WPM and SEA: description

1. Wood Product Model (WPM)

The wood product model is based on the model concept introduced by Karjalainen et al. (1994) and further developed by Eggers (2002). The WPM simulates carbon pools and fluxes in the wood product sector. The parameters are based on aggregated values of the German timber market report 2002 and 2003 (BMV 2003, BMV 2004) and parameters according to Eggers (2002). The WPM consists of three main processes, the grading of the harvested timber, the processing of the timber and allocation of timber to wood products, and the retention period of timber in the final product and later on landfills. Information about the usage of the WPM in 4C are given in 4C_WPM_SEA_manual.pdf.

1.1 The main processes of the WPM

1.1.1 Grading of harvested timber

The first step of the WPM is the grading of the harvested timber. The harvested timber is graded according to the German timber classification system (HKS). Table 1-1 lists the timber grades used in the WPM. Wood defects due to growth anomalies and defects through harvesting are not simulated in 4C. A down grading due to this wood defects is parameterised in the WPM. Actually 40% of the volume of logs or partial logs is classified as industrial wood.

Table 1-1: Timber grades of German timber classification system used in the WPM.

Abbreviation WPM	Timber grades - Englisch	Timber grades - German	Timber grades - German abbreviations	Abbreviations used in 4C (mansort)	
				type	spec
TG1	Coniferous logs	Stammholz Nadelholz	L	ste1,ste2	2, 3
TG2	Non coniferous logs	Stammholz Laubholz	L	ste1,ste2	1, 4
TG3	Coniferous partial logs	Stammholzabschnitte Nadelholz	LAS	sg1,sg2	2, 3
TG4	Non coniferous partial logs	Stammholzabschnitte Laubholz	LAS	sg1,sg2	1, 4
TG5	Industrial wood	Industrieholz	IS/IL	in1, in2	1-4
TG6	Fuelwood	Brennholz	X	fue	1-4

The amount of carbon in different timber grades is calculated for each year with timber harvest (thinning or harvest). Trees which die between two management operations are removed with the next thinning or harvest and are added to the amount of harvested timber.

1.1.2 Timber processing

In the next step the timber (carbon) is distributed into *industrial lines* which display the different wood industry branches (sawmills, plywood and veneer industry, particle board manufactures and pulp and paper mills). The distribution of the harvested timber (carbon) into the industrial lines (IL) is based on figures of the German timber market report (BMV 2003, BMV 2004). In the report list the main consumer of timber and the amount of purchased coniferous timber, deciduous timber and industrial wood. The following industrial lines are differentiated:

- IL1: coniferous sawn timber,
- IL2: deciduous sawn timber,
- IL3: plywood and veneer,
- IL4: particle board,
- IL5: chemical pulp,
- IL6: mechanical pulp,
- IL7: fuel wood.

The distribution of timber (carbon) into these industrial lines is described in Table 3-1.

The timber (carbon) of the industrial lines is further distributed into *product lines*. This distribution reflects the processing of the timber into the main product and by-products. The distribution is based on parameters according to Eggers (2002) (Table 3-2, Table 3-3, Table 3-4).

1.1.3 Timber products

In the third step the timber (carbon) is distributed into *use categories*. The following use categories (U) are distinguished according to Eggers (2002):

- U1 building material,
- U2 other buildings,
- U3 structural support,
- U4 furnishing,
- U5 packing material,
- U6 long life paper,
- U7 short life paper.

The distribution of wood (carbon) from the product lines into the use categories is described in

Table 3-5

The retention period of the timber (carbon) in the different use categories is defined by a life span function, an extended logistic decay function by Row and Phelps 1990:

$$f(pu) = d - \frac{a}{1 + b \cdot e^{-c \cdot t}} \qquad (1)$$

where

pu	-	the fraction of products (carbon) in use,
a, b, d	-	parameters,
c	-	the reciprocal of the half-life period ($year^{-1}$), and
t	-	time (year).

