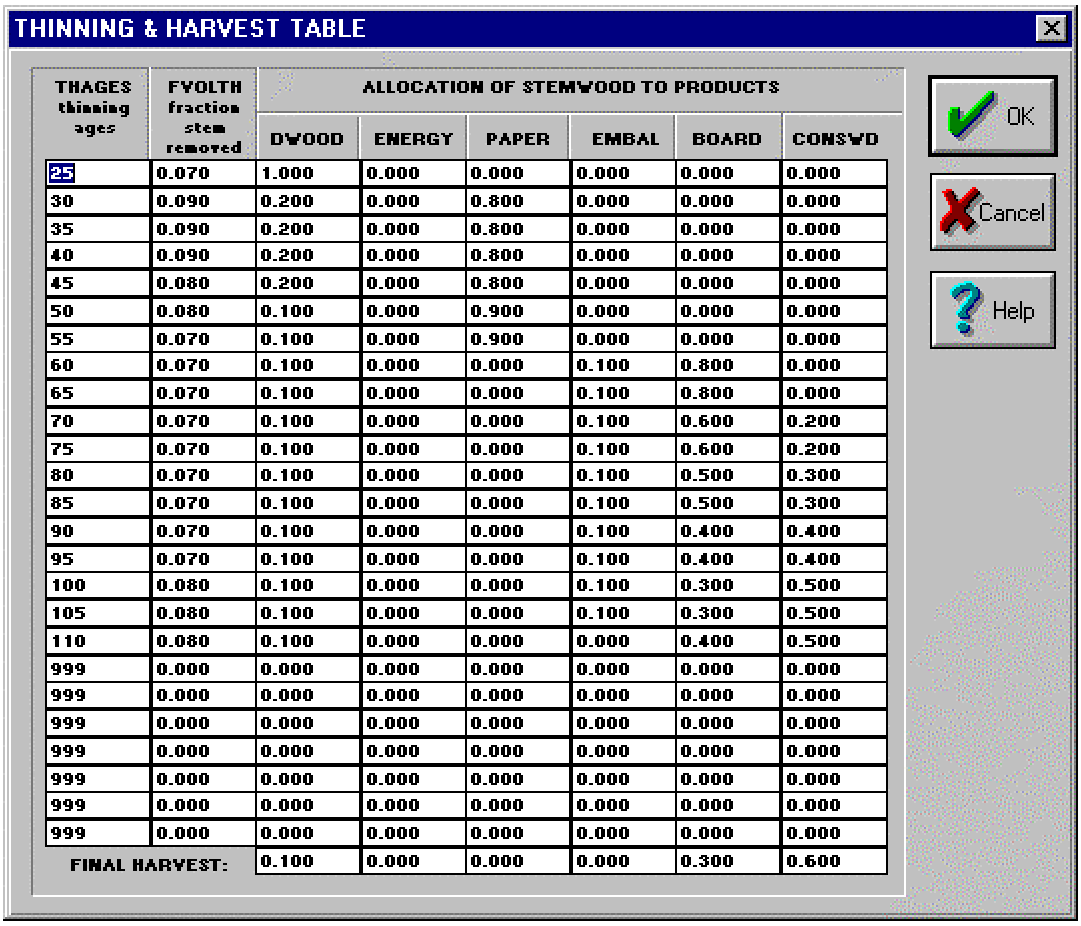
MAIN MENU 'EDIT'

Under this main menu, the five input dialogue boxes can be opened.

Comments: Open this dialogue box to enter comments or documentation on the parameters or premises of the project.
Stands: Open this dialogue box for the stand parameters. (See list of acronyms.)



