Landowners' willingness to promote bioenergy production on wasteland – future impact on land use of cutaway peatlands

Abstract

Landowners are the key players in bioenergy production on wasteland; such as cutaway peatlands. In this study, the landowner's interest to use cutaway peatlands for bioenergy production was investigated using a survey and GIS (Geographic Information Systems) methods in an area in South Ostrobothnia, Finland. The focus was to identify which different bioenergy production chains are preferred by the respondents: combustion, gasification or biogas production from agriculture, energy-willow short-rotation forestry or forestry based energy crops. Also, the influence of personal environmental values on the selection was measured and the future impacts and barriers for the land use were assessed.

Afforestation was the most popular after-use method among the landowners. The next most favorable method was energy crop cultivation but it was highly dependent on economic profitability and subsidies. Currently, approximately 8.2% or 500 ha of the total peat extraction area could be used for bioenergy production in the region by 2035. Based on the survey, forest based biomass is the best option if bioenergy is to be produced. The next choice was agro biomass and the least favored plant was willow. This study suggests that the biggest cutaway peatlands will be converted to forest energy in the future. Suggestive results were that the owners with high environmental values are especially interested in agro biomass growing and the landowner having a distant home place does not have a negative influence on bioenergy production. Altogether, land use and biomass production of cutaway peatlands is connected with the demands of the Finnish bio-economy.

Keywords: *biogas, gasification, combustion, GIS, energy crop, willow*

1 Introduction

In literature there has been a debate concerning land use planning and bioenergy production targets (Gamborg et al. 2012, Scarlat et al. 2013). The fundamental concern has been the effect of energy crops on land use and food prices; because the growing of energy plants for 1st generation biofuels has taken space from food production and increased food prices. In developing countries especially, this has been considered to have a negative socio-economic impact (Edrisi & Abhilash 2016). Consequently, bioenergy production is increasingly conducted on marginal lands globally, to avoid competition with food production and to increase the sustainability aspect of bioenergy production (e.g. Xue et al. 2016, Stoof et al. 2015, Abolina et al. 2015).

The term “marginal land” has multiple definitions: the land can be economically barely profitable for agriculture purposes or it is not in commercial use. Marginal land can also be considered as “idle, under-utilized, barren, inaccessible, degraded, excess or abandoned lands, lands occupied by politically and economically marginalized populations or land with characteristics that make a particular use unsustainable or inappropriate” as defined in Dale et al. (2010). Wasteland is one form of marginal land. The definition of wasteland is also contradictory and environment dependent, but in this study wasteland is considered as a patch of land having no appreciable vegetative cover and degraded by natural as well as anthropogenic activities (as presented in Edrisi & Abhilash 2016, Oxford Dictionary 2016).

Peat extraction lands, common in Finland as well as in Sweden, Ireland and the Baltic countries, can be specified as wasteland after peat extraction. Peat is a commonly used fuel especially in Finland and Ireland, where about 5–7% of primary energy consumption relies on peat. Peat is used as agricultural and horticultural purposes as well (World Energy Council 2013). At the beginning of the peat extraction, the pristine mire is dried with ditches and the surface layer (vegetation and partially decomposed organic matter) is removed. After ca. 20–30 years of peat extraction, the area is left bare without vegetation. E.g. in Finland, about 2,500 ha of peat extraction areas is shifting to cutaway phase annually (Leupold 2004, Salo & Savolainen 2008). Cutaway peatlands suit well the definition of wasteland because the pristine mire is modified and left barren by anthropogenic action. Even though the area can be considered as wasteland, the surface is usually barren or untapped only for a relatively short time (max. a few years), because it is recommended that a profitable after-use method is applied as soon as possible. However, the transition from barren surface to vegetative cover can vary greatly, depending on soil properties (Leupold 2004). Natural vegetation succession is a very slow process on cutaway peatlands (Tuittila et al. 1998, Silvan & Hytönen 2016).

In Northern Europe, the cutaway peatlands have been identified as a potential wasteland to grow energy crops, such as: willow, reed canary grass (RCG), and forest energy (Leupold 2004, Pahkala et al 2005, Picken 2006, Parviainen 2007, Salo & Savolainen 2008, Järveoja et al. 2013, Jylhä et al. 2015). However, a relatively small amount of cutaway peatland is suitable for energy crop production because there are challenges related to water level, remote locations, site nutrition, the size of the released area, landowner’s interests and ignorance which can have a negative impact concerning bioenergy production. According to Picken (2006) about 26–42 % of these areas are suitable for agricultural use and 57 % for afforestation, based on the mineral sub-soil characteristics. However, the poor nutrition is often a challenge on cutaway peatlands. Especially, phosphorus and potassium are limited nutrients. The nutrition can be improved by soil preparation, fertilization, and mixing of the bottom peat with the underlying mineral soil (Leupold 2004, Huotari et al. 2006, Salo & Savolainen 2008, Huotari et al. 2009).Nowadays, the most popular form of after-use is afforestation, but there are several other after-use methods available, such as: agriculture, tourism, restoration, and bird sanctuary (Leupold 2004, Salo & Savolainen 2008). If the bioenergy after-use method is chosen, then special attention must be paid to the location, since the transportation distance of biomass to a biomass utilization plant has a significant effect on the net energy yield. The cost-effective transportation distance is dependent on a variety of factors, such as: plant species, type of transportation method and bioenergy conversion technology. E.g. in the case of reed canary grass (RCG, *Phalaris arundinacea*) which is harvested in spring time for combustion, the highest economically transportation distance to a combustion plant is roughly 70–80 km (Lötjönen & Knuuttila 2009). If the distance is higher, the transportation costs are usually too high to achieve a feasible production chain.