The lifespan (half-life period) of the use categories is listed in Table 3-6. The timber (carbon) which is removed from the use categories will to a certain shares be recycled, put on landfills or be burned (Table 3-6). The redistribution of the recycled timber (carbon) to the use categories is listed in Table 3-7.

1.2 Output of the WPM

WPM creates two output files with the following content:

(1) general file

- total harvested timber [t C ha^{-1}] – annually
- use categories [t C ha^{-1}] – annually
- landfill [t C ha^{-1}] - annually
- burning [t C ha^{-1}] - annually
- atmosphere [t C ha^{-1}] – annually
- atmosphere [t C ha^{-1}] – cumulative

(2) files with detailed information

- timber grades [t C ha^{-1}] – annually
- industrial lines [t C ha^{-1}] - annually
- product lines [t C ha^{-1}] - annually
- use categories [t C ha^{-1}] – annually

1.3 WPM for Brandenburg

In the case of Brandenburg it is assumed that the share of timber which goes to pulp mills is purchased by the closest mills. These mills use chemical method to process the wood. Therefore no wood goes to the industrial – and product line 6 (mechanical pulpwood). These parameters should be adapted if the model is used in other regions. Figure 1 shows the flow chart of the WPM for Brandenburg.

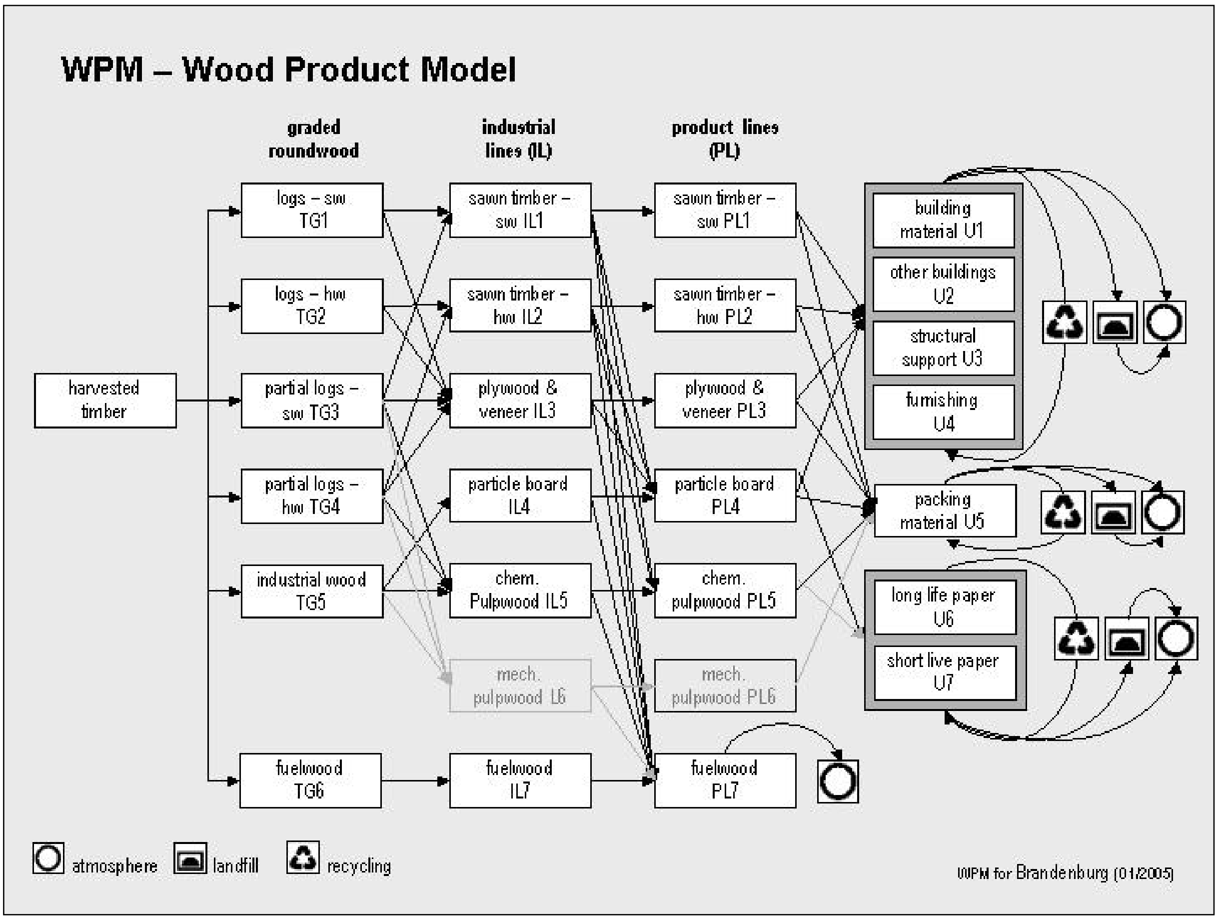

Figure 1: Flow chart of the WPM for Brandenburg

1.4 Spin up for WPM

The spin up calculates the initial amount of carbon in use categories based on average timber production of the study area. The average timber production of the study area has to be simulated by 4C. A mansort- and a manrec-file have to be created for the spin up (for an example see Table 3-8 and Table 3-9) which characterizes the timber production of the area. The time span of the spin up can be chosen.

2. Socio economic analysis (SEA)

SEA calculates costs, revenues and subsidies of forest management and furthermore the net present value (NPV) of forest management and the liquidation value of the standing stock.

2.1 Timber grades