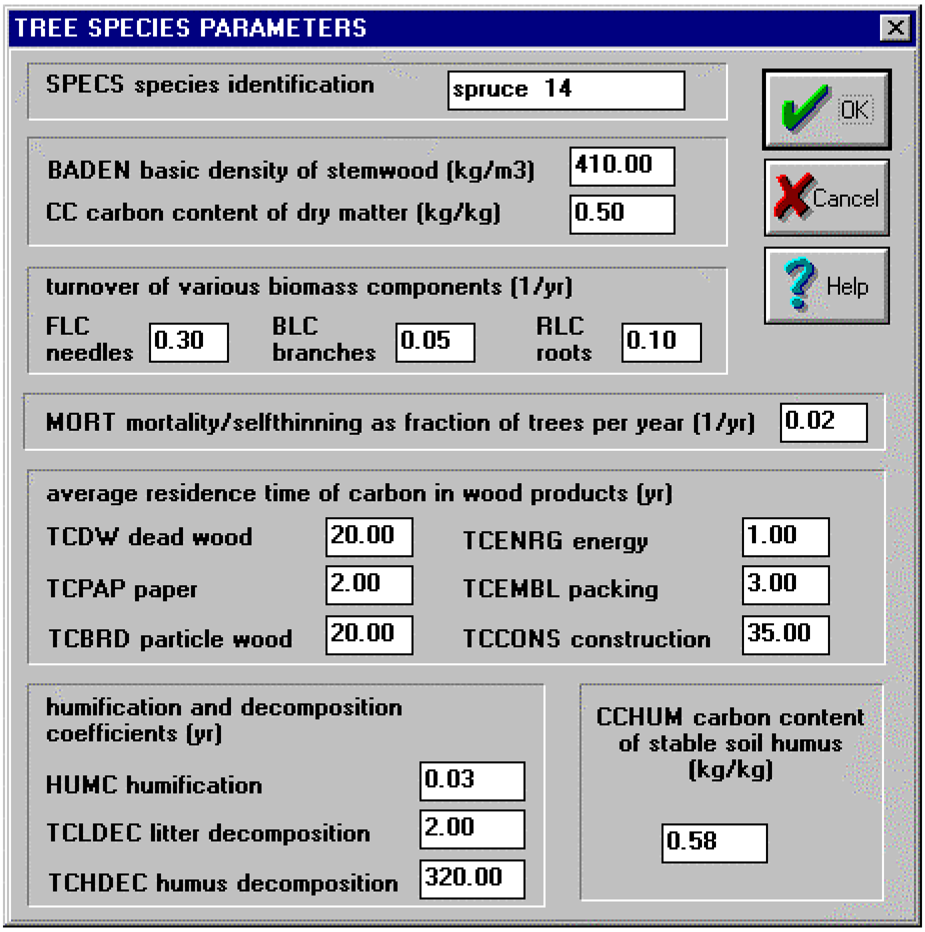
Thinning and harvest: Open the dialogue box for the thinning table. (See list of acronyms.)



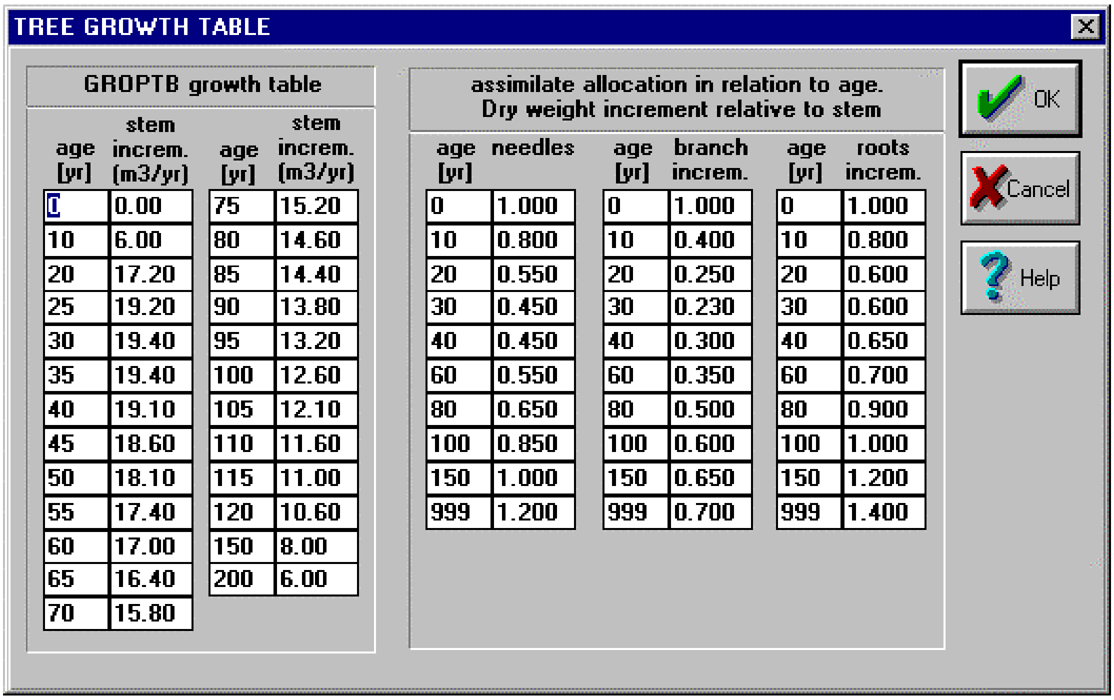
THAGES thinning ages	FVOLTH fraction stem removed	ALLOCATION OF STEMWOOD TO PRODUCTS					
		DWOOD	ENERGY	PAPER	EMBAL	BOARD	CONSWD
25	0.070	1.000	0.000	0.000	0.000	0.000	0.000
30	0.090	0.200	0.000	0.800	0.000	0.000	0.000
35	0.090	0.200	0.000	0.800	0.000	0.000	0.000
40	0.090	0.200	0.000	0.800	0.000	0.000	0.000
45	0.080	0.200	0.000	0.800	0.000	0.000	0.000
50	0.080	0.100	0.000	0.900	0.000	0.000	0.000
55	0.070	0.100	0.000	0.900	0.000	0.000	0.000
60	0.070	0.100	0.000	0.000	0.100	0.800	0.000
65	0.070	0.100	0.000	0.000	0.100	0.800	0.000
70	0.070	0.100	0.000	0.000	0.100	0.600	0.200
75	0.070	0.100	0.000	0.000	0.100	0.600	0.200
80	0.070	0.100	0.000	0.000	0.100	0.500	0.300
85	0.070	0.100	0.000	0.000	0.100	0.500	0.300
90	0.070	0.100	0.000	0.000	0.100	0.400	0.400
95	0.070	0.100	0.000	0.000	0.100	0.400	0.400
100	0.080	0.100	0.000	0.000	0.100	0.300	0.500
105	0.080	0.100	0.000	0.000	0.100	0.300	0.500
110	0.080	0.100	0.000	0.000	0.000	0.400	0.500
999	0.000	0.000	0.000	0.000	0.000	0.000	0.000
999	0.000	0.000	0.000	0.000	0.000	0.000	0.000
999	0.000	0.000	0.000	0.000	0.000	0.000	0.000
999	0.000	0.000	0.000	0.000	0.000	0.000	0.000
999	0.000	0.000	0.000	0.000	0.000	0.000	0.000
999	0.000	0.000	0.000	0.000	0.000	0.000	0.000
999	0.000	0.000	0.000	0.000	0.000	0.000	0.000
FINAL HARVEST:		0.100	0.000	0.000	0.000	0.300	0.600