Currently, peat extraction covers almost 1000 km^2 area in Finland and the most intensive extraction area is situated in the western parts of Finland (Laasasenaho et al. 2016). The status of peat as a natural resource is contradictory, because it has many environmental impacts. Peat extraction usually causes: deterioration of peatland habitats and biodiversity, hydrological problems, emissions into waterways, and increased greenhouse gas emissions (e.g. Mäkiranta et al. 2007). However, the extraction is regulated by Finnish Environmental regulation (Ministry of Environment 2015). On the other hand, peat extraction can be a significant employer in rural areas. The conflict between economy and conservation of nature in peatland utilization has been studied (e.g. Chapman et al. 2003, Tolvanen et al. 2013). There are always trade-offs involved between services the ecosystem provides (clean air and water, flood protection etc.) and economical goals in peatland and people's opinions are highly dependent on a person's background, such as: home location (city or countryside) and education (Tolvanen et al. 2013). An inquiry, clarifying the attitude of local inhabitants towards different after-use methods (North Ostrobothnia region, Finland; Kittamaa & Tolvanen 2013) indicates that the most favored after-use method is forestry or a bird sanctuary/wetland and the second favorable choice is agriculture or energy crop cultivation, whereas the least wanted after-use form is pasture or special plant tillage. The remarkable thing is that 52 % of the local people highlighted recreational after-use choices in the study. Similar results about the popularity of afforestation and agriculture have been collected amongst the landowners of the peat extraction areas in Alavus, South Ostrobothnia, Finland (Karjala 2014). Consequently, because of a lack of studies concerning the landowners' background and their environmental opinions as well as their personal motivation versus their chosen after-use method, more studies were needed concerning landowners' interests.

Landowners' opinions towards bioenergy production on abandoned farm land has been investigated, e.g., in Latvia (concerning the growth of short rotation woody crops; Abolina & Luzadis 2015). There, one of the biggest barriers for the utilization of abandoned farm land is the fact that the landowners do not live near the areas. In another study conducted in Michigan, USA, energy crop growing on marginal lands is limited by trade-offs between farmland availability and marginal land and only one third of the landowners were willing to rent their marginal lands at the rental rates offered (Hayden 2014). In Finland, as well as in Sweden and in Canada, the peat extraction area is usually located on private or public land (Leupold 2004). The peat producing company can own the peatland or it can rent the mires. When the peat is exhausted, the area is passed to the after-use phase and the landowner can decide the after-use method. Therefore, the landowner is the key player when the after-use methods are planned. Consequently, the objective of this study was to make a survey of the landowners of peat extraction areas and combine the data collected with geographical information systems (GIS) to recognize the spatial distribution of the potential bioenergy production areas. The main goal was also to improve the knowledge of landowner derived bioenergy after-use methods on cutaway peatlands and future impacts on land use within them.

2 Material and methods

2.1 The study area

The study was conducted in the “Kuudestaan” region, Finland (Fig. 1). The region is one of the European Union’s (EU) Rural Development Action Groups located in Western Finland (Erkkilä & Ahonpää 2014) and the area was chosen because there is intensive peat extraction nationally (Laasasenaho et al. 2016). The municipalities in the area are Alavus, Kuortane, Soini and Ähtäri. There are in total approximately 25,000 inhabitants in the area whose size is 3,119 km^2. Economic life is strongly based on forestry and agriculture (Erkkilä & Ahonpää 2014) and thousands of hectares of peat extraction areas will become wastelands in the area in the near future. Mires and peat extraction intensity in the area is presented in Table 1.

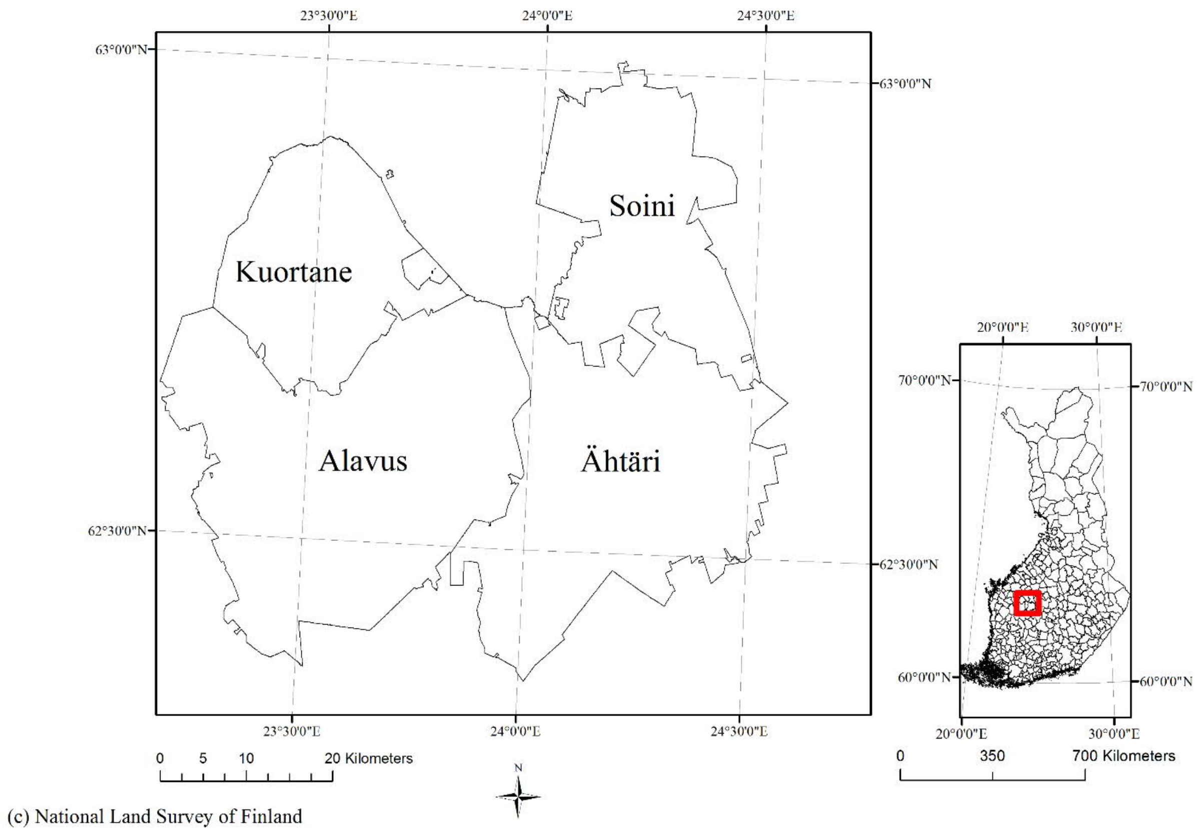

Fig. 1. The Kuudestaan area– a map of the studied area (left). Its location in Finland is denoted with the red square (right).