In the first step of SEA the harvest timber and standing stock is graded according to the German timber classification system (HKS). Timber grading after the German timber classification (HKS) is based on the diameter at the middle of the log and a minimum top diameter of a log. The middle diameter is rounded down to centimetres. Table 2-1 lists the timber grades used in the SEA. Wood defects due to growth anomalies and defects through harvesting are not simulated in 4C. A down grading due to this wood defects is parameterised in SEA. Actually 40% of the volume of logs or partial logs is classified as industrial wood.

Table 2-1: Timber grades in SEA.

Assortment group	Dimension class	Timber grade – German abbreviations	Middle diameter [cm]	Top diameter [cm]	Kind of timber
fuelwood		X		< 7 cm wo.b.	Coniferous and deciduous
Industrial wood		IN		7 cm wo.b.	Coniferous and deciduous
Partial log	1a	L1a	11-14 cm o.b.	11 cm o.b.	pine
Partial log	1b	L1b	15 – 19 cm o.b.	11cm o.b.	Coniferous
Partial log	2a	L2a	20 – 24 cm o.b.	14 cm o.b.	Coniferous and deciduous
Partial log	2b	L2b	25 – 29 cm o.b.	14 cm o.b.	Coniferous and deciduous
Partial log	3a +	L3a	>= 30 cm o.b.	14 cm o.b.	Coniferous and deciduous
Log	2b	L 2b	25 – 29 cm o.b.	14 cm o.b.	Coniferous and deciduous
Log	3a	L 3a	30 – 34 cm o.b.	14 cm o.b.	Coniferous and deciduous
Log	3b +	L 3b	>= 35 cm o.b.	14 cm o.b.	Coniferous and deciduous

2.2 Cost, revenues and subsidies

Forest management costs consist of four components: cost of timber harvest including timber hauling, silvicultural costs including regeneration, fencing, and pre-commercial thinning costs, fix costs (e.g. administrative cost and road maintenance) and cost for the assistance of a forest manager in a private owned forest. Revenues of forest management are the prices for the harvested timber. Subsidies of forest management consist of three components: subsidies for silvicultural operation including regeneration, fencing, and pre-commercial thinning, subsidies for fix costs in a private owned forest and subsidies for the cost for the assistance of a forest manager in a private owned forest (Table 3-13). Costs and revenues of timber harvest and pre-commercial thinning are derived from statistics on state forestry in Brandenburg (MLUR 2000,Table 3-10, Table 3-11, Table 3-12). Regeneration costs (e.g. price of plants, cost for planting) are based on an actual price list of a tree nursery in the region and the practical experience of local forest service personnel (**Error! Reference source not found.**).

Timber harvesting is cost dependent on the harvesting method (chainsaw or harvester). Calculating the profit from timber harvest the following assumptions were made:

- forest stands with a share of at least XXX% of deciduous trees are harvest with chainsaw,
- the other stands are harvested mainly with harvester (fixed percentage harvester chainsaw - 80:20

2.3 Liquidation Value and NPV

Two different methods, based on the net present value approach, are applied to investigate the economic impact of forest management. The NPV in general, is the difference between the discounted value of the future net cash flow (C) of a certain time span (t) expected from forest management and the initial investment. In the first case, the initial investment value is assumed to be zero because no investments had to be done since the forest stands are already owned. Therefore, the term of initial investment are neglected (Eq. 2). Parameter p is the discounting rate.

$$NPV = \sum_{t=1}^{T} \frac{C_t}{(1+p)^t} \qquad (2)$$

The second economic measure, NPV+, integrated the value of the standing stock. It was assumed that the investment value is the liquidation value of the standing stock at the beginning of the simulation. Additionally, the discounted liquidation value of the standing stock at the end of the simulation time (L_{100}) was added to the NPV (Eq.2).

$$NPV+ = \sum_{t=1}^{T} \frac{C_t}{(1+p)^t} - L_1 + \frac{L_T}{(1+p)^T} \qquad (3)$$

Both approaches are calculated with three different interest rates (p = 0.02, 0.04, 0.06).

2.4 Output

- timber grades of the harvested timber and standing stock
- cost, revenues of thinning and harvest per tree species (2 x 4), silvicultural costs, fix cost and subsidies
- liquidation value, NPV, NPV+

3. Appendix

3.1 Parameters for the WPM

Table 3-1: Distribution of timber into industrial lines (IL) - Germany.

	IL1	IL2	IL3	IL4	IL5	IL6	IL7
Coniferous logs	0.97	0	0.03	0	0	0	0
Non coniferous logs	0	0.83	0.17	0	0	0	0
Coniferous partial logs	0.86	0	0.01	0	0.13	0	0
Non coniferous partial logs	0	0.53	0.10	0	0.37	0	0
Industrial wood	0	0	0	0.66	0.34	0	0
Fuelwood	0	0	0	0	0	0	1.0

Table 3-2: Distribution of timber in industrial lines (IL) to product lines (PL) (Eggers 2002, Table 8.6, p. 78) – Central Europe.

	PL1	PL2	PL3	PL4	PL5	PL6	PL7
IL1	0.610	0.000	0	0.152	0.141	0	0.097
IL2	0	0.670	0	0.129	0.119	0	0.082
IL3	0	0	0.530	0.095	0	0	0.375
IL4	0	0	0	0.690	0.080	0	0.230
IL5	0	0	0	0	0.472	0	0.528
IL6	0	0	0	0	0	0.928	0.072
IL7	0	0	0	0	0	0	1.000

Table 3-3: Distribution of timber in industrial lines (IL) to product lines (PL) (Eggers 2002, Table 3.11, p. 30) – Northern Europe.

	PL1	PL2	PL3	PL4	PL5	PL6	PL7
IL1	0.435	0.000	0	0.270	0.435	0	0.130
IL2	0	0.435	0	0.270	0.435	0	0.130
IL3	0	0	0.384	0	0.339	0	0.277
IL4	0	0	0	0.690	0.080	0	0.230
IL5	0	0	0	0	0.472	0	0.528

IL6	0	0	0	0	0	0.928	0.072
IL7	0	0	0	0	0	0	1.000

Table 3-4: Distribution of timber in industrial lines (IL) to product lines (PL) (Eggers 2002, Table 8.7, p. 78) – Southern Europe.

	PL1	PL2	PL3	PL4	PL5	PL6	PL7
IL1	0.430	0.000	0	0.270	0.130	0	0.170
IL2	0	0.430	0	0.270	0.130	0	0.170
IL3	0	0	0.530	0.095	0	0	0.375
IL4	0	0	0	0.690	0.080	0	0.230
IL5	0	0	0	0	0.472	0	0.528
IL6	0	0	0	0	0	0.928	0.072
IL7	0	0	0	0	0	0	1.000

Table 3-5: Distribution of timber from product lines (PL) into use categories (U) (Eggers 2002, p. 31).

	U1	U2	U3	U4	U5	U6	U7
PL1	0.35	0.30	0.10	0.15	0.10	0	0
PL2	0.35	0.30	0.10	0.15	0.10	0	0
PL3	0.05	0.05	0.30	0.30	0.30	0	0
PL4	0.20	0.30	0.10	0.20	0.20	0	0
PL5	0	0	0	0	0.33	0.33	0.34
PL6	0	0	0	0	0.34	0.33	0.33

Table 3-6: Distribution of wood removed from use categories into end use categories: recycling, burning, landfill (Eggers 2002) - Germany

		life span	Recycling	landfill	burning
U1	building material	long use timber (50 y.)	0.30	0.35	0.35
U2	other buildings	medium use timber (16 y.)	0.25	0.50	0.25
U3	structural support	short use timber (1 y.)	0.15	0.45	0.40
U4	furnishing	medium use timber (16 y.)	0.25	0.50	0.25
U5	packing material	short use paper (1 y.)	0.72	0.14	0.14
U6	long life paper	medium use paper (4 y.)	0.72	0.14	0.14
U7	short life paper	short use paper (1 y.)	0.72	0.14	0.14

Table 3-7: Distribution of recycled timber to use categories (Eggers 2002, Table 3.9, p. 25) – all countries.

		U1	U2 (= U4)	U3	U4 (=U2)	U5 (=U7)	U6	U7 (=U5)
U1	Long use timber	0.33	0.34	0.33	0	0	0	0
U2	Medium use timber	0	0.50	0.50	0	0	0	0
U3	Short use timber	0	0	1.00	0	0	0	0
U4	Medium use timber	0		0.50	0.50	0	0	0
U5	Short use paper	0	0	0	0	1.00	0	0
U6	long use paper	0	0	0	0	0.50	0	0.50
U7	Short use paper	0	0	0	0	0	0	1.00

3.2 WPM Spin up

Table 3-8: Example of a manrec file for the spin up.

# Management record		
# Year	management	measure
1	thinning	1
2	thinning	1
3	thinning	1
4	thinning	1
5	thinning	1

Table 3-9: Example of a mansort file for the spin up.

\# Management assortment

				cm	cm	cm	cm	cm	m³/ha	kg C/ha	
# year	count	spec	type	len	diam	diam wob	top_d	t_d wob	Volume	DW	number
1	1	3	in1	0.000	0.000	0.000	0.000	0.000	0.0000	7.153	1
1	2	3	sg1	0.000	0.000	0.000	0.000	0.000	0.0000	654.050	1
1	1	4	in1	0.000	0.000	0.000	0.000	0.000	0.0000	71.235	1
1	2	4	sg1	0.000	0.000	0.000	0.000	0.000	0.0000	227.563	1
2	1	3	in1	0.000	0.000	0.000	0.000	0.000	0.0000	7.153	1
2	2	3	sg1	0.000	0.000	0.000	0.000	0.000	0.0000	654.050	1
2	1	4	in1	0.000	0.000	0.000	0.000	0.000	0.0000	71.235	1
2	2	4	sg1	0.000	0.000	0.000	0.000	0.000	0.0000	227.563	1

3.3 SEA

Table 3-10. Recalculated average CPI-corrected net prices (€/m³) for dimensional classes within assortment groups for Germany (Federal State of Brandenburg).

Assortment		[CPI-corrected price in €/m³ o.b.]			
Assortment group	Dimension class	*Pinus sylvestris*	*Picea abies*	*Quercus spp.*	*Fagus sylvatica*
fuelwood		18.7	20.1	17.5	22.6
Industrial wood		18.7	20.1	17.5	22.6
LAS	1a(2)				
LAS	1b(1)	34.9	36.5	----	----
LAS	2a	39.6	41.4	37.2	35.3
LAS	2b	41.1	42.9	37.2	35.3
LAS	3a	50.1	52.4	49.5	48.3
L	2b	49.8	52.1	42.5	43.5
L	3a	58.6	55.7	65.5	62.1
L	3b	64.9	70.2	76.4	137.7

(1) special assortment only used for pine in the Federal State of Brandenburg

(2) according to the German timber grading classification the assortment LAS1b does not exist for oak and beech

Table 3-11. Timber harvesting costs per assortment for Germany (Federal State of Brandenburg) in the year 2000 (harvesting costs in €/m³).

Assortment		chainsaw(1) (incl. skidding)				harvester(2) (incl. skidding)			
Assortment group	Dimension class	*Pinus sylvestris*	*Picea abies*	*Quercus spp.*	*Fagus sylvatica*	*Pinus sylvestris*	*Picea abies*	*Quercus spp.*	*Fagus sylvatica*
fuelwood		46.5	48.7	40.2	40.2	17.4	17.4	----	----
Industrial wood		46.5	48.7	40.2	40.2	17.4	17.4	----	----
LAS	1a(2)	---	---	----	----			----	----
LAS	1b(1)	16.9	23.5	----	----	16.9	16.9	----	----
LAS	2a	14.1	19.3	21.5	17.2	16.3	16.3	----	----
LAS	2b	12.0	17.2	18.1	15.3	16.3	16.3	----	----
LAS	3a	10.2	13.1	14.9	11.5	15.3	15.3	----	----
L	2b	12.0	17.2	18.1	15.3	16.3	16.3	----	----
L	3a	10.2	13.1	14.9	11.5	15.3	15.3	----	----
L	3b	9.2	11.9	14.1	11.0	15.3	15.3	----	----

(1) timber harvesting costs with chainsaw after eastgerman tarif with all workers costs
(2) timber harvesting costs with harvester (mean costs over all assortments)

Table 3-12. Silvicultural operations costs.

Silvicultural operation	*Pinus sylvestris*	*Picea abies*	*Quercus spp.*	*Fagus sylvatica*
brushing	310	310	310	310
tending	310	310	310	310
Planting [1000pieces ha^{-1}]	391	518	772	664

Table 3-13. Overview on costs, revenues and subsidies calculation (RP – rotation period)

	Cost (C), revenues (R), subsidy (S)			Time steps	Depending on species Input / output	Management	Unit	Comments
	C	R	S					
Averaged fixed costs	x			Every year	No / no		ha	
Averaged fixed costs			x	Every year	No / no		ha	
Planting (plants and loan)	x			Once in RP	Yes / no	Harvest	Stk./ha	
Planting subsidy			x	Once in RP	Yes / no	Harvest	ha	
Planting – only shelterwood			x	Once in RP	Yes / no	Harvest	ha	
Fence	x			Once in RP (with planting)	Yes / no	Harvest	ha	Only one price
Fence			x	Once in RP	Yes / no	Harvest	ha	Only one price
Brushing	x			Once in RP	Yes / no	Brushing	ha	
Brushing			x	Once in RP	No / no	Brushing	ha	
Tending	x			Once in RP	Yes / no	Tending	ha	
Tending			x	Once in RP	No / no	Tending	ha	
Thinning and harvesting with chainsaw	x			Several times in RP	Yes / yes		fm	
Thinning and harvesting with harvester	x			Several times in RP	Yes / yes	Thinning / harvest	fm	
Thinning and harvesting		x		Several times in RP	Yes / yes	Thinning / harvest	fm	
Thinning and harvesting (forester)	x			Several times in RP	Yes / no	Thinning / harvest	ha	
Thinning and harvesting (forester)			x	Several times in RP	Yes / no	Thinning / harvest	ha	
Timber selling (forester)	x			Several times in RP	No / no	Thinning / harvest	fm	
Timber selling (forester)			x	Several times in RP	No / no	Thinning / harvest	fm	

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