

## Sustainable use of Estonian peat reserves and environmental challenges

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**Abstract.** Estonia is rich in peatlands, which cover 22.3% of its territory. About 1/4 of them are under protection, ~2% have been assigned for peat production, and ~1% is abandoned. Several peatlands are drained, which poses a challenge to their sustainability. The use of Estonian peat resources is regulated following the principles of sustainable management. During the inventory of Estonian peatlands (1971–1987) the properties (i.e. botanical composition) and quantity of peat were specified. In this paper an overview of these studies is given and new research fields focussing on chemical components of Estonian peat, i.e. trace elements, balneological characteristics, as well as the usability of the abandoned peatlands, are discussed.

**Key words:** peat, peatland, production, protection, Estonia.

### INTRODUCTION

Peatlands cover over 4 million km<sup>2</sup> or 3% of the land and freshwater surface of the Earth (Maltby & Proctor 1996). Considering the area of peatlands, Estonia holds the third position in Europe after Finland and Sweden (Lappalainen 1996). Paludification of peat deposits began soon after the glacial epoch about 12 000 years ago (Tikkanen 2006), first in Upper and somewhat later in Lower Estonia. Through the postglacial period, climatic conditions have favoured the rise and development of mires. The oldest mires are Napsi, Kuiksilla, and Mehiksoo in Upper Estonia, where peat started to accumulate 9100–8800 years ago during Preboreal time (Orru et al. 1992).

Peat is organic matter accumulating at ground surface and containing a high proportion of water (92–94%). Its organic part is a mixture of plant remains at different stages of humification. The organic constituents of peat could be classified into four groups: a) bitumens, b) carbohydrates, c) lignins, and d) humic substances (Fuchsman 1980). Besides these, peat contains nitrogen components, inorganic substances, etc. Peat is well humified if over 25% of its organic mass has decayed, and poorly humified when the decayed constituents form less than 25%. Dry matter of peat can contain up to 35% mineral matter.

The chemical composition of peat depends on a number of factors:

- feeding type;
- geomorphological position;
- vegetation;
- geological, geobotanical, and microbiological processes.

To clarify the confusing terminology, the term “peatland” has been introduced, comprising areas with both natural and drained peat layers. When defining and distinguishing the peatlands, the so-called zero-contour of peat thickness is considered, i.e. all areas covered with peat in spite of its thickness are considered peatlands. Furthermore, the term “mire” is used for an undrained area with an over 30 cm thick peat layer (Masing 1988). Mires can be categorized as raised bogs (feeding from precipitations), transitional mire (mixed feeding), and fens (feeding from groundwater).

This paper aims to give an overview of systematic peat investigations carried out in Estonia and of results of more recent trace element analysis and balneological studies. We also discuss the challenges to sustainable managing of peatlands, relying on the experience of past decades and possibilities for future improvement in balancing the peat production and protection and restoration of mires.

### INVENTORY OF ESTONIAN PEATLANDS

In 1971–1987 an inventory of Estonian peatlands was carried out by the Geological Survey of Estonia (EGS). According to guidelines of that time, the research incorporated the landscape areas covered with a peat layer (MRSFSR 1973). The inventory was carried out by counties and its results showed that peatlands took up nearly 25.8% of Estonia’s territory (Orru 1987). Some small peatlands with a thin (0.00–0.30 m) peat layer have been excluded from the monograph *Estonian Peat Resources* (Orru et al. 1992) as at the time of the inventory

the organic matter had become even more mineralized due to drainage. Thus, according to its composition such peat was no longer a typical peat, but rather a mixture of peat and mineral soil. After recalculations the total number of peatlands was 9836 and their area was 10 091 km<sup>2</sup> (22.3% of Estonia's territory). The monograph is complemented by a map of Estonian peatlands at a scale of 1 : 400 000.

#### Methods used in the inventory and review of unpublished data

In the peat inventory all 9836 peatlands with an area over 1 ha were prospected – the thickness and area of the peat layer were determined. Most of the peatlands were fens with a relatively thin (0.9–1.6 m) peat layer. More typical 539 peatlands with a thick peat layer and typical genesis were investigated in more detail. Samples were taken for the determination of botanical composition, degree of humification, natural moisture content, ash content, and pH value of peat. In addition, the vegetation and hydrological conditions of peatlands were described.