Table 1. Mires, peat extraction and the area of protected mires in the "Kuudestaan" area. Total land area is 3,119 km^2 (GTK 2016).

Municipality	Mires, ha	Under peat extraction, %	Protected, %
Alavus	20400	12	7
Kuortane	9200	7	< 1
Soini	15900	11	9
Ähtäri	17800	6	2

2.2 Search for potential peat extraction areas and landowners

In this study, GIS based methods were used to recognize landowners and potential cutaway peatlands in the "Kuudestaan" region. At first, all the peat extraction areas in the "Kuudestaan" region and all the property or estate codes located within the area were checked using Paikkatietoikkuna web service which contains maps from the National Land Survey of Finland

(NLS) (Paikkatietoikkuna 2016). The estate code was accepted if there were at least 15 ha of peat extraction land within the landowner's property. The area limitation was based on an assumption of reasonable bioenergy production size by after-use experts from a national bioenergy company (personal communication by Ari Laukkanen, Kimmo Aho and Juha Kinnunen on the 12th of January 2016). The size of the areas was calculated by using the Finnish Topographic database and using the "Measure an area on the map" tool. The data on the map was from the year 2014.

Because peat extraction areas are usually situated in remote locations (Salo & Savolainen 2008), only the most potential areas were then chosen. This meant that the peat extraction areas and landowners within a 10 km radius (by Euclidean distance, personal communication by Ari Laukkanen, Kimmo Aho and Juha Kinnunen on the 12th of January 2016) from the center of the municipality or local farms (from middle sized to big farms having more than a 50-head of cattle, 500 poultry, 30 horses or 500 pigs) were identified. The farm size and location were obtained from the Finnish animal production regulation organization, Evira (Finnish Food Safety Authority). The information was supplemented, partially, based on a previous study in Soini (Laasasenaho 2012). The identification was made with a buffer tool in ArcGIS v 10.3.1 (ESRI Inc, Redlands, CA, USA). After locating the suitable areas on the map, the landowners' contact information related to the estate codes were requested from NLS. The areas already removed to after-use were not included or analyzed in this study, because there is a lack of statistics concerning peat extraction areas' after-use.

2.3 The survey

The survey (see appendix) about different after-use methods was sent to 75 landowners in total, including 69 private persons, 5 companies, and 1 foundation. The answers were anonymous and confidential. The response rate of the survey was 33 %. 76 % of the respondents were men and 24% were women. The educational level was set in an ordinal scale and the respondents had a median of upper secondary education (from comprehensive school to university degree) and the median of age class was 41–50 years old (Table 2). The survey included: some background information (sex, age, education, home town, the location of owned property under peat extraction, the size of the peat extraction area on the property, the year peat extraction ends/ending of the rental contract and the planned after-use method), evaluation of different after-use and bioenergy production choices, as well as questions related to environmental values. In the latter questions, the answers were asked to be given on an ordinal scale (from 1 to 7 = does not matter to matters a lot). The bioenergy choices were combustion, biogas production and gasification from agriculture energy plants, energy willow, or wood. Environmental values were measuring the general attitude towards nature, global warming and greenhouse gases, nature well-being, and water pollution. Also, different barriers to the utilization of cutaway lands for bioenergy production were evaluated with the same scale. The questions concerned general challenges in cutaway peatlands, such as: problematic water economy, stones and bedrock, low fertile soils, frost damage, logistics, etc. Separate questions also handled the willingness to produce bioenergy on cutaway peatlands as an after-use alternative (yes, probably, no). The survey was not sent to the largest Finnish peat producing company, despite the fact that it has a significant amount of land in the area. This was because it is usually selling the cutaway peatlands after peat extraction and the company does not usually operate after-use businesses.

The cover letter was sent via regular mail, but the survey was asked to be filled in on the Internet where the answers were collected using the Wepropol 2.0 program. A voluntary guidance event was held in Tuomarniemi Forest School where it was possible to answer the survey also in paper form. Because there was a lack of responses, the respondents were also contacted by phone to remind them about the survey during April and May 2016. Both the paper and electronic forms were used. In addition, one interview was carried out by phone.

Table 2. Background information of the respondents (*n* = 25, if less then there are missing values).

Background	**Parameter**	**N**
Sex	Women	6
	Men	19
Home municipality	Alavus	9
	Kuortane	1
	Soini	12
	Ähtäri	3
Median age class (a)	41-50	25
Median education class	Upper secondary education and training	24

2.4 Analyses

2.4.1 GIS analyses

The location of potential cutaway peatlands and after-use choice data from the survey were modified to GIS data. The landowners who were interested in bioenergy after-use methods on peat extraction areas were located with the ArcGIS program. Coordinates (ETRS-TM35FIN) were defined to the center of the owned peat extraction area and they were added to the ArcGIS program from the Microsoft Excel 2016 based table. Kernel density estimation was carried out with a Kernel Density tool by emphasizing the points according to the peat extraction area size. The cell size for the results was set to 200 m and the search radius to 5000 m. The most potential peat extraction areas were located by using soil class 32113 (the mining of organic soil, usually peat) from the Finnish topographic database by using methods from previous studies (Laasasenaho et al. 2016).

2.4.2 Statistical analyses

The survey was analyzed with the SPSS program v. 22.0 (IBM Inc., Armonk, NY). Spearman's correlation coefficient values were determined for background variables and environmental attitudes and for bioenergy production alternatives (2-tailed) with the statistical significance level of $p = 0.05$ (Analyze → Correlate → Bivariate). Missing values were omitted pairwise. The Compute Variable tool was used to calculate integrated values for environmental values and different forms of bioenergy (combustion, biogas production and gasification of agriculture or forest based plants and energy willow).

3 Results

3.1 Potential peat extraction areas

At first, logistically the most potential future cutaway peatland areas for bioenergy production were identified. Most of the peat extraction areas in the Kuudestaan region are inside the 10 km buffer zone defined from municipal centers and large scale farms. However, a large proportion of the peat extraction areas in the Soini municipality were located outside this buffer area, making them logistically challenging (Fig. 2). The total area under peat extraction is 6035 ha in the "Kuudestaan" region and 4742 ha are located inside the buffer zone (79 % of the total peat extraction area).

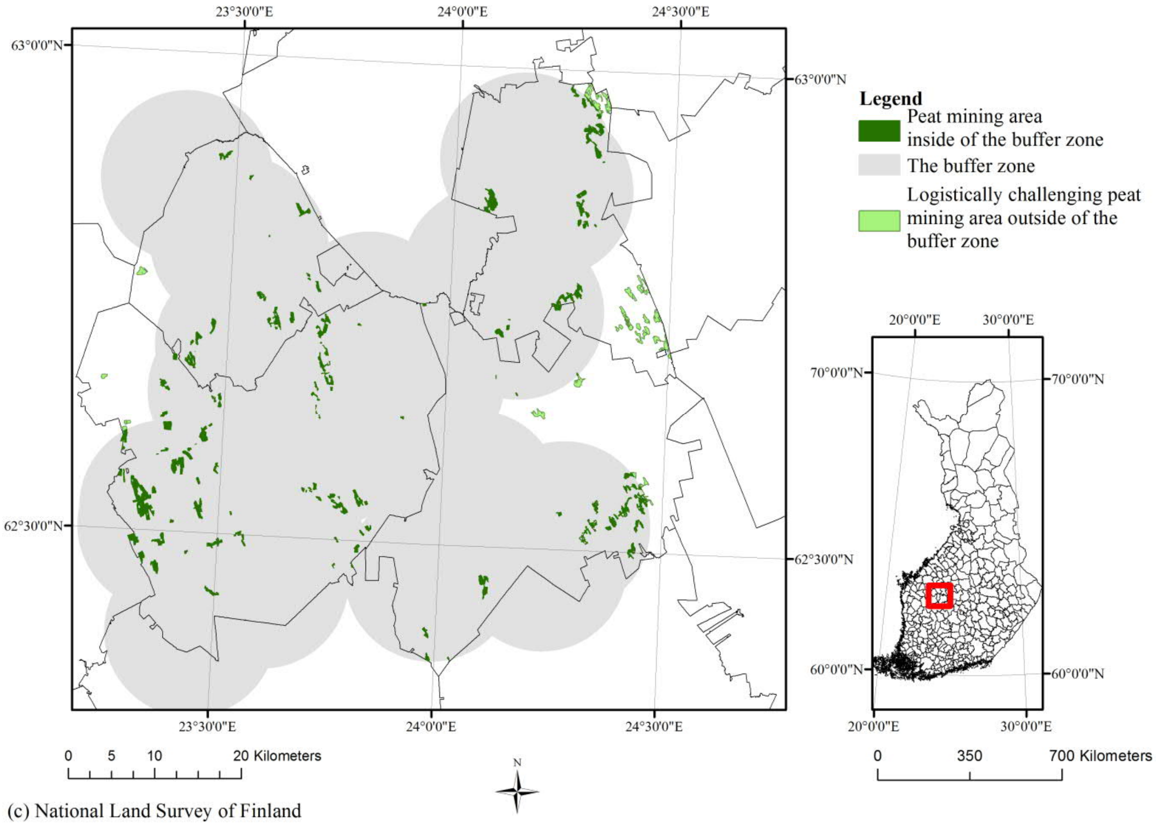

Fig. 2. Logistically the most promising peat extraction areas and remote peat extraction areas in the "Kuudestaan" region were determined using the ArcGIS program.

3.2 The results of the survey

3.2.1 Evaluation of different after-use methods

The respondents lived a little bit over 20 km away from the owned peat extraction area on average, and they had a positive attitude towards nature. 84 % of the respondents lived in Soini and Alavus, and the mean owned area sizes in these municipalities were 27 and 22 ha respectively (Table 3).

According to the survey, the highest ranked after-use method was afforestation amongst all of the respondents (on average 5.6 out of 7; Table 4). Anyhow, the interest to grow biomass for bioenergy production was the highest in both Alavus and Soini municipalities (Fig. 2). There was lack of responses from Kuortane and Ähtäri and none of the landowners were interested in bioenergy production in Ähtäri. However, in Alavus and Soini the cutaway peatlands in the potential locations are not immediately available, because there are long renting contracts and usually many years of peat extraction going on in the areas. The cumulative amount of released peat extraction areas for bioenergy production was close to 500 ha by the year 2035 (Fig. 3). However, a significant proportion of the peat extraction areas will be in the cutaway phase until the mid-2020's.

Most of the landowners (80 %) were interested in growing biomass for energy production as an after-use method. Over half of the respondents (56 %) were farmers and 86 % of them were also interested to use their agriculture fields in growing biomass for bioenergy production as well. This agricultural field area was 320 ha in total. The best bioenergy production chain was forest energy for heat production. Overall, the forest energy was considered as the best biomass type while the agro biomass was the second most favorable option. Willow seems to be the least attractive choice of all bioenergy conversion technologies (Table 5).

Table 3. Background information of the respondents and environmental values (*n* = 25, if less then there are missing values).

Background	**Parameter**	**Std. Deviation**	**N**
Mean distance between home and the owned peat extraction area	20.3 km	33.2	24
Median size of the peat extraction area	over 30.1 ha		24
Mean ending year of the peat extraction	year 2023	7.1	21
The most common after-use method in the peat extraction plan	Undefined		23
Interested in producing biomass for bioenergy production as an after-use method	Yes		20
	No		5
Farmers	Yes		14
Integrated environmental value*	5.3	1.6	Min. 24

*evaluation from 1 to 7 = = not significant … very significant

Table 4. Different after-use methods evaluated by the landowner of the peat extraction areas.

After-use method*	**Mean value**	**Std. Deviation**	**N**
Afforestation	5.6	1.5	25
Energy crop plantation	5.0	1.7	24
Agriculture	4.8	1.8	24
Special plant cultivation	4.3	1.6	25
Wetland	3.9	1.7	25
Pasture	3.4	2.0	19
Mire regeneration	3.4	2.1	24
Nature tourism	2.9	1.5	24

*evaluation from 1 to 7 = not important…very important

Table 5. The three most realistic bioenergy after-use methods from the landowner's perspective in every biomass type (CHP = Combined Heat and Power).

Bioenergy production chain*	**Value**	**Std. Deviation**	**N**
Forest biomass for heat production	5.00	1.44	25
Forest biomass for CHP	4.92	1.41	25
Forest biomass for syngas based heat production and CHP	4.56	1.58	25
Agrobiomass for heat production	4.40	1.8	25
Agrobiomass for CHP	4.40	1.87	25
Agrobiomass for biogas based CHP	4.40	1.85	25
Energy willow for heat production	4.20	1.89	25
Energy willow for CHP	4.16	1.86	25
Energy willow for syngas based vehicle fuel production	3.84	1.8	25

*evaluation from 1 to 7 = not a meaningful method … a very meaningful method

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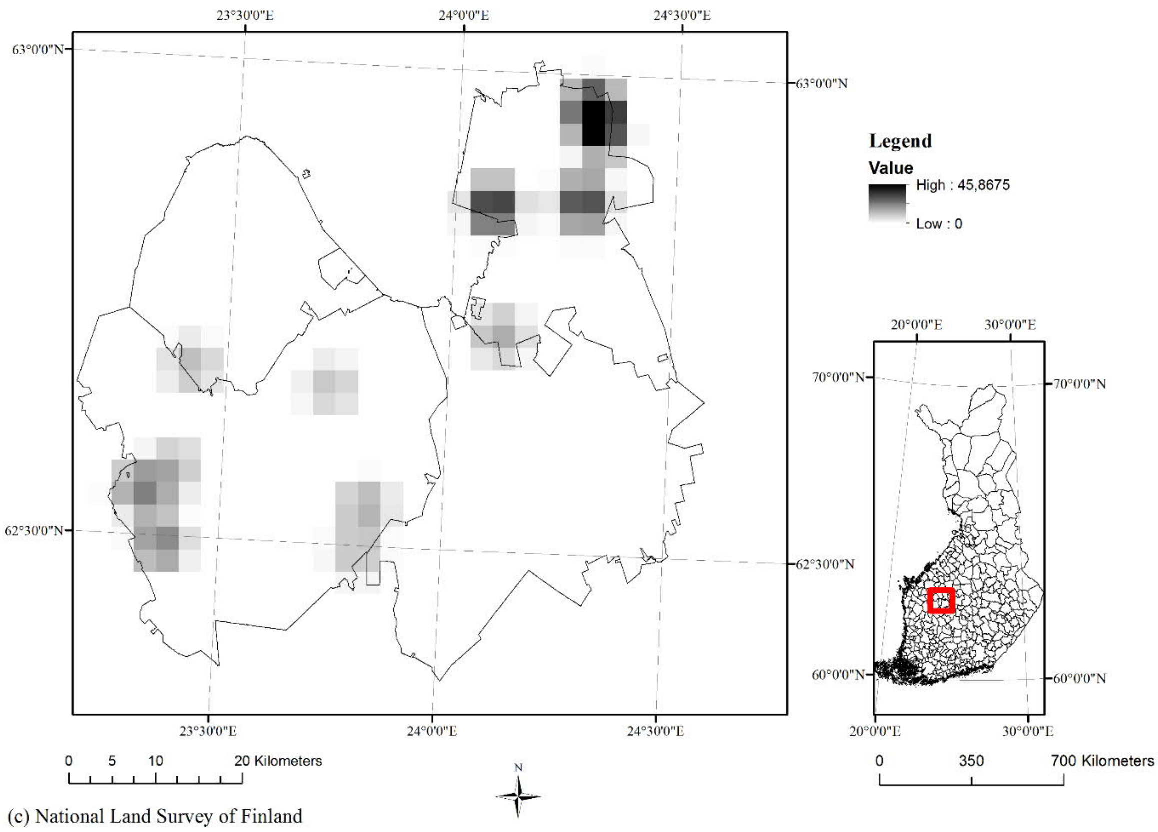

Figure 2. Kernel density map of the most potential areas to grow energy crops on cutaway peatlands by the year 2035. The color illustrates the relative density only, not specific units (© NLS, 2014).

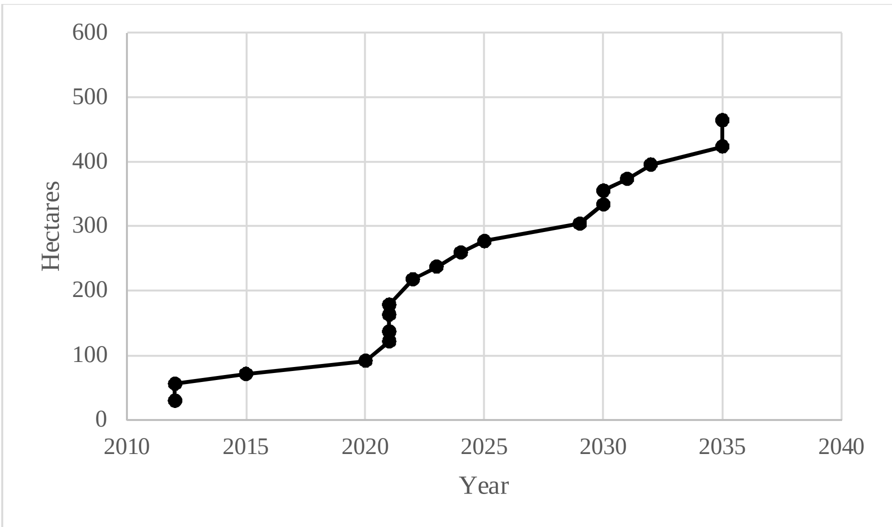

Fig. 3. The area released from peat extraction (over 15 ha units) per year which could be utilized in energy crop cultivation based on the landowner's willingness to do so in the "Kuudestaan" region.

3.2.2 Correlations between variables

Different background values and measured variables were then analyzed with Spearman's correlation analysis to observe specifically future land use related questions. The statistical significance was measured between the variables presented in Table 6. The strongest positive correlation was noted between the willingness to promote energy crop cultivation and the willingness to promote special plant growing. Strong correlation was also seen between the distance between the home and the owned area and the ending time of the contract/peat extraction. Moreover, the size of the owned area was positively correlated with the willingness to promote future forest energy on the cutaway peatlands. Negative correlation was obtained between the size of the area and the distance between the home and the area, which means that local people usually own the biggest peat extraction areas. There was negative correlation also between the willingness to promote energy crop cultivation and the willingness to promote mire regeneration, but the highest negative correlation was calculated between the willingness for mire regeneration and the size of the owned area.

Table 6. Spearman's correlation coefficient (2-tailed, $p < 0.05$) between the significant variable pairs in the survey.

Variable pairs	**Correlation coefficient**	**p-value (2-tailed)**	**N**
Positively correlating variables			
The willingness for energy crop cultivation//The willingness for special plant growing	0.672	< 0.000	24
The ending time of production//The distance between home and the area	0.515	0.02	20
The willingness to promote future forest biomass usage in bioenergy production//The size of the owned area	0.46	0.024	24
The willingness for afforestation//The willingness for wetland	0.44	0.028	25
Negatively correlating variables			
The willingness for mire regeneration// The size of the owned area	–0.637	0.001	23
The willingness for energy crop cultivation//The willingness for mire regeneration	–0.562	0.004	24

The distance between home and the area//The size of the owned area	–0.447	0.028	24
Nature matters to you//The distance between home and the area	–0.408	0.048	24

4 Discussion

The role of the cutaway peatland, as a potential wasteland to be promoted to grow energy crops, is notable. This study clarifies the future land use of peat extraction areas and suggests that afforestation will supposedly be the most common after-use method in Finland. In Finland, afforestation can be seen as a natural choice because most of the land (86 %) is anyhow covered by forest (Natural Resource Institute Finland 2015). Previous studies support this study about the popularity of afforestation (Selin 1999, Kittamaa & Tolvanen 2013, Karjala 2014). Anyhow, a new finding in this study was that forest energy will be the best bioenergy option on cutaway peatlands and that especially the biggest cutaway peatlands will most probably be converted to forest energy if bioenergy is promoted. The results also show that GIS based methods are promising ways to investigate potential peat extraction areas, as well as other wasteland types, in assuming biomass potential when it is used together with spatial data collected from a survey. The methods helped to recognize spatial distribution and gave data for, e.g., further bioenergy plant planning (Fig. 4).

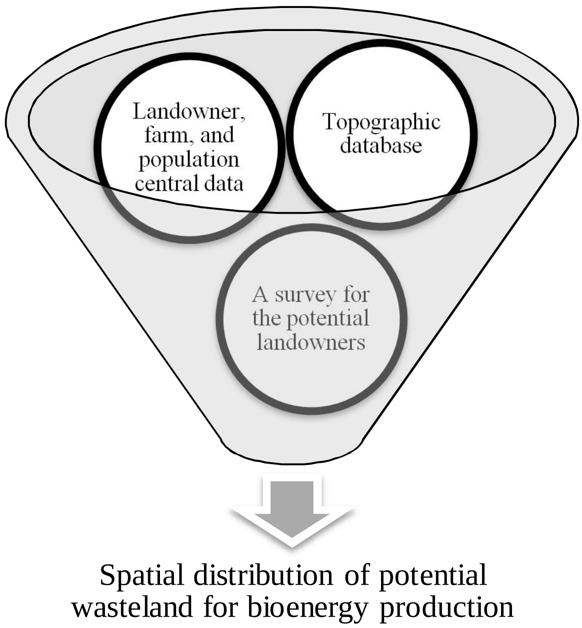

Fig. 4. Generic model of bioenergy planning on wasteland based on GIS data

However, the accuracy of the analysis could be improved by taking into account the road network and by optimizing plant locations and transport distances with the Network Analyst toolset in ArcGIS. The bigger concern was the scarcity in the location of large scale farms. Most of the farmers do not share their background information (when asked by Evira), so it was not possible to get spatial information about all available middle and large scale farms. This had a very significant effect on the searching of the most potential bioenergy production areas. In some cases, a larger buffer zone could have improved the analysis as well as if the farms and population centers in neighbor municipalities would have been taken into account.

However, the reason why significant areas of peat extraction areas are left outside of the buffer zone (10 km radius from large scale farms and municipality centrals) in Soini municipality is caused by the smaller population and amount of agriculture. The municipality is mostly sparsely inhabited in the countryside, having a total population of only 2,284 inhabitants (Statistics Finland 2013). This fact supports the assumption that peat extraction areas are usually located in remote locations (Salo & Savolainen 2008). Afforestation can be the best after-use method in these areas, because they are mostly already under traditional forestry. However, there are more people living in the city of Alavus, having a population size of 12,228 (Statistics Finland 2013) which can be seen as a bigger and a more comprehensive buffer zone. The reason why there is overall bigger potential in Soini municipality is caused partially by the fact that the owned land areas are bigger compared to Alavus, where the division of land between the landowners is more fragmented. In other words, there are usually more landowners in one peat extraction area in Alavus than in Soini.

The respondents to the survey were quite similar to average forest owners in Finland. A typical forest owner in Finland is a 60-year-old man. Generally, only approximately 25 % of forest owners are women (Hänninen et al. 2011) which can be seen as a similar proportion of women in this study (24 %). The educational level of the respondents was relatively low, and even though there was a short information page about different bioenergy chains attached to the survey, the lack of knowledge can cause errors in the results. It was not possible to measure the level of background knowledge separately in the survey. Respondents could have a lack of knowledge specifically concerning different energy conversion technologies, such as gasification and biogas production, but also concerning economical income levels. The ignorance about economical income and rental rates could be studied e.g. by using a contingent valuation survey (Hayden 2014). For instance, many landowners had a negative impression about RCG because the cultivation for combustion plants failed in the last 10 years (fall in RCG cultivation, Farm business register 2015, Kautto 2014) which could have an effect on investments. This was seen during the guidance event held in Tuomarniemi Forest School and in the interview which was carried out by phone. Also, there was a lack of responses from Ähtäri and Kuortane municipalities. However, this could probably be interpreted as a signal of a slightly negative attitude towards biomass growing for energy production, but it is also caused by the smaller intensity of peat extraction.

It was notable that the landowners in the “Kuudestaan” region were not very interested in wetlands, which was one of the best after-use methods according to local inhabitants in North Ostrobothnia (Kittamaa & Tolvanen 2013). Also, special plant tillage was evaluated much higher in this study. It is no surprise that landowners prefer economically profitable after-use methods.

According to the landowners, in some cases, if economic and environmental circumstances meet, energy crop growing and agriculture can be better options compared to afforestation. Depending on governmental decisions, such as energy crop subsidies, energy crop cultivation can become a more and more common way to utilize cutaway peatlands in the future. The fact that local people usually own the biggest cutaway peatlands has a positive effect if distributed bioenergy production is promoted. This study suggests that the biggest cutaway peatlands will fall into forest based bioenergy production more commonly in the future. The interesting thing, as a suggestive result, is that the distance between home and the owned area was not seen as barrier to bioenergy production (correlation coefficient –0.386, p-value 0.063, n = 24) which can have a clearly positive effect towards the promotion of distributed bioenergy. There were interesting negative correlations between the willingness to promote regeneration of peatlands and energy crop cultivation. This could be seen as a disagreement between the regeneration of mires and the cultivation of energy crops; if more of the cutaway peatlands are used for bioenergy production. As a contradiction, a suggestive result was also that the people with high environmental values are the most willing to promote agro biomass usage in bioenergy production in cutaway peatlands (correlation coefficient between the future willingness to promote agro biomass usage in bioenergy production and environmental integrate 0.360, p-value 0.084, n = 24).

If local opportunities in the field of bioenergy are available, energy crop growing as an after-use alternative could attract many landowners. The choice to grow energy crops is anyhow highly dependent on future policies and subsidies. Consequently, if more societal support is addressed to energy crop growing, more cutaway peatlands will be taken into biomass cultivation. According to Bryngelsson & Lindgren (2013) large-scale bioenergy production on marginal lands is economically unfeasible because the soil is unproductive in many cases. The same kind of assumptions were observed amongst the landowners when most of them highlighted poor economic profitability, big investments and a lack of governmental support as being practical barriers. Anyhow, the feasibility is plant species dependent. According to Jylhä et al. (2015), there are possibilities for profitably bioenergy production with downy birch even in the climatic conditions in Northern Finland without any governmental incentive schemes or support. It was interesting that the distance between home and the location of the owned area, area size, frost damage or disagreements between the landowners were seen as smaller barriers. As a contradiction, a remote home place of landowners was seen as a significant barrier to energy crop cultivation on abandoned agriculture land in Latvia (Abolina & Luzadis 2015).

There is high interest in using cutaway peatlands as well as agricultural fields for bioenergy production. If the cutaway peatland of 494 ha is combined with the reported agricultural field area of 320 ha, the total potential area for bioenergy could be 814 ha. Theoretically, it would be possible to achieve 13-25 GWh of bioenergy in these areas every year. E.g. gross energy yield of combustion of birch (*Betula pubescens*), RCG by biogas production and willow by combustion could be 13.1, 15.6 and 25.2 GWh a^{-1} respectively (Table 7)

Table 7. Energy and biomass yields of birch (combustion), RCG (biogas) and willow (combustion) grown on cutaway peatlands.

Plant	**Yield total solids (TS) Mg ha^{-1} a^{-1}**	**Ref.**	**Calorific value (TS) MJ kg^{-1}**	**Ref.**	**Energy yield MWh ha^{-1}a^{-1}**
Birch (*Betula pubescens*)	3	Hytönen & Reinikainen 2013, Hytönen et al. 2016	19.30	Alakangas 2000	16.1
RCG (*Phalaris arundinacea*)	6	Parviainen 2007	11.52	Unpublished result	19.2
Willow (*Salix subsp.*)	6	Hytönen 1996	18.54	Hurskainen et al. 2013	30.9

Therefore, the cutaway peatlands can have a supporting role in distributed renewable energy production. In the future more studies are needed, especially about bioenergy production, in which the potential cutaway peatlands are integrated into the same system with other biomass streams. In addition, the expansion of the Finnish forest industry and the need for pulp wood and saw logs is growing in conventional forest land areas.

5 Conclusions

This study investigated cutaway peat extraction lands' after-use for bioenergy production from the landowners' perspective. The results suggest that the most popular after-use method for cutaway peatlands in the near future is afforestation in Finland and combining GIS based methods and a survey can help effectively in the planning of bioenergy production. Finland has large forest resources, so afforestation could be seen as a neutral and familiar choice for the cutaway peatlands. However, agriculture and energy crop growing are both popular methods, but specifically energy crop production needs better subsidies and other support from the society. The most promising and logistically approachable areas for bioenergy production in the "Kuudestaan" region are located in Alavus and Soini municipalities. The survey pointed out that almost 500 ha or 8.2 % of the current peat extraction areas could be used for energy crop cultivation by 2035 in the "Kuudestaan" region. Most of the landowners who own over 15 ha of peat extraction land are interested in growing biomass for energy production as an after-use alternative. The best bioenergy chain is heat production from forest biomass. Less attractive are agro biomass production and energy willow. Overall, gasification of biomasses seems to be less attractive amongst the energy conversion techniques having even negative impressions; especially in the case of willow.

When background information and different variables were compared, significant correlation was measured between the future willingness to promote forest biomass usage in bioenergy production and the size of the owned area. It means that usually the greater the owned land area, the better alternative forest energy is; according to the landowner. There is negative correlation between regeneration of peatlands and energy crop production and it might cause conflicts between nature conservation and bioenergy production in the future. On the other hand, the people who are interested on afforestation are also interested to establish wetlands. But, as a suggestive result, the distance between the landowner's home place and the peat extraction area is not considered a problem.

The future bio economy will have an influence on the land use of cutaway peatlands. Currently, cutaway peatlands have a supplementary role as a place to grow more biomasses on wastelands. This study suggests, also, that GIS based methods can be useful as decision-making tools in bioenergy production planning and the selection of power plant locations.

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References

Abolina, E., Luzadis, V-A. 2015. Abandoned agricultural land and its potential for short rotation woody crops in Latvia. Land Use Policy 49, 435–445.

Abolina E., Volk, T-A., Lazdina, D. 2015. GIS-based agricultural land availability assessment for establishment of short rotation woody crops in Latvia. Biomass Bioenerg 7, 226–72.

Alakangas, E. Suomessa käytettyjen polttoaineiden ominaisuuksia [Properties of fuels used in Finland]. Espoo 2000. Technical Research Centre of Finland, VTT Tiedotteita − Meddelanden − Research Notes 2045. 172 p. + app. 17 p.

Bryngelsson, D., Lindgren K.2013. Why large-scale bioenergy production on marginal land is unfeasible: A conceptual partial equilibrium analysis. Energy Policy 55, 454–466.

Chapman, S., Buttler, A., Francez, A-J., Laggoun-Défarge, F., Vasander, H., Schloter, M., Combe, J., Grosvernier, P., Harms, H., Epron, D., Gilbert, D., Mitchell, E. 2003. Exploitation of northern peatlands and biodiversity maintenance: a conflict between economy and ecology. Frontiers in Ecology and the Environment 1, 525-532. http://dx.doi.org/10.1890/1540-9295(2003)001[0525:EONPAB]2.0.CO;2

Dale, V., Kline, K., Wiens, J.,Fargione, J. 2010. Biofuels: implications for land use and biodiversity. Biofuels and Sustainability Reports. Ecological Society of America.

Edrisi, S., Abhilash, P. 2016 Exploring marginal and degraded lands for biomass and bioenergy production: An Indian scenario. Renewable and Sustainable Energy Reviews 54, 1537–1551.

Erkkilä, P., Ahonpää, H. 2014. Elävä maaseutu – hyvinvoivat ihmiset. Kuudestaan strategia 2014-2020. Kuudestaan ry, Alavus, Finland. Available: http://www.kuudestaan.net/Documents/Strategia%202014-2020%208.12.2014.pdf (3.8.2016). In Finnish.

Farm business register 2015, Agency for Rural Affairs, Finland [cited 22.10.2015].

Gamborg, C., Millar, K., Shortall, O., Sandøe, P. 2012. Bioenergy and Land Use: Framing the Ethical Debate. J Agric Environ Ethics 25, 909–925. DOI 10.1007/s10806-011-9351-1

GTK (Geolocigal Survey of Finland) 2016. Turvevarojen tilinpito. Available: http://gtkdata.gtk.fi/Turvevarojen_tilinpito/index.html (17.2.2016). In Finnish.

Hayden, N. 2014. Landowner willingness to supply marginal land for bioenergy production in Michigan. Master Thesis. Department of Agricultural, Food and Resource Economics, Michigan State University. 107 p. 1553299

Huopalainen, M., Tuittila, E-S., Laine, J., Vasander, H. 1998. Seed and Spore Bank in a Cutaway Peatland Twenty Years after Abandonment. International Peat Journal 8, 42-51.

Huotari, N., Tillman-Sutela, E., Kauppi, A., Kubin, E. 2006. Fertilization Ensures Rapid Formation of Ground Vegetation on Cut-Away Peatlands. Canadian Journal of Forest Research 37, 874-883.

Huotari, N., Tillman-Sutela, E., Kubin, E. 2009. Ground Vegetation Exceeds Tree Seedlings in Early Biomass Production and Carbon Stock on an Ash-Fertilized Cut-Away Peatland. Biomass and Bioenergy 33, 1108-1115. http://dx.doi.org/10.1016/j.biombioe.2009.05.009

Hurskainen, M., Kärki, J., Korpijärvi, K., Leinonen, A., Impola, R. 2013. Pajun käyttö polttoaineena kerrosleijukattiloissa [The use of willow as a fuel in fluidized bed boilers]. Research Report VTT-R-06093-13. VTT Technical Research Centre of Finland Ltd . 43 p. In Finnish.

Hytönen, J. 1996. Biomass production and nutrition of short rotation plantations. – Working Papers of the Finnish Forest Research Institute (Doctoral dissertation). ISBN 951-40-1494-4. 61 p.

Hytönen, J., Reinikainen O. 2013. Energiapuuta suopohjilta? (Energy wood from cutaway peatlands?). Presentation in “Älyäkkö nää energiaa” –seminar, 11th of November in 2013 Oulu, Finland. Available: http://www.metsakeskus.fi/sites/default/files/1._energiapuuta_suonpohjilta_oulu_2013_final.pdf (1.7.2016).

Hytönen, J., Ahtikoski, A., Aro, L., Jylhä, P. 2016. Short-rotation downy birch for energy on cutaway peatlands: cultivation, harvesting and financial performance. Suo- Mires and Peat 67(1), 13-17.

Hänninen, H., Karppinen, H., Leppänen, J. 2011. Suomalainen metsänomistaja 2010 (Finnish Forest Owner in 2010). Working Papers of the Finnish Forest Research Institute 208. Vantaa, Finland. ISBN 978-951-40-2318-7 Available: http://www.metla.fi/julkaisut/workingpapers/2011/mwp208.pdf (20.6.2016). In Finnish.

Jylhä, P., Hytönen, J., Ahtikoski, A. 2015. Profitability of short-rotation biomass production on downy birch stands on cut-away peatlands in northern Finland. Biomass and Bioenergy 75, 272-281. doi:10.1016/j.biombioe.2015.02.027

Järveoja, J., Laht, J., Maddison, M., Soosaar, K., Ostonen, I., Mander, Ü. 2013. Mitigation of greenhouse gas emissions from an abandoned Baltic peat extraction area by growing reed canary grass: life-cycle assessment. Reg Environ Change 13(4), 781–95.DOI: 10.1007/s10113-012-0355-9

Karjala, P. 2014. Reuse of peat-mining areas Haapaneva and Vuorenneva in Alavus. Forestry training programme, Thesis. Seinäjoki University of Applied Sciences. 54 p. (In Finnish, with English abstract).

Kautto, M. 2014. Production Engineer in Vapo. Personal communication [2014 May 12].

Kittamaa, S., Tolvanen, A. 2013. Suopohjien jälkikäyttö Pohjois-Pohjanmaalla ja Kainuussa – esimerkkialueena Kuivaniemi. Working Papers of the Finnish Forest Research Institute 258:112–153. 253 p. ISBN 978-951-40-2412-2 (PDF). Available: http://www.metla.fi/julkaisut/workingpapers/2013/mwp258.htm. (in Finnish)

Laasasenaho, K., Lensu, A., Rintala, J. 2016. Planning land use for biogas energy crop production: The potential of cutaway peat production lands. Biomass Bioenerg 85, 355–62.

Laasasenaho, K. 2012. Possibilities to utilize biogas in small rural communes – a case study at Soini commune. Master Thesis. University of Jyväskylä, Faculty of Science. Department of Biological and Environmental Science -Environmental Science and Technology, Jyväskylä, Finland.

Leupold, S.2004. After use of cutaway peatlands – an overview of options and management planning. Swedish University of Agricultural Sciences, Department of Forest Ecology; