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Wetlands as essential basis for sustainable development: Estonian case

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Abstract

We see wetlands as an important basis for sustainable development. Besides the biodiversity and landscape functions they can be widely used for wastewater treatment and energy/material production.

We assume that a significant part of the oil shale, the main national fossil energy source, but also a part of the imported fuel and gas can be replaced by the energy production from wetlands. Based on the average biomass production of reed and cat-tail (1.5 kg m^{-2} yr^{-1}) the estimated energy value of one hectare of energy reed-bed is approximately 200 GJ. On the other hand, from approximately 600,000 ha of drained agricultural areas in Estonia about 300,000 ha will be abandoned in coming decades. A major part of this area (excluding all protected areas of about 100,000 ha, forested wetland sites, raised bogs and transitional marshes) does not provide interest for further agricultural use and can be turned to wastewater treatment and/or energy wetlands. However, only about 100,000 ha are the most favorable as energy/treatment wetlands. Biomass of reed and/or cat-tail from this favorable area can provide about 27,000 TJ energy a year. It can cover about 30% of Estonia's annual heat consumption and 20% of electrical energy production. This rate can be increased combining the biomass use with innovative technology like micro-turbines or thermoacoustic-Stirling engines.

In respect of the nutrient cycle, one can suppose that the land-use change from drained grassland to treatment and energy wetland can reduce the pollution load with trace gases.

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1 Introduction

Wetlands (mires, swamps, fens, bogs, moors, coastal and floodplain wetlands) are common features in the Estonian landscape covering approximately 30% of the country's total area (4,522,726 ha). Beside the traditional biodiversity and landscape values (habitats for various species, regulators of floods, water quality and energy/material fluxes in general, aesthetic and heritage values; [8]) we consider the Estonian wetlands also as active elements in sustainable rural development.

We analyze the capacity of wetlands as on-site wastewater treatment systems and alternative energy sources. Based on the GIS analysis of various cartographic sources we propose suitable areas for energy/treatment wetlands in Estonia.

2 Changes in land use and agricultural politics

The main trends in Estonian land-use dynamics have been a decrease in agricultural land (from 65% in 1918 to 27% in 1999) and an increase in forested areas (from 21 to 51%, respectively). Natural and seminatural grasslands show the most significant decrease [6]. This trend is especially remarkable after the regaining of independence in 1991. Land amelioration in 1960s and 1970s has shifted the agricultural activities from the former arable lands to marginal areas (natural grasslands, wetlands). It caused an essential disturbance of the stabilized nutrient cycling in landscapes. Since the early 1990's, many drainage systems have fallen into disrepair. Substantial areas of drainage infrastructure are now in need of rehabilitation. About 70% of polder systems (10,000 ha of total size) are already in the stage of natural succession. With the shift in agricultural policy and accessing the European Union, there is no realistic possibility to return these drained wetland areas into the agricultural use. According to our estimation, there are approximately 300,000 ha of currently or potentially abandoned drained wetland areas in Estonia.

3 Wastewater treatment in wetlands

Wastewater treatment in wetlands is a well-known technology in the whole world [3]. In Estonia, both natural and artificial wetlands have been used for purifying polluted waters from agricultural fields and various point-pollution sources [5]. These systems have a potential for treatment of wastewater from single houses, villages, small towns, tourist resorts, farms and landfills, as well as from some industrial areas. They are gaining popularity because of the bad shape of existing small purification plants (proportion of inefficient plants is more than 60%, during the last five years more than 300 of the 1080 plants were closed down [4]) and high costs of new purification plants.

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Table 1: Average annual mass removal rates (g m^{-2} yr^{-1}) and efficiency rates (%) of 5 constructed wetlands (a vertical subsurface flow system, a horizontal subsurface flow system, a combined overland/subsurface flow wetland and two open water surface wetlands)in Estonia ; (after Mander & Mauring [5]; Mander *et al.* [7]).

Parameters	**BOD_7**	**Total N**	**Total P**
Efficiency (%)	65-81	36-73	34-91
Mass removal (g m^{-2} yr^{-1})	0.01-0.29	0.1-12.8	0.03-1.7

During the last 6 years, twenty constructed wetlands for wastewater purification were established. Currently, about 50 communes around the country are planning to construct treatment wetland systems.

Table 1 shows some examples on the nutrient purification efficiency and mass removal capacity of constructed wetlands for wastewater treatment. Treatment by nutrient-rich wastewater is an important presumption for the effective macrophyte growth in wetlands.

4 Energy sources, production and consumption in Estonia

Oil shale (*kukersite*) is the main local primary energy source in Estonia (58% of the total). It is mainly used for electrical energy production (96%). Oil shale is the second largest resource in heat production (22%) after the imported natural gas (26%),. However, due to the high losses in different stages of production and also caused by the large selfuse of power plants, the efficiency of the oil shale consumption is only 22%. Therefore, it makes only 7% of the final consumption being outstripped by imported engine fuel (54%) and wood (22%) (Fig. 1) [11]. In the same time, oil shale production and consumption causes the heaviest environmental problems in Estonia (Fig. 2). These environmental problems are interrelated with the severe socio-economic and regional political problems in the oil-shale region. At present the oil shale burning process in the power plants situated in NE Estonia is relatively effective (ca 30%) but due to the absence of local heat users and the transmission losses the end users can consume only 12% of the primary energy accumulated in the oil shale.

Despite the decline of the fossil fuel use in Estonia (Fig. 1) the anthropogenic emission of CO_2 is exceeding the environmental space (1.7 tons of CO_2 per capita per year) about 9 times while the emission due to the use of fossil fuels alone exceeds it 8.4 times. The carbon emission associated with fuel use is exceeding the carbon fixation potential of the Estonian forests 2.8 times in the conditions where about half of the Estonian territory is covered by forests. Accordingly, the ecological footprint of Estonia calculated on the basis of the use of fossil fuels is exceeding the territory of the forests about 3 times and the whole territory of Estonia about 1.5 times [10].

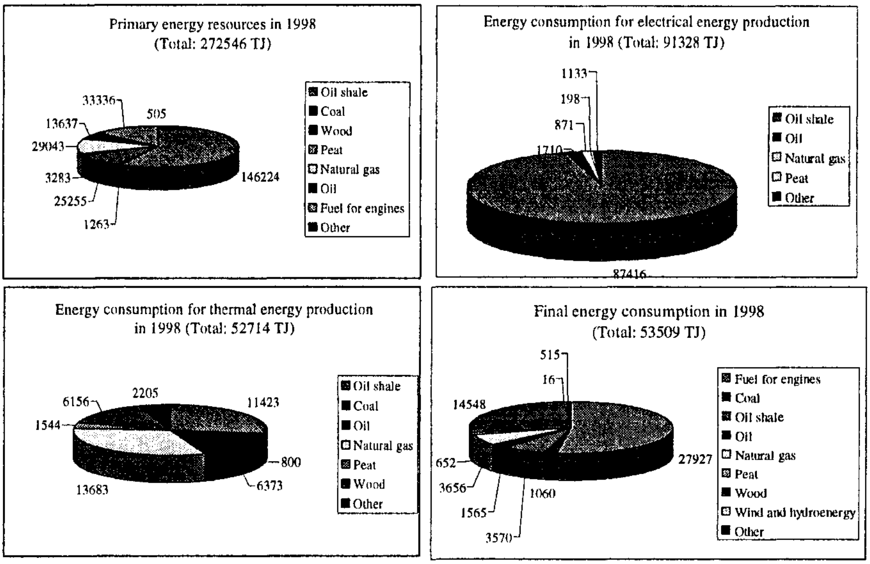

Figure 1: Primary energy sources and their consumption in Estonia in 1998 [11].

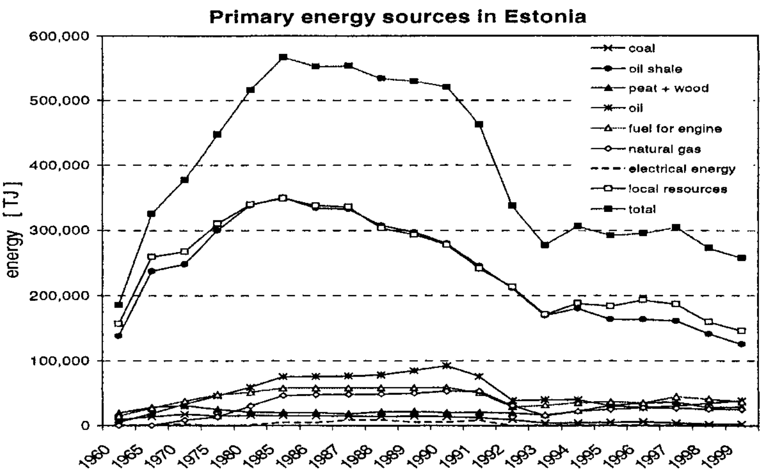

Figure 2: Dynamics of primary energy sources in Estonia 1998 [11].

The carbon emission from Ida-Virumaa, an industrialised oil shale region of Estonia, is exceeding the carbon fixation potential of the district about 20 times. The ecological footprint of Ida Virumaa is 20 times larger than the territory of the forests of the area and 10 times larger than the territory of the district [10].

We assume that a significant part of the oil shale, and also of the imported fuel and gas, can be replaced by the energy production based on wetlands.

5 Wetlands as building materials source

Reed (*Phragmites australis*) from wetlands is already a well-known valuable building materials, especially for roofs. Likewise, cat-tail (*Typha latifolia*) biomass can be easily used for different construction works [8, 12]. The leaf mass of cat-tail shows a high porosity and elasticity of the aerenchyma tissue. At the same time there is a uniform distribution of bast fibres. Thus, the leaves have a high stability and show excellent insulation qualities. Furthermore the leaf tissue has a high content of polyphenols, so the dry raw material shows a high resistance of decay. Cat-tail chips mixed with clay is used for the cost-efficient building blocks production. The cat-tail wool is an excellent isolation material [12].
The aboveground biomass will be harvested in winter when the leaf mass has a minimum water content. The harvesting technique has been adopted from a common reed harvest. There are vehicles with wide tyres or caterpillar tracks constructed specially for the amphibious environment [12].

6 Wetlands as potential energy production sites

6.1 Leaf mass for energy production

Wetland based energy production scheme is a promising source for small scale central heating plants (CHPs) as well as for micro-generation systems. The dry biomass growth will be 1...3 kg m^{-2} yr^{-1} depending on presence of nutrients in wetland. Natural dehydration after vegetation period amplifies the energy content of biomass up to 3.7 MWh per ton. Low density of wetland biomass restricts the feasible transportation distance to energy production facility. However, portable charcoal production unit can be a usable energy concentrator to increase the energy content of biomass by increase of density up to 1100 kg m^{-3}.
Based on the average biomass production of reed and cat-tail (1.5 kg m^{-2} yr^{-1}) the estimated energy value of one hectare of energy reed-bed is approximately 200 GJ., The dry leaf mass can achieve 3-4 kg m^{-2} yr^{-1} if used for wastewater treatment. Biomass of reed and/or cat-tailfrom 300,000 ha of energy reed-beds provides about 44,000 TJ energy a year. This is about 83% of the current thermal energy consumption in Estonia (Fig. 1). Therefore, it is possible to use the cat-tail and reed biomass for the electrical energy production if a suitable technique is implemented. Dispersed electricity production and innovation in micro-energetic technologies (e.g., micro-turbines, Stirling engines, thermo-acoustic engines) can reduce the need for primary energy. For instance, some thermo-acoustic engines are able to produce electricity at 30-40% of effectiveness over 24 thousand hours maintenance free operation [1]. See also http://www.lanl.gov/mst/engine/, and http://www.io.com/~frg/.

This new technology would significantly relief the environmental pollution caused by the current oil-shale burning (see Fig. 1). Considering that a part of the potential biomass of wetland plants will be used for electricity production, and that the dispersed pattern of local power plants significantly decreases the energy losses, we estimate that the potential energy/treatment wetlands of 300,000 ha can cover about 61% of annual heat consumption and 55% of electrical energy production.

6.2 Socio-economic aspects

Many wetlands in Estonia can be considered as potential fields for biomass production. They act as the driving force for dispersed settlement formation and development. New and attractive areas for real estate development can be explored because the relative independence of settlement planning due to energy production and wastewater treatment using wetlands.
Small (1-10 ha) and medium (ca 100 ha) size production wetlands have the economic sense in terms of micro-energetic technology if the rate of produced electric power is few kilowatts up to hundreds of kilowatts. A 2 ha treatment wetland is capable to feed ca 4kW micro-CHP, it is enough to cover electricity and heat demand of ca 200 m^2 house in Estonian climate. Even more: Estonian Energy Company has to buy all the renewable origin electricity at the 90% level of end user price. Depending on machinery used the revenue might be 1000-1300 USD yr^{-1} in case all produced electricity will be sold to network.
Employment of 500...1000 people as wetland farmers is necessary when 1...30 MW CHP facilities will use the biomass from 300,000 ha of production wetlands. It could be a remarkable contibution to release unemployment in countryside.
Variety of possibilities for countrywide renewable energy solutions is another obvious geo-political advantage for Estonia beside the often performed trading and transit benefit due to the closeness to Russia.

7 Trace gases budget of treatment and energy wetlands

Drained wetlands are the second largest source of unbalanced carbon flow in Estonia. According to the estimations an average rate of decomposition of the sphagnum in drained wetlands is about 4.3 t CO_2-C ha^{-1} yr^{-1}, whereas the fixation rate of carbon due to the formation of the sphagnum is only 0.9 t CO_2-C ha^{-1} yr^{-1}. The amount of decomposed sphagnum is exceeding the amount of sphagnum formed for about 2660 thousand tons of CO_2-C annually. According to the data of the beginning of 1990s the carbon flow originating from drained wetlands alone was exceeding the environmental space of Estonia about 4 times and was 6.7 times higher than the World's average per capita emission of carbon from the land use changes [10]. Primary production of Estonian forests is not compensating the carbon flow from the wetlands. Therefore, one of the ways to

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improve the CO_2 balance can be the restoration of wetlands and turning them to productive sites.
Measurements of trace gas fluxes (nitrous oxide, methane) in constructed wetlands have shown significantly higher cumulated nitrous oxide fluxes compared to the drained grasslands [12]. However, the situation can be the other way around for methane – the global warming potential (GWP; summarises the influence of all greenhouse gases fluxes) of newly created wetlands is more favourable compared to the drained grassland. Development of vegetation in wetlands can compensate the lack of oxygen in sediments. For instance, root oxygen release from plants like cat-tail can significantly alter rates of biogeochemical processes such as methanogenesis [2]. In respect of the nutrient cycle, one can suppose that the land-use change from drained grassland to treatment and energy wetland can reduce the pollution load with trace gases.

8 Suitable areas for energy and treatment wetlands in Estonia

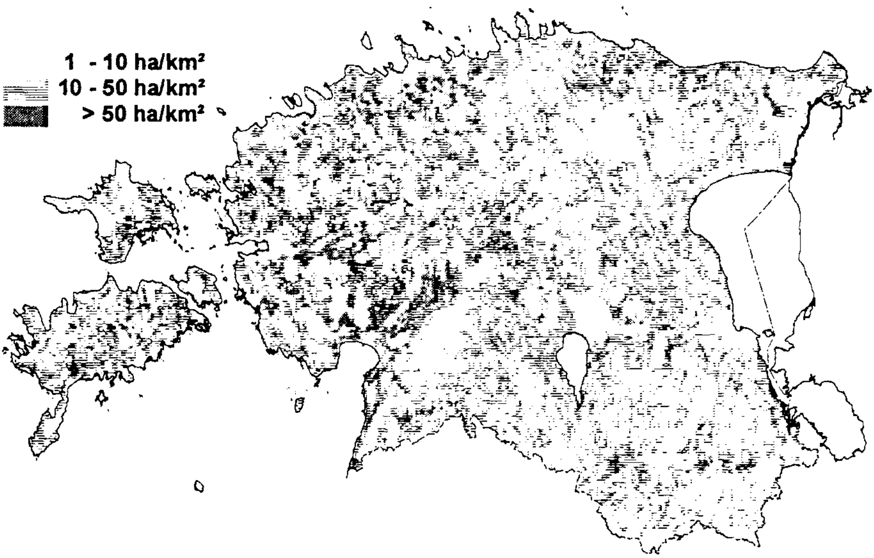

Figure 3: Coverage of potential energy and treatment wetlands in Estonia.

Percentage of wet and moist land in Estonia is relatively large (Fig. 3). Peat soils cover 21% of Estonian territory and gleysols cover even more – 33%. Not all of this territory is acceptable for *Phragmites* or *Typha* plantations. After exclusion of protected areas (about 100,000 ha are protected as special mire protection sites or located in protected areas of different regime [9], forested sites, raised bogs and transitional marshes' about 594,000 ha of potential territory for energy and treatment wetlands remains. Some of these sites are in riparian or coastal buffer zones, some are well drained and intensively used in agriculture, some are too small, and some are located in distant places. Presumably, reed and cat-tail plantations are not the only possible land use for these potential areas. About 100,000 ha of most favorable sites for *Phragmites* and *Typha* plantations were selected using these criteria. Sites distant at least 200 m from the coastal line, lake shores, riverbanks and not drained bogs, and larger sites closer to the settlement were preferred (Fig. 4). Also, all the peat mining areas as potential reclamation sites were included.

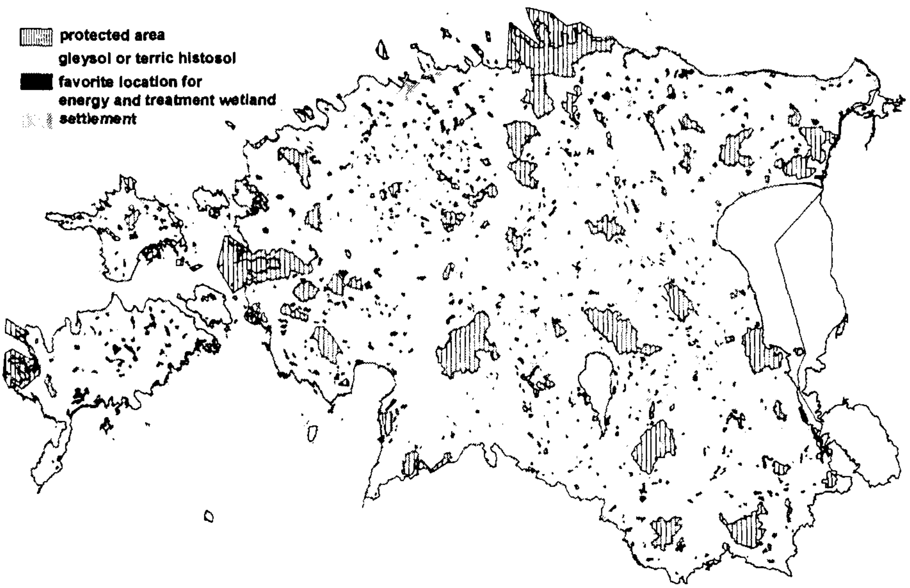

Figure 4: Favorite areas for energy and treatment wetlands in Estonia.

9 Conclusions

We see wetlands as important basis for the sustainable development. Beside the biodiversity and landscape functions they can be widely used for wastewater treatment, for energy and building materials production.
About 300,000 ha of approximately 600,000 ha of drained agricultural land of Estonia is estimated to be abandoned in coming decades. A major part of this area does not provide interest for further agricultural use and can be turned into treatment and/or energy wetlands. About 100,000 ha are the most favorable for this purpose. They are equally spread over the entire territory.
Potential biomass from 300,000 ha of energy/treatment wetlands can cover about 30% of Estonia's oil shale based energy production. However, implementation of this innovative technology needs significant reorganization of socio-economic pattern, especially in the oil shale region in the northeastern part of the country.

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References

[1] Backhaus, S. & Swift, G. W. A thermoacoustic-Stirling heat engine, *Nature* **399**, 335-338, 1999.

[2] Jespersen, D.N., Sorrell, B.K. & Brix, H. Growth and root oxygen release by Typha latifolia and its effects on sediment methanogenesis. *Aquatic Botany* 61(3), 165-180, 1998.

[3] Kadlec, R.H. & Knight, R.L. *Treatment Wetlands*. CRC Lewis Publishers, New York, 1996. 883 pp.

[4] Kuusik, A. *Small biological wastewater purification plants in Estonia*. TTKK, Tallinn, 247 pp. 1995. (In Estonian with summary in English).

[5] Mander, Ü. & Mauring, T. Constructed wetlands for wastewater treatment in Estonia. *Water Science and Technology* **35**, 323-330, 1997.

[6] Mander, Ü. & Palang, H. Landscape changes in Estonia: reasons, processes, consequences (Chapter 9). *Land-Use Changes and Their Environmental Impact in Rural Areas in Europe*. MAB Series, Vol. 24. R. Krönert, J. Baudry, I.R. Bowler & A. Reenberg, Eds. The Parthenon Publishing Group, Paris, pp. 165-187. 1999.

[7] Mander, Ü., Kuusemets, V., Öövel, M., Ihme, R., Sevola P. & Pieterse, A. 2000. Experimentally Constructed Wetlands for Wastewater Treatment in Estonia. *Journal of Environmental Science, Part A - Toxic/Haz. Subst. & Environmental Eng*., **A35(8)**, 195-210.

[8] Mitsch, W.J. & Gosselink, J.G. *Wetlands*. 3rd Edition. John Wiley & Sons, 920 p., 2000.

[9] Paal, J., Ilomets, M., Fremstad, E., Moen, A., Børset, E., Kuusemets, V., Truus, L. & Leibak, E. *Estonian Wetland Inventory*. Publication of the Project "Estonian Wetlands Conservation and Management". Eesti Loodusfoto, Tartu, 166 + xxviii p., 1997.

[10] Randla, T, Kurissoo, T. & Vilu, R. Estimation of the eco-efficiency and sustainability of Estonia. 2000. Manuscript.

[11] Statistical Yearbook of Estonia. (Eesti statistika aastaraamat). 1992-1999.

[12] Wild, U. Lenz, A. Kamp, T. Heinz, S. & Pfadenhauer, J. Vegetation development, nutrient removal and trace gas fluxes in *Typha* wetlands. *Advances in Ecological Sciences*, Vol. 12. Ü. Mander & P.D. Jenssen, Eds. WIT Press, Southampton, Boston, 2001. (In press).