All 9836 peatlands were marked on aerial photos at a scale of 1 : 10 000. The prognosticated resources were calculated in 1059 and inferred resources in 539 peat deposits. As the remaining 8238 peatlands have a thin peat layer (0.1–0.9 m) and small area (1–10 ha), the resources were not calculated there. After that technical plans of 539 peat deposits were composed, presenting peat types (eutrophic, mesotrophic, oligotrophic), thickness and range of peat deposits, areas suitable for peat production, and potential drainage network. Of those, 520 are included in the handbook *Estonian Mires* (Orru 1995). It appeared that these well-investigated 539 peatlands (7499.5 km<sup>2</sup>) form the majority of the total area of peatlands (10 091 km<sup>2</sup>) (Table 1). The peatlands with prognosticated resources cover 1520.1 km<sup>2</sup> and small peatlands 1071.4 km<sup>2</sup>.

During further investigation of Estonian peatlands and their peat deposits in 1987–1992 also the contents of trace elements and chemical composition of organic substances were analysed and samples for C<sup>14</sup> and pollen analyses were taken to determine the genesis and age of peat deposits.

The aim of the overview in Table 1 was to introduce data of manuscript reports stored in the archives of the EGS. It appeared that during the inventory altogether 33 611 samples were taken for analysing general characteristics of peat (natural moisture content, ash content, degree of humification) and botanical composition, and 18 794 samples were collected for determining the acidity of peat (Table 1). Systematic analysis of the obtained data could be useful for solving the topical problems

related to mires and peat, such as genesis of mires and peat, peat accumulation rate, influence of drainage, climate change, environmental protection and nature conservation issues. For example, such analysis has been made for Männikjärve bog (Sillasoo et al. 2007), but using the data obtained during the inventory, could also be compiled for different types of mires in many other regions.

#### Peat deposits

During the inventory of Estonian peatlands (1971–1987) and the following research (1987–1992) peat resources were calculated in accordance with the guidelines (MRSFSR 1973) for the investigation of the deposits with an at least 0.9 m thick peat layer in a more than 10 ha area. The peat deposits within the zero-contour cover 9016 km<sup>2</sup>, with the commercial resources occurring on 5382 km<sup>2</sup>, i.e. on 60% of the area (Table 1). The geological peat resources in Estonia are 2.37 billion tonnes (Orru et al. 1992), while the total peat resources of the planet amount to approximately 5000–6000 billion m<sup>3</sup> (Lappalainen 1996).

Altogether, 279 of the total of 1598 peat deposits are included into the environmental register compiled by the EGS. These deposits are vacant for peat production (Fig. 1). Peat resources included in the register amount to 1.60 billion tonnes, i.e. 67% of total peat resources established by the inventory.

#### PEAT PRODUCTION

The first written notes of using peat as a fuel in Estonia, at Sindi textile factory, date back to 1861. In 1876 peat from Laugesoo mire was used in Ilmatsalu and approximately at the same time in Lavassaare (Valk 1988).

Before the Second World War 140 km<sup>2</sup> in 422 mires were rented out to peat production companies or individual producers, mainly for production of litter peat. Presently most of these peat production areas are depleted. In 1939, a total of 1.7 million m<sup>3</sup> of peat was extracted (Raudsepp 1946). Among others, the extracted fuel peat was used at Meleski and Järvakandi glass factories and Kreenholm textile factory in Narva. Until 1936 the proportion of peat in country's fuel balance was 6.7% (Raudsepp 1946), since the trend was to use less timber for heating purposes to preserve forests.

Today peat production in Estonia is regulated by the Sustainable Development Act, according to which the quota is 2.6 million tonnes (40% air-dry peat) per year. The volume of produced peat must not exceed its natural

