Preventing the load from forestry

1. The general overview of the problems and background information.

Estonia is rich of forested areas, with 2142, 260 ha, or 47% of the total territory of Estonian Republic. There are 594,200 ha forested areas in Peipsi Sub-Basin and 161,954 ha forested areas in Viru Sub-Basin.

Coniferous forests take of 40% in L. Peipsi Sub-Basin and of 42 % in Viru Sub-Basin;
Deciduous forests take of 20% in " " " ", and of 20% in " " ;
Mixed forests take of 40% in " " and of 38% in " "

The dominating species are Scotch pine (43-44% Norwegian spruce (22-21) and birch (22-33%) in L.Peipsi and Viru Sub-Basin respectively. In the forests of private owners there is less Scotch pine stands and more birch and grey alder stands.

25% of the forested areas in L.Peipsi Sub-Basin and 19% forested areas in Viru Sub-basin are peatland forests. 1468 km^2 in L.Peipsi Sub-Basin and 389 km^2 in Viru Sub-Basin are drained. The construction of the new forest drainage systems is postponed, but during last 5-years period a total of 30 000 hectares has been maintenance drained.
10 000 hectares on average will be maintenance drained every year in Estonia in future.

A part of the nutrient- and suspended solids load into the watercourses is caused by forestry actions; ditching, logging, soil cultivation and fertilisation. Nowadays the fertilisation of forest soils is not practised anymore.

Fire in forest increases the leaching of nutrients, and may cause a significant additional load to watercourses and lakes in the catchment area of the rivers-inlets into the Lake Peipsi. Draining and soil cultivation increase the runoff as well as the washout of suspended solids, nutrients and iron; clear cutting increases the washout of nutrients and iron; fertilisation increases the washout of phosphorus in peatlands, and the washout of nitrogen from mineral types of soil. Fortunately the load in watercourses caused by forestry is short-term in comparison to the circulation time of the growing stock. Furthermore, forestry management areas are usually small and scattered. Fertilisation of forest soil in Estonia is used in nursery gardens and plantations only, their territory in Lake Peipsi and Viru Sub-basins is small (3- 12 km^2 as average of the last 10-years period) One of the biggest nursery gardens in Lake Peipsi region is located in Räpina, very close to the Lake Lämmijärv, where the impact to the lake is possible.

The load in the watercourse caused by forestry can be minimised by modern water protection actions. Water protection methods used in maintenance drainage are, for example, sedimentation ponds, sedimentation pits, digging breaks and overland-flow fields. In logging and soil cultivation, the most important water protection method is to leave buffer zones along watercourses. There are usually natural buffer zones on the bank of rivers and rivulets, and planning of those is easy, and do not need much additional money.

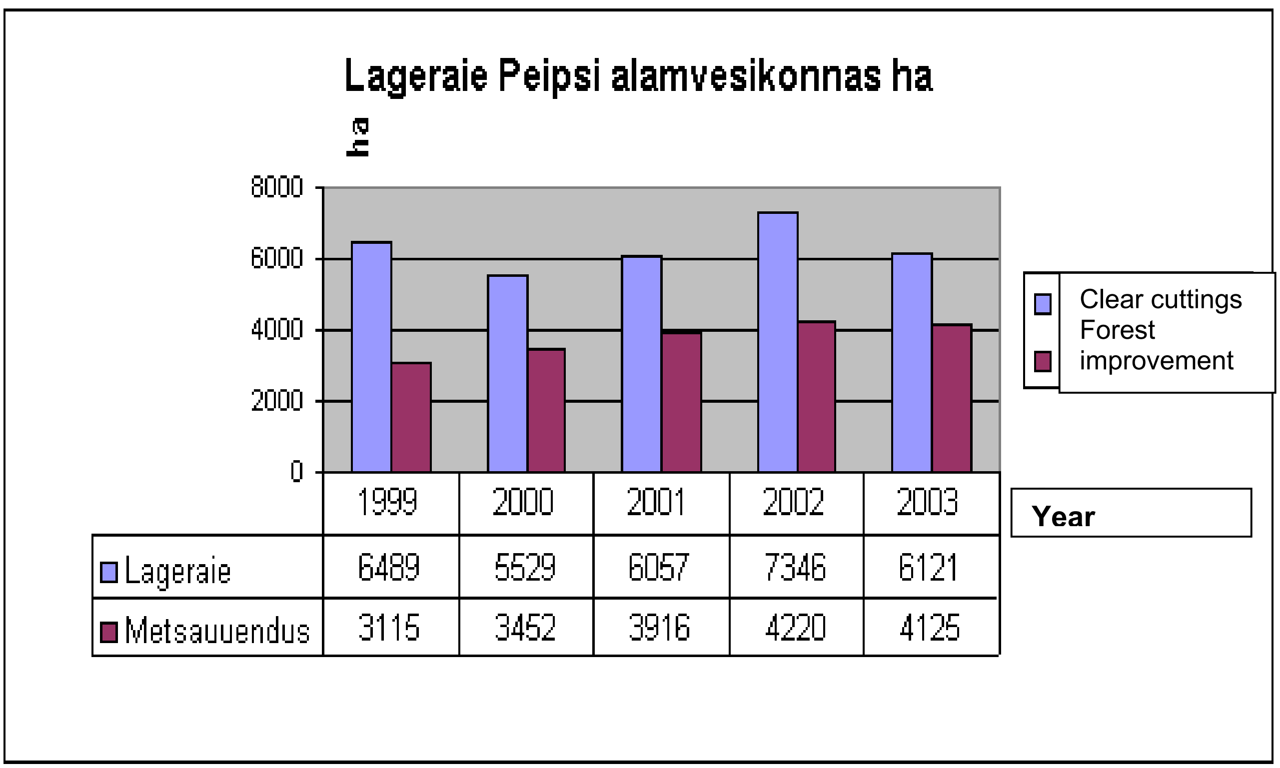
The more detailed description of those water protection measures is given in next chapters.

2. Collected data
2.1. Data collection methods.

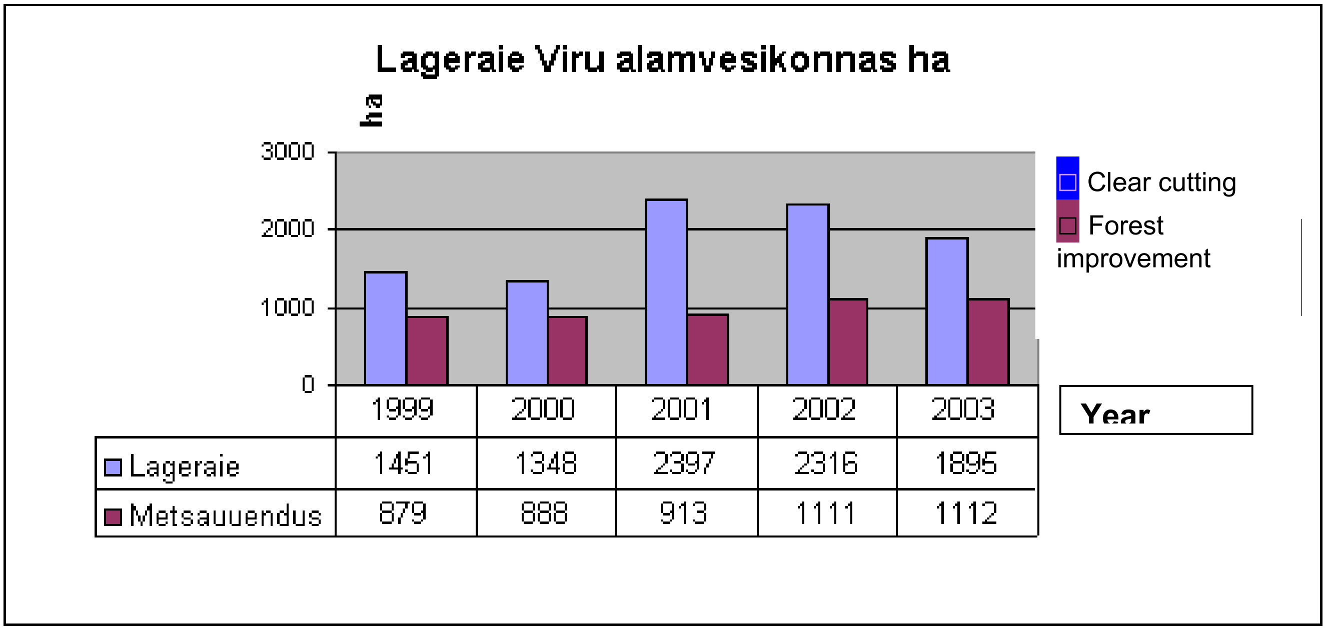
One of the most important sources of data was **The Governmental Centre of Forest Management** in Estonia (RMK), which is dealing with forest areas under the governmental ownership, and managed by forest districts. The total number of forest districts in Estonia is 66 in five regions of Estonia. The Governmental Centre of Forest Management is managing approximately 40% of the forests in Estonia.

The Gis–map of different stands and stands on different soils has been created using Corine Land Cover maps. The numerical data have been compared and corrected with data from the governmental Centre of Forest Management in Estonia. The very same method has been used to identify the clear cutting areas. The GIS-map of the burnt woodland areas has been created for year 2002 whilst that year was the fire-richest during the last 5 years period.

Clear cutting areas, L.Peipsi sub-basin



Clear cutting areas (ha) in Viru Sub-basin



2.2. Burnt woodlands

The most excessive fire damages in forests have been regisered in very dry 2002 year. The surface of the burnt woodlands was as big as 808 hectares in L.Peipsi Sub-basin and 109 hectares in Viru Sub-basin. The biggest fire on 504 hectares was in Alatskivi forest district, Tartu County , which is located in the lake-shore area of Lake Peipsi, and had direct negative effect to the lake.

3. The impact of the clear cutting to the water quality.

According to the results of investigations, made in Finland, the increase of nutrient loading after clear cutting is as follows:

INGREDIENTS	INCREASE
Sediments	4x
Total phosphorus, P_{TOT}	2x
PO_4-P	>2x
Total nitrogen, N_{TOT}	1,3x
NO_3-N	4x
NH_4-N	5x
Fe	1,7x
Mn	1,4x

3.1. Reducing the nitrogen load.

Nitrogen has been the growth-regulating nutrient in forest ecosystems on mineral soils in Estonia. Forests and woodlands cover approximately 50 % of the Viru-Peipsi Basin District. A remarkable big part of woodland areas are bog and marshes on peat soils.

East Estonian mires are the oldest and began to develop immediately after the Ice Age when the melted ice had left thousands of water bodies. Their terrestrialization has lasted for millenia and it continues also today. At the bottom of lakes mud, marl and other sediments have been covered with poorly humified plant remains forming peat deposit – the average thickness of peat deposits reaches 3 meters in Estonia. In the big bog complexes in East Estonia: Muraka, Puhatu and Emajõgi- Suursoo the thickness of peat deposit reaches of 7-8 meters.

When at last dense sphagnum moss, stunted pines and dwarf shrubs have covered the whole surface, the mire has reached the nutrient poor (oligotrophic) phase, called in English **bog.** The nutrient content of the upper 0,20 m layer of these bogs is very low:

- 40- 500 kg N/ha;
- 30 –100 kg P_2O_5-P /ha

The nutrient load from those bogs and mires (natural background load) is very small, and not compared with nutrient load from mineral soils. In mineral soils where nitrogen deposition is high, nitrogen will accumulate in forest ecosystems, and with time affect the environment negatively. According to a literature review (A. Lundborg, 1997, *Ambio* Vol. 26 No. 6. Sept. 1997, pp.387-393) in Sweden, the nitrogen load was highest in the southwestern parts of the country with deposition (wet + dry) around 20-25 kg N ha^{-1} yr in closed Norway spruce forest, and was even higher in particularly exposed locations.

High supplies of nitrogen will affect the forest ecosystem through changes to the vegetation, nitrification, acidification, losses of base cations and nutrient imbalance, leading to the risk of forest decline. Other environmental effects are ***nitrogen leaching, acidification of watercourses, eutrophication of lakes and inshore marine areas,*** and the ***formation of tropospheric ozone.***

In our case, the most important impacts are nitrogen leaching and increasing eutrophication of the water bodies. Acidification of water bodies is of low importance whilst lots of Estonian rivers are flowing in calcareous river- beds, which neutralizes the acidification effect.

In stands that are finally felled, branches and needles contain 200–670 kg N ha^{-1} . When forest fuel is utilized, then normally about 70% of this biomass is removed, *i.e.* , about 140-470 kg N ha^{-1}. When thinning, there are about 35-85 kg N ha^{-1}. If 85% of the slash is removed in practical thinning, then three thinnings will give removal of ca. 90-220 kg N ha^{-1}. When removing fuel during all these silvicultural operations, then about 500-700 kg N extra per ha can be harvested per forest generation (80-100 years) in an N-rich forest. This corresponds to a minor part of the entire soil reserve, but perhaps as much as 50% of the nitrogen reserve in the humus.

Nitrogen leaching from different forest areas in Viru Sub-basin

Woodland category	area km² (2000)	% from total area (2000)	area km² (2001)	% from total area (2001)	area km² (2002)	% from total area (2002)	area km² (2003)	% from total area (2003)	area km² (2004)	% from total area (2004)	Leaching coefitsient kg/ha year	Leaching coefitsient antropogenic kg/ha year	Total leaching coef.	Leaching of N (tons) Average of 5 years
Recent clear cutting, mineral soils	8,7	0,3	9,6	0,3	9,3	0,3	7,6	0,2	7,2	0,2	0,9	5,6	6,5	**5,5**
Recent clear cutting, peat soils	2,1	0,1	2,3	0,1	2,2	0,1	1,8	0,1	1,7	0,1	1,7	8,3	10,0	**2,0**
Former clear cutting, mineral soils	8,7	0,3	9,6	0,3	9,3	0,3	7,6	0,2	7,2	0,2	0,9	3,4	4,3	**3,6**
Former clear cutting, peat soils	2,1	0,1	2,3	0,1	2,2	0,1	1,8	0,1	1,7	0,1	1,7	2,1	3,8	**0,8**
Plantations	8,9	0,3	9,1	0,3	11,1	0,3	11,1	0,3	11,2	0,3			1,3	**1,3**
Coniferous stands on peat soils	190,9	5,7	190,4	5,7	190,6	5,7	191,4	5,7	191,6	5,7	1,7	0,0	1,7	**32,5**
Drained forests	340,2	10,1	326,1	9,7	340,2	10,1	340,2	10,1	330,2	9,8	1,7	2,8	4,5	**150,9**
Drained forests, recently restored drainage		0,0	14,1	0,4		0,0		0,0	10,0	0,3	1,7	7,0	8,7	**4,2**
Natural forests on mineral soils	1062,6	31,6	1061,0	31,5	1059,6	31,5	1062,1	31,6	1062,6	31,6	0,9	0,0	0,9	**95,5**
Burned woodlands	0,68	0,02	0,2	0,01	1,1	0,03	0,6	0,02	0,6	0,02	0,9	8	8,9	**0,6**
TOTAL	**1624,8**	**48,3**	**1624,8**	**48,3**	**1625,5**	**48,3**	**1624,2**	**48,3**	**1624,0**	**48,2**				**297**

Nitrogen leaching from different forest areas in Peipsi Sub-basin

Woodland category	area km²	% from total area	area km²	% from total area	area km²	% from total area	area km²	% from total area	area km²	% from total area	Leaching coefitsient kg/ha year	Leaching coefitsient antropogenic kg/ha year	Total leaching coef.	Leaching of N (tons) Average of 5 years
	2000		2001		2002		2003		2004					
Recent clear cutting, mineral soils	33,1	0,27	24,8	0,20	30,1	0,25	25,10	0,21	24,60	0,20	0,9	5,6	6,5	17,9
Recent clear cutting, peat soils	7,1	0,06	5,5	0,04	6,6	0,05	5,51	0,05	5,40	0,04	1,7	8,3	10	6,0
Former clear cutting, mineral soils	33,1	0,27	24,8	0,20	30,1	0,25	25,10	0,21	24,60	0,20	0,9	3,4	4,3	11,8
Former clear cutting, peat soils	7,1	0,06	5,5	0,04	6,6	0,05	5,51	0,05	5,40	0,04	1,7	2,1	3,8	2,3
Plantations	3,5	0,03	3,9	0,03	4,2	0,03	4,13	0,03	4,20	0,03	1,3		1,3	0,5
Coniferous stands on peat soils	804,8	6,59	808,1	6,62	805,8	6,60	808,0	6,62	808,2	6,62	1,7	0	1,7	137,2
Drained forests	1338,7	10,96	1337,8	10,96	1310,9	10,74	1337,2	10,95	1332,1	10,91	1,7	2,8	4,5	599,1
Drained forests, recently restored drainage	4,0	0,03	4,9	0,04	31,8	0,26	5,52	0,05	10,64	0,09	1,7	7	8,7	9,9
Natural forests on mineral soils	3724,9	30,51	3737,6	30,61	3729,1	30,54	3737,0	30,61	3737,7	30,61	0,9	0	0,9	336,0
Burned woodlands	1,2	0,01	0,2	0,002	8,1	0,07	0,55	0,00	0,5	0,00	0,9	8	8,9	1,9
TOTAL	**5957,4**	**48,8**	**5953,1**	**48,8**	**5963,3**	**48,8**	**5953,6**	**48,8**	**5953,3**	**48,8**				**1123**

Phosphorus leaching from different forest areas in Viru Sub-basin

Woodland category	area km²	% from total area	area km²	% from total area	area km²	% from total area	area km²	% from total area	area km²	% from total area	Leaching coefitsient kg/ha year	Leaching coefitsient antropogenic kg/ha year	Total leaching coef.	Leaching of P (tons) Average of 5 years
	2000		2001		2002		2003		2004					
Recent clear cutting, mineral soils	8,7	0,3	9,6	0,3	9,3	0,3	7,6	0,2	7,2	0,2	0.15	0.3	0.5	**0,4**
Recent clear cutting, peat soils	2,1	0,1	2,3	0,1	2,2	0,1	1,8	0,1	1,7	0,1	0.20	0.4	0.6	**0,1**
Former clear cutting, mineral soils	8,7	0,3	9,6	0,3	9,3	0,3	7,6	0,2	7,2	0,2	0,06	0.06	0.1	**0,1**
Former clear cutting, peat soils	2,1	0,1	2,3	0,1	2,2	0,1	1,8	0,1	1,7	0,1	0,03	0.2	0.2	**0,0**
Plantations	8,9	0,3	9,1	0,3	11,1	0,3	11,1	0,3	11,2	0,3		0.2	0.2	**0,2**
Coniferous stands on peat soils	190,9	5,7	190,4	5,7	190,6	5,7	191,4	5,7	191,6	5,7	0.1	0.0	0.1	**1,9**
Drained forests	340,2	10,1	326,1	9,7	340,2	10,1	340,2	10,1	330,2	9,8	0.1	0.1	0.2	**6.7**
Drained forests, recently restored drainage		0,0	14,1	0,4		0,0		0,0	10,0	0,3	0.2	0.4	0.6	**0,3**
Natural forests on mineral soils	1062,6	31,6	1061,0	31,5	1059,6	31,5	1062,1	31,6	1062,6	31,6	0	0,06	0,06	**6.4**
Burned woodlands	0,68	0,02	0,2	0,01	1,1	0,03	0,6	0,02	0,6	0,02	0.06	0.4	0.4	**0,025**
TOTAL	**1624,8**	**48,3**	**1624,8**	**48,3**	**1625,5**	**48,3**	**1624,2**	**48,3**	**1624,0**	**48,2**				**16,2**

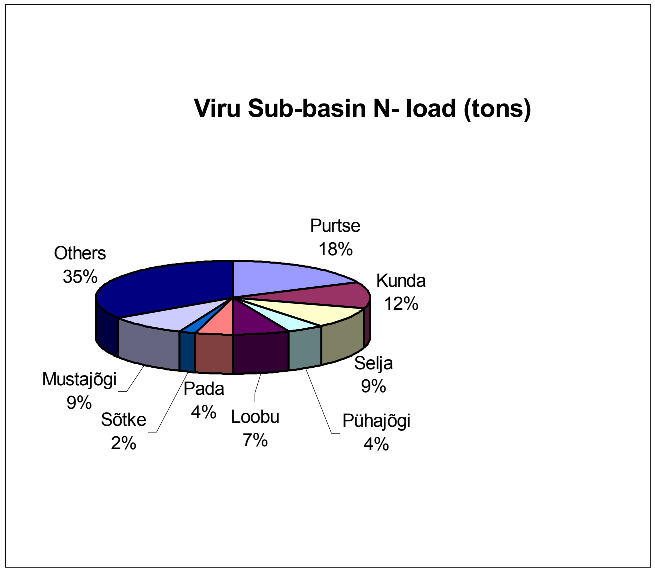
Phosphorus leaching from different forest areas in Peipsi Sub-basin

Woodland category	area km²	% from total area	area km²	% from total area	area km²	% from total area	area km²	% from total area	area km²	% from total area	Leaching coefitsient kg/ha year	Leaching coefitsient antropogenic kg/ha year	Total leaching coef.	Leaching of P (tons) Average of 5 years
	2000		2001		2002		2003		2004					
Recent clear cutting, mineral soils	33.1	0,27	24.8	02	30.1	0,25	25.1	0,21	24.6	0,2	0.15	0.3	0.45	**1,2**
Recent clear cutting, peat soils	7.1	0,06	5.5	0,1	6.6	0,05	5.51	0,05	5.4	0,04	0.20	0.06	0.06	**0,4**
Former clear cutting, mineral soils	33.1	0.27	24.8	0,3	30.1	0,25	25.1	0,21	24.6	0,2	0,06	0.06	0.1	**0,3**
Former clear cutting, peat soils	7.1	0,06	5.5	0,04	6.6	0,05	5.51	0,05	5.4	0,04	0,03	0.2	0.23	**0,1**
Plantations	3.5	0.03	3.9	0,3	4.2	0,03	4.13	0,03	4.2	0,03		0.2	0.2	**0,1**
Coniferous stands on peat soils	804.8	6.59	808.1	6.62	805.8	6.6	808.0	6.62	808.2	6.62	0.1	0.0	0.1	**8,1**
Drained forests	1338.7	10,96	1337.8	10.96	1310.9	10,74	1337.2	10,95	1332.1	10.91	0.1	0.1	0.2	**26.6**
Drained forests, recently restored drainage	4.0	0,03	4.9	0,04	31.8	0,26	5.52	0,05	10,64	0,09	0.2	0.4	0.6	**0,7**
Natural forests on mineral soils	3724.9	30,51	3737.6	30,61	3729.1	30,54	3737.0	30,61	3737.7	30,61	0	0,06	0,06	**22.4**
Burned woodlands	1.2	0,01	0,2	0,002	8,1	0,07	0,55	0,00	0,5	0,00		0.4	0.4	**0,08**
TOTAL	**5957.4**	**48,8**	**5953.1**	**48,8**	**5963.3**	**48,8**	**5953.8**	**48,8**	**5953.3**	**48,8**				**60.01**

3.2. Nutrient load from forest areas in main river catchments

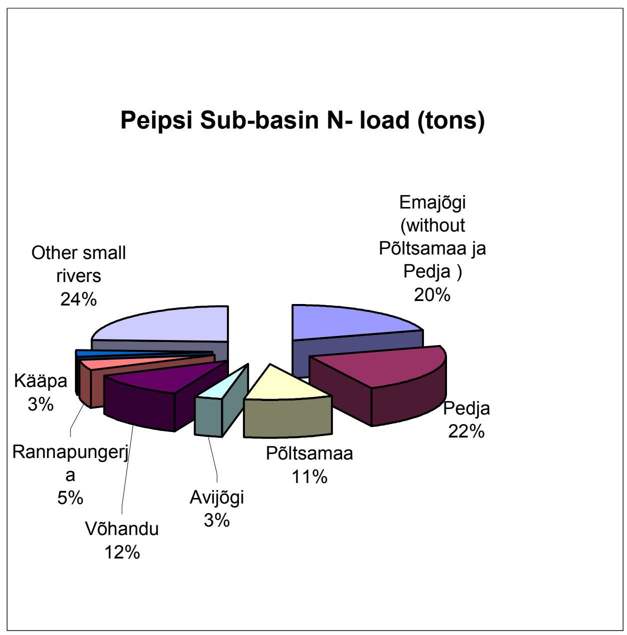
Viru Sub-basin , N-load from forest areas
Catchment areas of the main rivers

Rivers	Catchment area km^2	%	N-load (tons)
Purtse	810	0,18	53
Kunda	530	0,12	35
Selja jõgi	410	0,09	27
Pühajõgi	196	0,04	13
Loobu jõgi	308	0,07	20
Pada	196	0,04	13
Sõtke	94	0,02	6
Mustajõgi	418	0,09	28
Other small rivers and brooks	1540	0,34	102
TOTAL	**4502**	**1**	
			297



Peipsi Sub-basin , N-load from forest areas
Catchment areas of the main rivers

Rivers	Catchment area km^2	%	N-load (tons)
Emajõgi (without Pedja, Põltsamaa)	2468	0,20	227
Pedja	2710	0,22	249
Põltsamaa	1310	0,11	120
Avijõgi	393	0,03	36
Võhandu	1420	0,12	131
Rannapungerja	601	0,05	55
Kääpa	366	0,03	34
Other small rivers and brooks	2942	0,24	270
TOTAL	**12210**	**1**	**1123**
			1123



3.3. Reducing the phosphorus load

Phosphorus content in most Estonian forest soils is very low. Extremely low is it in oligotrophic bogs. Outflow from the central part of big bog massif is approximately zero, and so ca 25% of the forest areas practically are not responsible of phosphorus loading at all.

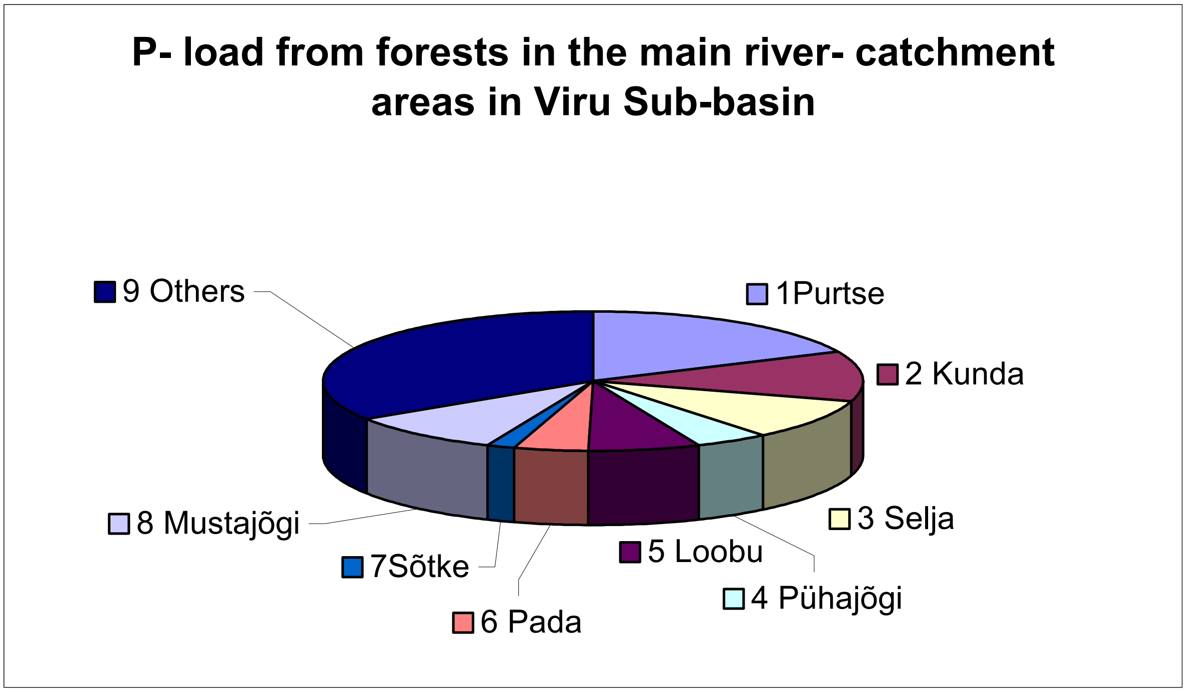
P- loading from clear-cutting areas on mineral soils is remarkably higher because the big caterpillar tractors and harvesters are disturbing the soil surface and a lot of residues have been left in the forest after the clear cutting. Increase of leaching of nutrients (N and P) starts 2-4 years after clear cutting and is lasting during 6-7 years.

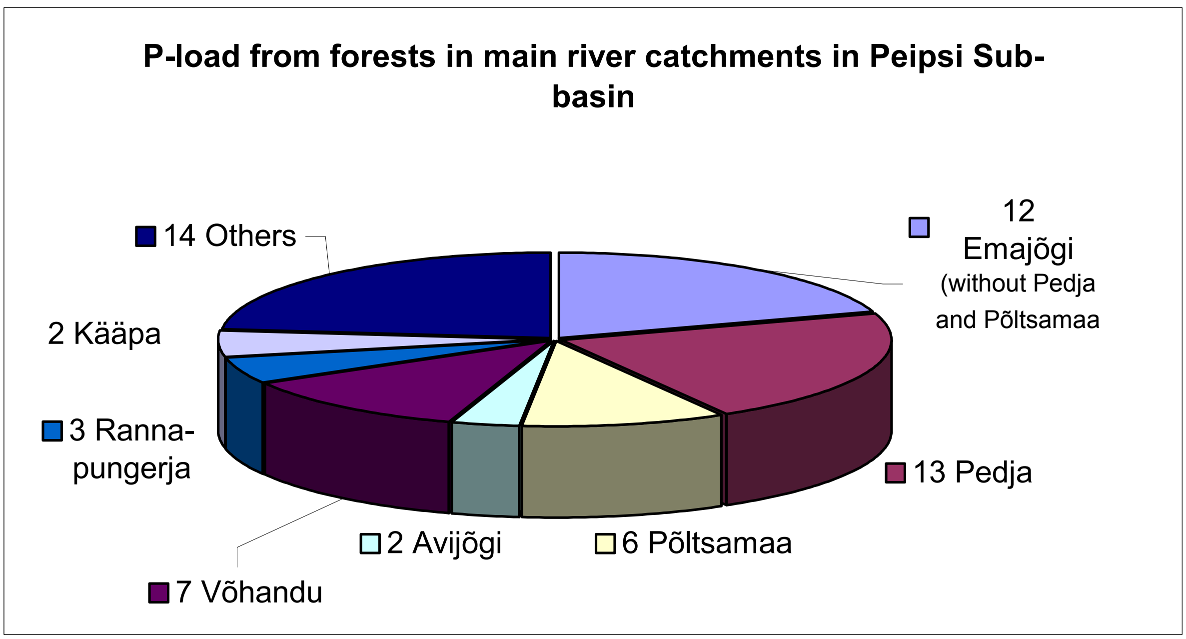
Viru Sub-basin , P-load from forest areas
Catchment areas of the main rivers

Rivers	Catchment area km^2	%	P-load (tons)
Purtse	810	0,18	2,9
Kunda	530	0,12	1,9
Selja jõgi	410	0,09	1,5
Pühajõgi	196	0,04	0,7
Loobu jõgi	308	0,07	1,1
Pada	196	0,04	0,7
Sõtke	94	0,02	0,3
Mustajõgi	418	0,09	1,5
Other small rivers and brooks	1540	0,34	5,5
TOTAL	**4502**	**1**	
			16,2

Peipsi Sub-basin, P- load from forest areas
Catchment areas of the main rivers

Rivers	Catchment area km^2	%	P-load (tons)
Emajõgi (without Pedja, Põltsamaa)	2468	0,20	12
Pedja	2710	0,22	13
Põltsamaa	1310	0,11	6
Avijõgi	393	0,03	2
Võhandu	1420	0,12	7
Rannapungerja	601	0,05	3
Kääpa	366	0,03	2
Other small rivers and brooks	2942	0,24	14
TOTAL	**12210**	**1**	**60**





It is clear that the total loads of phosphorus (TP) reaching lakes and rivers from mature, forested catchments are relatively small. This is mainly because phosphorus is retained in the biomass of stands.