Since this version of the model does not calculate losses during wood processing, the residence times of carbon in products are generally estimated relatively short, or the user should take into account processing losses when allocating harvested wood to product groups.

Tree species : Open this dialogue box for the parameters of the species cultivated. (See list of acronyms.)



Growth: Open the dialogue box for the Tree Growth Table. (See list of acronyms.)



TREE GROWTH TABLE

GROPTB growth table

age [yr]	stem increm. (m3/yr)	age [yr]	stem increm. (m3/yr)
0	0.00	75	15.20
10	6.00	80	14.60
20	17.20	85	14.40
25	19.20	90	13.80
30	19.40	95	13.20
35	19.40	100	12.60
40	19.10	105	12.10
45	18.60	110	11.60
50	18.10	115	11.00
55	17.40	120	10.60
60	17.00	150	8.00
65	16.40	200	6.00
70	15.80		

assimilate allocation in relation to age.
Dry weight increment relative to stem

age [yr]	needles	age [yr]	branch increm.	age [yr]	roots increm.
0	1.000	0	1.000	0	1.000
10	0.800	10	0.400	10	0.800
20	0.550	20	0.250	20	0.600
30	0.450	30	0.230	30	0.600
40	0.450	40	0.300	40	0.650
60	0.550	60	0.350	60	0.700
80	0.650	80	0.500	80	0.900
100	0.850	100	0.600	100	1.000
150	1.000	150	0.650	150	1.200
999	1.200	999	0.700	999	1.400

3.5 Running the model

MAIN MENU 'RUN'

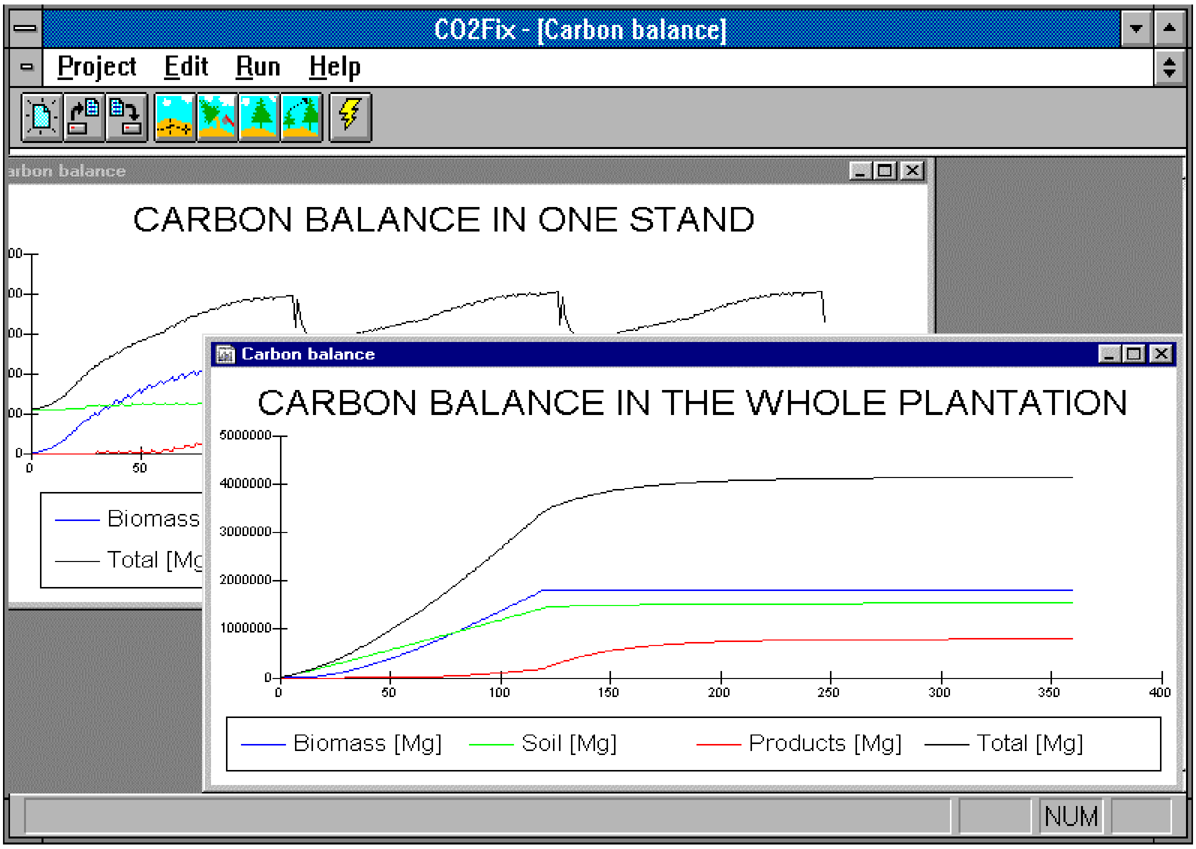
Run: This calculates the result table with the input data. It generates 12 result tables, the EXPORT.TXT file for exporting data to spreadsheets and presents a graph with the carbon fixation balance on screen.

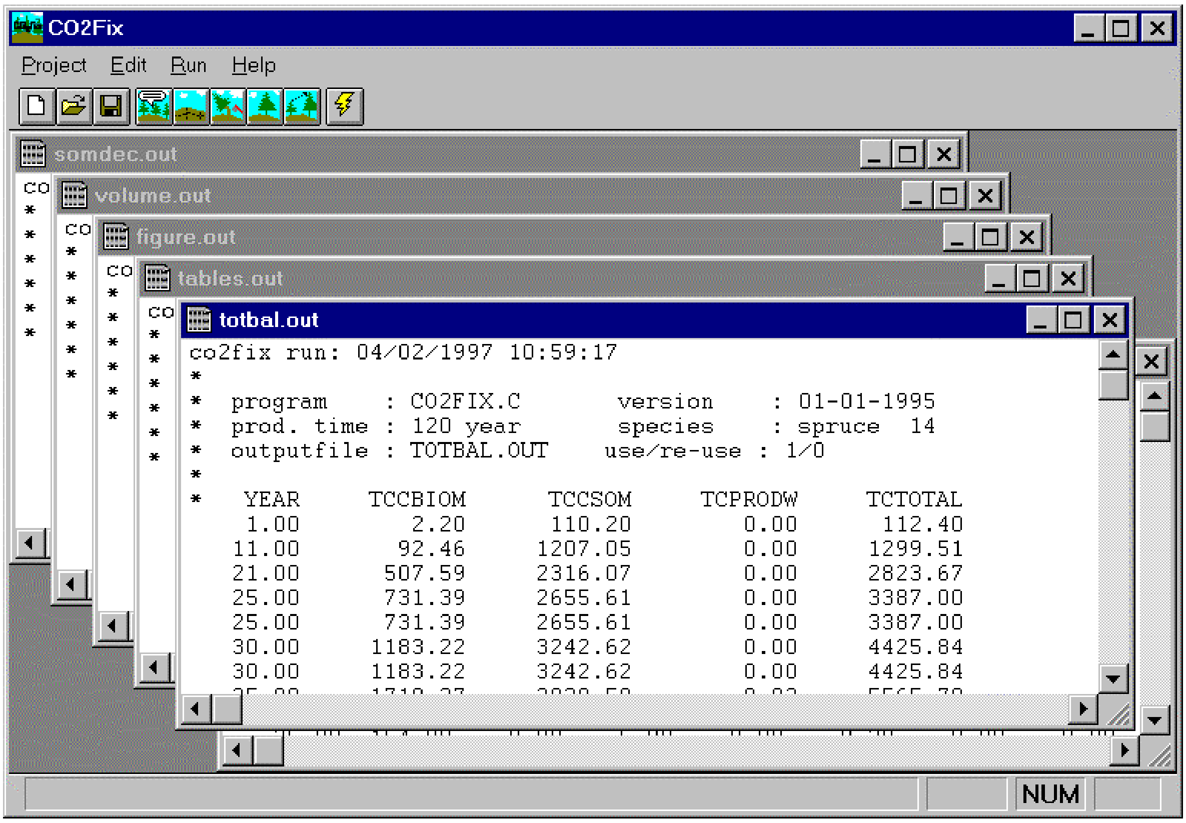
3.6 Output

Directly after running, the model produces two graphs which present a first look at the results. One graph presents the carbon balance of one stand (i.e. one hectare), the other the carbon balance in the whole plantation when an area of more than one hectare has been chosen.

MAIN MENU 'RUN'

View results: This feature allows on screen viewing of the different result tables which are produced as well. A submenu permits you to choose which table you wish to see. You may select the 'All Tables' option to view all the result tables at once (as is shown below).





3.7 Help functions

MAIN MENU 'HELP'

Contents: This presents a help window with general information about the program and a table of contents for this manual.
Search: The search option allows you to locate and open any help file.

Acronyms: This option provides a list of the acronyms used in the CO2Fix model, identical to the list provided in this manual.

About: This option contains two dialogue boxes. The first one briefly describes the program and the second gives credit to the authors.

Tool bar
The tool bar provides quick access to the Project-New, Project-Open, Project-Save, Edit-Stands, Edit-Comments, Edit-Thinning, Edit-Tree, Edit-Growth and Run menu options. Each of them possesses a bits map with an icon representing the option. As you pass the mouse cursor over each tile, a description of the option will appear.

REFERENCES

Brown, S., J. Sathaye, M.G.R. Cannell, & P. Kauppi et al. 1996. Management of forests for mitigation of greenhouse gas emissions. In: Climate Change 1995, Impacts Adapatations and Mitigations of Climate Change: Scientific Technical Analyses. IPCC 1995 Assessment. Chapter 24. Working group II. p. 773-797.

Jong, B.H.J. de., S. Ochoa-Gaona, L. Soto-Pinto, M.A. Castillo-Santiago, G. Montoya-Gómez, R. Tipper & I. March-Mifsut. 1998. Modelling Forestry and Agroforestry Opportunities for Carbon Mitigation at Landscape Level. In: G.J. Nabuurs et al, Forest Scenario Modelling for Ecosystem Management at Landscape level. EFI. Procedings 19, p. 221-237.

Kangas, A.S. 1997 On the prediction of bias and variance in long-term growth projections. Forest Ecology and Management 96: 207-216.

Mohren, G.M.J. & C.G.M. Klein Goldewijk 1990a. CO_2 storage in forests. Report 613, Research Institute for Forestry and Urban Ecology, Wageningen, The Netherlands.

Mohren, G.M.J. & C.G.M. Klein Goldewijk 1990b. CO2FIX: a dynamic model of the CO2 fixation in forest stands. Rapport 624, ‘De Dorschkamp’, Research Institute for Forestry and Urban Ecology, Wageningen, The Netherlands. 96 p.

Nabuurs, G.J. & G.M.J. Mohren 1993. Carbon fixation through forestation activities; a study of the carbon sequestering potential of selected forest types. Commisioned by the foundation FACE. IBN Research Report 93/4. Institute for Forestry and Nature Research, Wageningen, The Netherlands. 205 p.

Ordóñez, A. 1998. Estimación de la Captura de Carbono en un Estudios de Caso para Bosque Templado: San Juan Nuevo, Michoacán. Tesis de Licenciatura, Facultad de Ciencias, UNAM, Ciudad de México.

Ordóñez, A. 1999. Estimación de la Captura de Carbono en un Estudio de Caso. Instituto Nacional de Ecología, SEMARNAP. México DF.

Tomppo, E. 1996. Multi-source national forest inventory of Finland. In: R. Päivinen, J. Vanclay & S. Miina (eds.), New thrusts in forest inventory. EFI Proceedings No 7. p. 27-41.

UNFCCC 1997. The Kyoto Protocol to the Convention on Climate Change. Climate Change Secretariat, Bonn, Germany. 34 p.

Annex 1. List of Acronyms

ACRONYM	DESCRIPTION	UNIT
-CLIT	Carbon stock of litter '-' sign was added to allow depicting litter pool on negative y –axis.	Mg C ha^{-1}
+ -HUM	Carbon stock of litter '-' sign was added to allow depicting litter pool on negative y –axis '+' sign indicates that the value of this column in output table includes the value in the column(s) to the left	Mg C ha^{-1}
+CCB	Carbon stock of stem wood, roots, and branches	Mg C ha^{-1}
+CCF	Carbon stock of stem wood, roots, branches, and foliage	Mg C ha^{-1}
+CCSW	Carbon stock of stem wood + roots	Mg C ha^{-1}
AGE	Age counter for stand development	Yr
ALLOCATION	Table specifying the allocation of harvested wood over product groups. The total of DWOOD, ENERGY, PAPER, EMBAL, BOARD, and CONSWD should add up to 1.	-
AREA	Area counter	Ha
ASSIMILATE ALLOCATION	Table which specifies additional dry weight increment of tree components (foliage, branches, roots) relative to stem dry weight increment.	-
BADEN	Basic wood density of stem wood (dry matter / fresh volume)	kg m^{-3}
BALANS	Subroutine for bookkeeping and balance calculations	-
BALLBM	Balance counter of the living biomass	-
BALPDW	Balance counter of harvested products	-
BALSOM	Balance counter of soil organic matter	-
BALTOT	Overall balance counter	-
BINC	Branch dry weight increment	Mg ha^{-1} yr^{-1}
BLC	Turnover coefficient for branch biomass	yr^{-1}
BlOMDW	Total dry weight in the living biomass	Mg ha^{-1}
BLOSS	Branch dry weight loss rate	Mg ha^{-1} yr^{-1}
BMPROD	Total dry weight in products (referring to the area of production)	Mg ha^{-1}
BOARD	Dry weight of particle board	Mg ha^{-1}
BOARD	Dry weight of product category particle board	Mg ha^{-1}
BRDDEC	Dry weight decomposition rate of particle board	Mg ha^{-1} yr^{-1}
BRDDEC	Dry weight decomposition rate of particle board	Mg ha^{-1} yr^{-1}
BW	Dry weight of branches	Mg ha^{-1}
CAI	Current annual stem volume increment	m^3 ha^{-1} yr^{-1}
CBMPDA	Long-term average carbon stock of forest biomass and products	Mg C ha^{-1}
CBMSAV	Long-term average carbon stock in the biomass	Mg C ha^{-1}
CC	Carbon content per unit of biomass dry weight	kg kg^{-1}
CCBIOM	Carbon stock of living biomass	Mg C ha^{-1}
CCBMPD	Carbon stock of forest biomass and products	Mg C ha^{-1}
CCFIX	Total carbon stock accumulated in living biomass and harvested products	Mg C ha^{-1}
CCHUM	Carbon content of humus	kg kg^{-1}

CCNET	Total cumulative net sink in entire system	Mg C ha^{-1}
CCR	Carbon stock in roots	Mg C ha^{-1}
CCSOM	Carbon stock in soil organic material (including dead wood and litter)	Mg C ha^{-1}
CCSOMA	Long-term average carbon stock in soil organic material (including dead wood and litter)	Mg C ha^{-1}
CCSW	Carbon stock of the stems (standing)	Mg C ha^{-1}
CCWDAV	Long-term average carbon stock in wood (living, dead, products)	Mg C ha^{-1}
CCWOOD	Carbon stock in wood (living, dead, products)	Mg C ha^{-1}
CFIX	Carbon sink through dry weight production	Mg C ha^{-1} yr^{-1}
CFIXAV	Long-term average carbon sink rate	Mg C ha^{-1} yr^{-1}
CFIXNA	Long-term average net annual carbon sink in entire system	Mg C ha^{-1} yr^{-1}
CONSWD	Dry weight of construction wood	Mg ha^{-1}
CPRDAV	Long-term average carbon stock in products	Mg C ha^{-1}
CPRODW	Carbon stock in harvested wood products, ha referring to the area of production	Mg C ha^{-1}
CQUOTE	Percentage product-carbon in total amount of carbon	%
CREL	Carbon release through decomposition of dead wood, litter and humus	Mg C ha^{-1} yr^{-1}
CRELPD	Carbon release in product decomposition	Mg C ha^{-1} yr^{-1}
CREM	Carbon removed through wood harvesting	Mg C ha^{-1}
CTOTAL	Total carbon stock in the entire system of forest biomass, soil organic matter and harvested wood products	Mg C ha^{-1}
CTOTAV	Long-term average carbon stock in the entire system	Mg C ha^{-1}
CWDDEC	Dry weight decomposition rate of construction wood	Mg ha^{-1} yr^{-1}
CYCLE	Rotation period	yr
DWDEC	Dead wood dry weight decomposition	Mg ha^{-1} yr^{-1}
DWLIT	Dead wood dry weight resulting from thinning (= DWOOD from allocation table)	Mg ha^{-1}
DWOOD	Dead wood dry weight remaining in the forest	Mg ha^{-1}
DWTHIN	Amount of stem biomass dry weight removed in thinning	Mg ha^{-1}
EMBAL	Dry weight of packing wood	Mg ha^{-1}
EMBDEC	Dry weight decomposition rate of packing wood	Mg ha^{-1} yr^{-1}
ENERGY	Dry weight of energy wood	Mg ha^{-1}
FINC	Foliage dry weight increment	Mg ha^{-1} yr^{-1}
FLC	Turnover coefficient for foliage biomass	yr^{-1}
FLOSS	Foliage dry weight loss rate	Mg ha^{-1} yr^{-1}
FVOLTH	Fraction of stem volume removed by each thinning	-
FW	Dry weight of foliage	Mg ha^{-1}
GROPTB	Table with Current Annual Increment from yield tables	-
HDEC	Dry weight decomposition rate of stable humus	Mg ha^{-1} yr^{-1}
HUMC	Humification coefficient	yr^{-1}
HUMUS	Dry weight of stable humus in mineral soil	Mg ha^{-1}
LDEC	Dry weight decomposition rate of litter	Mg ha^{-1} yr^{-1}
LHUM	Dry weight humification rate of litter	Mg ha^{-1} yr^{-1}

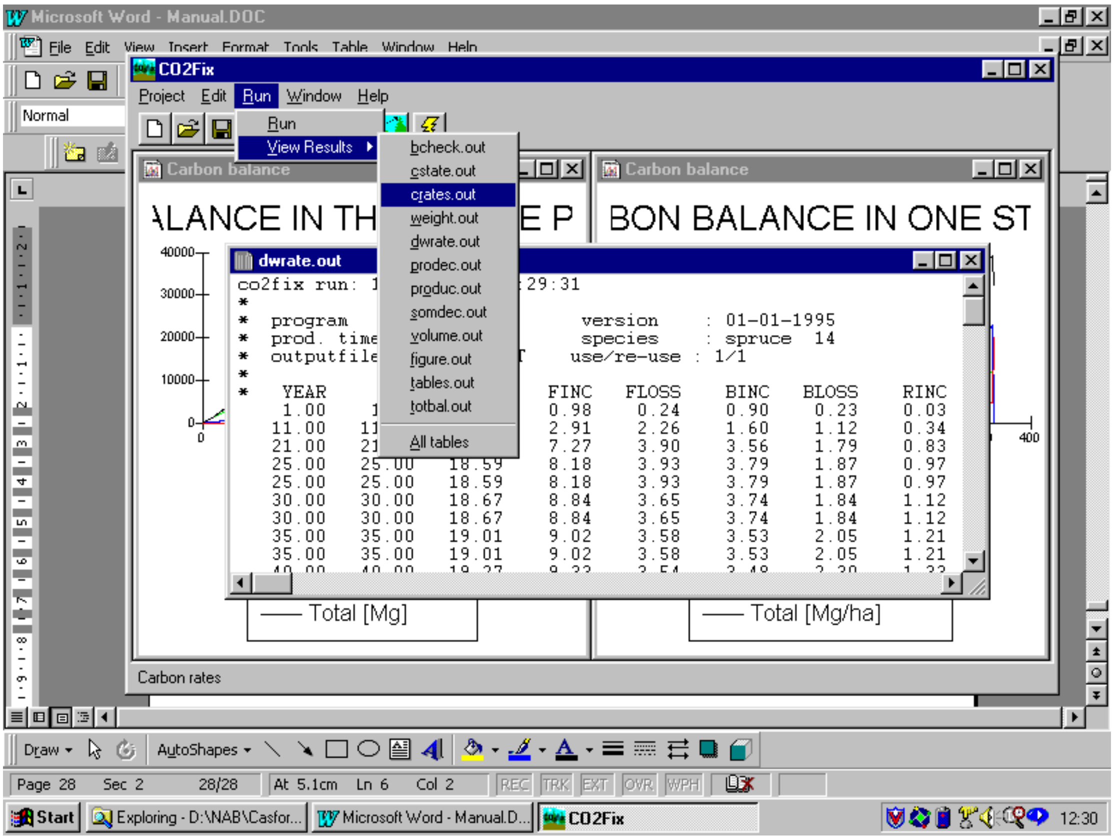
LITTER	Litter dry weight	Mg ha^{-1}
MAI	Mean annual stem volume increment	m^{3} ha^{-1} yr^{-1}
MCYCLE	Parameter indicating whether or not multiple cycles are simulated	-
MORT	Mortality/self-thinning as a fraction of standing volume	yr^{-1}
NCFLUX	Net carbon flux above the forest (positive value = sink)	Mg ha^{-1} yr^{-1}
NCYCLE	Number of rotations to be simulated	-
PAPDEC	Dry weight decomposition rate of paper	Mg ha^{-1} yr^{-1}
PAPER	Dry weight of product category paper	Mg ha^{-1}
PARTHN	Parameter specifying whether in a year of thinning output is desired before and after (=yes) the thinning	-
PLANTATION	Total plantation area = CYCLE * AREA	Ha
PRDDEC	Total product dry weight decomposition rate	Mg ha^{-1} yr^{-1}
PRDEL	Output interval	yr
RESTIM	Mean residence time of fixed carbon	yr
RINC	Root dry weight increment	Mg ha^{-1} yr^{-1}
RLC	Turnover coefficient for root biomass	yr^{-1}
RLOSS	Root dry weight loss rate	Mg ha^{-1} yr^{-1}
RW	Dry weight of roots	Mg ha^{-1}
SCBC	Table with correction factors for effects of site quality on foliage dry weight increment relative to stem increment	-
SCFC	Table with correction factors for effects of site quality on branch dry weight increment relative to stem increment	-
SCRC	Table with correction factors for effects of site quality on root dry weight increment relative to stem increment	-
SINC	Stem dry weight increment	Mg ha^{-1} yr^{-1}
SOM	Total soil organic matter including litter, humus, and dead wood	Mg ha^{-1}
SOMDEC	Total soil organic matter dry weight decomposition rate	Mg ha^{-1} yr^{-1}
SPECS	Identification of tree species and productivity level	-
SVOL	Stem volume	m^{3} ha^{-1}
SW	Dry weight of stems	Mg ha^{-1}
TCBRD	Average residence time of particle board	yr
TCCBIOM	Total carbon content of forest biomass in plantation	Mg C
TCCONS	Average residence time of construction wood	yr
TCCPRODW	Total carbon content of forest products from plantation	Mg C
TCCSOM	Total carbon content of soil organic matter in plantation	Mg C
TCDW	Average residence time of dead wood in the forest	yr
TCEMBL	Average residence time of packing wood	yr
TCENRG	Average residence time of energy wood	yr
TCFLUX	Total system net annual carbon flux, including product decomposition (positive value = sink)	Mg ha^{-1} yr^{-1}
TCHDEC	Average residence time of humus	yr
TCLDEC	Average residence time of litter	yr
TCPAP	Average residence time of paper	yr
TCTOTAL	Total carbon content in plantation	Mg C

TDVOL	Total amount of stem volume removed in successive thinnings	$m^3\ ha^{-1}$
THAGES	Ages at which thinnings are carried out	yr
THLIT	Litter (slash) dry weight resulting from thinning	$Mg\ ha^{-1}$
TLOSS	Total litter and root dry weight turnover loss rate	$Mg\ ha^{-1}\ yr^{-1}$
TVOL	Cumulative total stem volume production, including thinning	$m^3\ ha^{-1}$
USE	Parameter specifying whether (=yes) or not (=no) natural mortality occurs. The value of this parameter is determined by MORT under the main menu ‘tree species parameters’.	-

Annex 2. List of included forest types

SHORT NAME	TREE SPECIES	LOCATION	ROTATION LENGTH (yr)	MAI ($m^3\ ha^{-1}\ yr^{-1}$)
Albdipt	Albizia spp. underplanted with Shorea spp.	East Kalimantan	selective cutting cycle every 70 years.	8
Dougl14	Pseudotsuga mensiezii	Pacific Northwest of the USA	100	14.9
Joybir	Betula pendula	Southern Finland	80	6.1
Joyscp	Pinus sylvestris	Southern Finland	90	6.5
Liane	Dipterocarp tropical rain forest. Shorea spp Logged over for 80% at T=0 but with vigorous growth of lianes	East Kalimantan	selective cutting cycle every 70 years.	
Logg3	Modeling starts with a logged over situation. Dipterocarp tropical rain forest	East Kalimantan	selective cutting cycle every 70 years.	12
Loggsegr	Semi-evergreen tropical forest heavily logged at T=20.	East Kalimantan	selective cutting cycle every 70 years.	11
Pcar21	Pinus caribea	Venezuela and Brazil	25	20
Pell28	Pinus elliottii	Brazil	30	27.9
Pmenz-nl	Pseudotsuga mensiezii	The Netherlands	100	8.9
Popagr1520	Populus x euramericana	The Netherlands	45	11
Popagr11	Populus x euramericana	The Netherlands	20	15.7
Prad23	Pinus radiata	New Zealand	40	22.4
Ptae10	Pinus taeda	South east USA	30	10
Robagr9	Robinia pseudoacacia	The Netherlands	40	9
Selcutrf2	Dipterocarp tropical rain forest logged over for 50% with enrichment line planting	East Kalimantan	selective cutting cycle every 70 years.	16
Selcutsegr	Semi-evergreen tropical forest selectively logged with enrichment planting	East Kalimantan	selective cutting cycle every 70 years.	9
Spruce14	Picea abies	Central Europe	100	14

Annex 3. List of output tables



BCHECK	Simulation balance checker
CSTATE	Carbon stocks in various compartments
CRATES	Carbon fluxes in various compartments
WEIGHT	Dry matter weight in various compartments
DWRATE	Increment and decline of dry matter weight in various compartments
PRODEC	Dry weight wood products decomposition rates
PRODUC	Wood product carbon stocks
SOMDEC	Soil organic matter dry weight decomposition rates
VOLUME	Stem volume and increment
FIGURES	Compilation of various parameters
TABLE	Compilation of various parameters
TOTBAL	Simulation balance