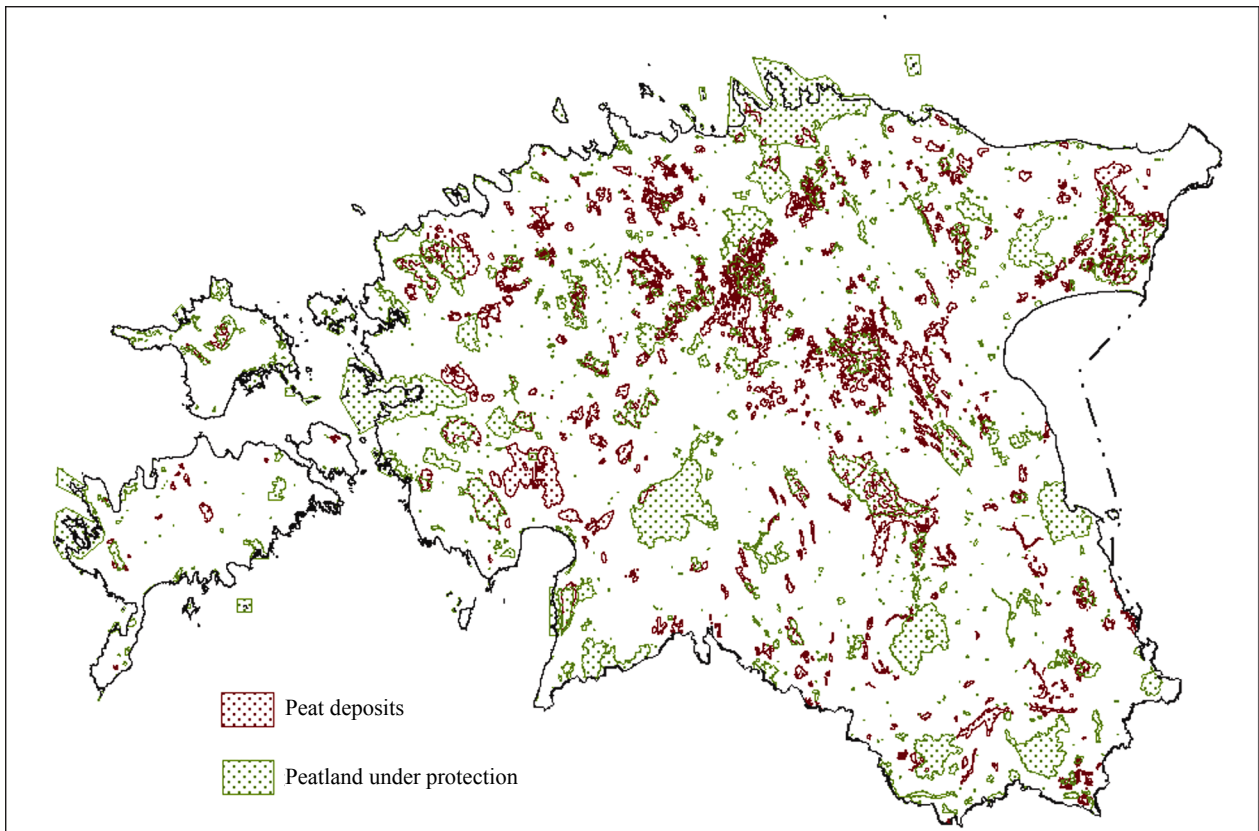


Fig. 1. Protected peat deposits and peatlands (with Natura 2000 areas) in Estonia.

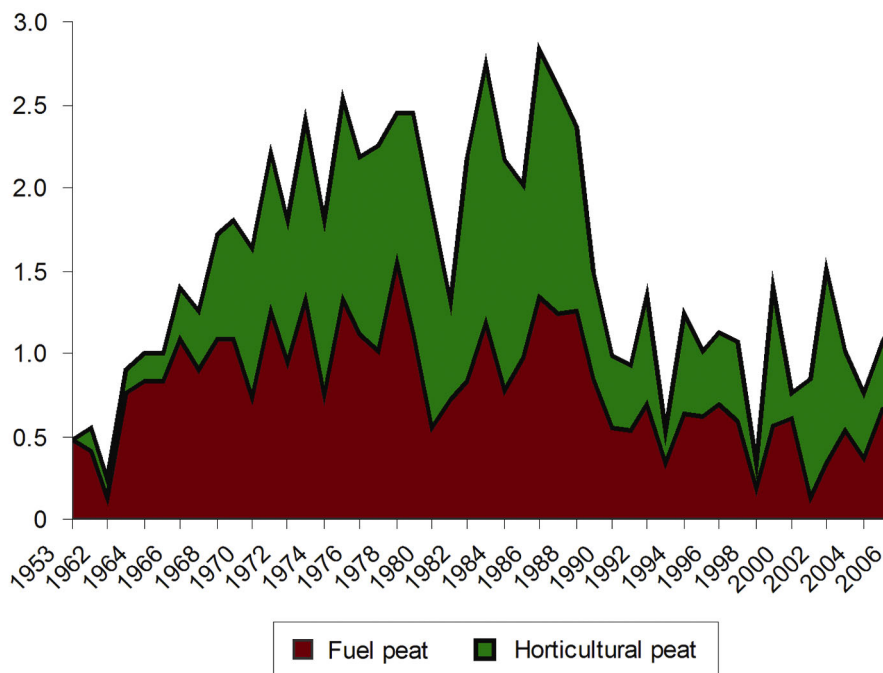


Fig. 2. Peat production (million tonnes) in 1953–2006.

**Table 1.** Overview of the data of the Estonian peatland inventory

County	Peatland area, km <sup>2</sup>				Peat reserves (million tonnes)	Number of samples in manuscripts				
	Well investigated 539 peatlands (inferred resources)	Other larger peatlands (prognostic resources)	Small peatlands (resources were not calculated)	Total		Peat deposits	Technical analyses (ash content, degree of humification)	Botanical composition	Oxides	Trace elements
Hiiu	73.5	0	0	73.5	38.5	203	203	62	36	203
Saare	158.4	5.00	0	163.4	87.5	652	652	74	44	0
Valga	202.4	67.1	81.8	351.3	152.0	2 310	2 310	48	24	2 310
Ida-Viru	804.6	77.4	137.0	1 019.0	530.1	2 123	2 123	32	12	1 775
Võru	189.9	76.4	94.6	360.9	176.6	1 665	1 665	26	32	832
Põlva	206.7	83.9	89.8	380.4	142.0	1 397	1 397	34	16	694
Lääne-Viru	417.1	65.3	59.3	541.7	233.8	1 660	1 660	26	56	855
Jõgeva	590.4	155.0	41.5	786.9	459.7	1 454	1 454	52	46	727
Tartu	711.0	99.6	59.1	869.7	543.0	2 181	2 181	38	44	1 080
Harju	833.3	251.4	162.4	1 247.1	506.8	2 562	2 562	32	114	1 129
Järva	712.4	100.7	23.0	836.1	489.2	2 400	2 400	34	53	1 700
Viljandi	617.7	174.1	66.7	858.5	474.5	3 150	3 150	54	65	1 575
Rapla	491.3	201.8	61.3	754.4	365.9	3 741	3 741	47	62	1 870
Pärnu	1 096.6	124.5	135.5	1 356.6	849.8	6 208	6 208	48	56	3 104
Lääne	394.5	37.8	59.3	491.6	332.7	1 905	1 905	38	24	940
Total	7499.8	1 520.0	1 071.3	1 0091.1	5 382.1	33 611	33 611	645	684	18 794

accumulation. The average accumulation rate of peat in fens is 19–100 cm and in raised bogs 12–300 cm per 1000 years (Maltby & Proctor 1996). It depends on climatic conditions; it has varied at different climate periods and may considerably vary between regions, even within one mire. Ilomets (1994) has estimated the annual average accumulation rate of peat to be 0.5 mm in fens and 1.5 mm in raised bogs in Estonia.

Systematic data about volumes of peat production have been collected since 1953. Peat production has ranged from 0.24 to 2.84 million tonnes (Fig. 2). In the increase of production three stages can be noted:

1. 1965 – Oru peat briquette factory was launched (nowadays closed);
2. 1967–1968 – a number of new deposits for litter peat production were taken into use;
3. 1985–1986 – production of peat fertilizers was started.

In the last decade 0.33–1.5 million tonnes of peat has been produced (40% air-dry peat) annually. In the nearest future these amounts will not increase because the recent milling technology does not enable extraction of larger quantities from the existing mining claims. As the protection of mires has become a priority, annual production up to 1.5 million tonnes can now be considered optimal, in spite of the quota of 2.6 million tonnes per year.

Presently 77 production areas (205 km<sup>2</sup>) are included into the environmental register, with the total resources of 0.24 billion tonnes of slightly humified and 0.75 billion tonnes of well humified peat. The currently operated production areas are in good condition. Many companies use modern equipment that has a low noise level and generates less dust. Recently several depleted peat fields have been newly taken into use.

## CONSERVATION OF PEATLANDS

In the 1960s peat extraction (40 deposits) was started in several raised bogs and in order to preserve the ecological balance, protection of mires became an issue.

There are several reasons for protecting the peatlands:

- preservation of biological and landscape diversity;
- preservation of natural resources (clean water, berries, herbs);
- as a habitat of threatened species;
- scientific value as a reference area in its uniqueness or typicality;
- recreational and educational value for humans;
- ecotourism.

Considering that Estonia has joined the European Union, it is important to see the protection of peatlands

in a broader context. Together with Natura 2000 areas ca 2500 km<sup>2</sup> of mires have been designated as protected areas (Fig. 1), 72% of which is represented by raised bogs (Ramst & Orru 2007). Especially important is the protection of natural fens that are extremely vulnerable to human activity due to their feeding type (groundwater, springs, floods).

Because of the importance of threatened species, the topmost part of peatlands has been recently studied (Paal et al. 1998; Karofeld & Pajula 2005; Kaakinen & Salminen 2006). The character and conditions of peatlands are often primarily connected to their vegetation. A more comprehensive view would consider also the hydrological conditions, composition of peat, and thickness of the peat layer, which influence the character of vegetation in a mire (Loopmann 1994). A considerable part of Estonian peatlands has been partly or completely drained, both peat production areas, and fields and forests with a thin peat layer. The exact area of such peatlands is presently under research and unambiguous data on the extent of the influence of draining are still missing. While Loopmann (1994) has suggested that non-drained peatlands make up nearly 71%, Ilomets et al. (2007, pp. 20–22) declare that only 30% of peatlands have not been drained. The authors of the present paper, relying on their extensive experience in peat investigations, suggest that the draining affects vegetation and groundwater generally down to the 200–500 m level. The more precise research on the extent and area of the influence is in progress.

## RECENT STUDIES

Abandoned peat production fields pose an important environmental issue in Estonia. They cover 89 km<sup>2</sup> according to the Environmental Register of Estonia. Many of them have considerable peat resources, including 0.05 billion tonnes of poorly humified and 0.25 billion tonnes of well humified peat. If the abandoned areas are not revegetated, they constitute an important source of CO<sub>2</sub> emission (Karofeld 2004). Under such conditions, peat finally mineralizes and ceases to exist as organic sediment.

The investigations carried out by the EGS revealed the variable state of abandoned peat production fields (Orru & Ramst 2008). Some fields are covered with forest, mostly with birches and pines while spruce is less common. Among mire plants Cyperaceae and Gramineae predominate but also different moss species, especially *sphagnum* species are common. Some abandoned areas are overgrown with cotton grass. The growth of cotton

grass is peculiar, being extensive at first, but ceasing later. This is probably due to changes in groundwater level as evaporation increases when trees grow taller.

In addition to using peat in horticulture and as a fuel, peat utilization in balneology has been introduced in Estonia. Respective investigations were carried out by the EGS and the East-Tallinn Central Hospital on patients with Heberden–Bouchard disease. The results show that the strength of hands and flexibility of fingers improved and pain decreased in patients treated with balneological peat (Orru et al. 2008). Balneological peat is rich in bioactive substances, e.g. humic (particularly hymatomelanic) and fulvic acids. The amount of peat suitable for balneological purposes in Estonia is estimated at 1 million tonnes (Orru et al. 2008).

Peat is able to bind hazardous elements, and can thus be used in several environmental technological solutions. In Estonia the content of harmful elements is highest in fens in river valleys feeding from springs (Orru & Orru 2006). As a result of natural processes these substances have been transported into peat by groundwater. Because of anthropogenic pollution like traffic, in some roadside peatlands the content of Pb and Cd was higher in the upper part of the peat layer (Orru & Orru 2006).

## CONCLUSIONS

During the last decades the Estonian peatlands and their peat resources have been thoroughly investigated. Nevertheless, there are several issues that need more detailed research. In recent years the studies have focussed on the processes occurring in the top 50-cm layer of mires and on their vegetation, while less attention has been paid to the genesis of peat and hydrological conditions, i.e. the processes in natural mires and the influence of drainage. The manuscript reports of the inventory contain much material (first of all, the data on the botanical composition of peat) that should be systematically analysed. In the future the use of peat as a natural resource (e.g. in environmental technology solutions, balneology, peat chemistry) should be expanded. Cooperation between geologists, botanists, hydrologists, ecologists, and other environment specialists is of vital importance for successful resolution of the problems related to the complex ecosystem of mires.

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## Eesti turbavarude jätkusuutlik ja keskkonnasäästlik kasutamine

Mall Orru ja Hans Orru

Eesti on rikas turbasoode poolest, need katavad 22,3% territooriumist. Ligi veerand turbasoodest on kaitse all. Turbatootmiseks on kasutusel ~2% ja ~1% võtavad enda alla mahajäetud turbaväljad. Kuna paljud turbasood on kuivendatud, tõstatub keskkonnavalne probleem – soo kui tervikliku ökosüsteemi säilimine. Eesti turbavarude kasutus on reguleeritud jätkusuutliku majandamise printsiipidest johtuvalt. Eesti soode revisjoni käigus (1971–1987) määrati turba hulk ja omadused (sh botaaniline koostis) kõigi Eesti turbasoode lõikes. Käesolev artikkel annab ka ülevaate nimetatud uuringute tulemustest. Lisaks on keskendutud uutele uurimisteedele, mis hõlmavad turba keemilisi omadusi, kahjulike elementide sisaldust, balneoloogilisi karakteristikuid ja mahajäetud turbatootmisalade kasutusvõimalusi, lähtuvalt eri uurimisdistipliinide vaatevinklist.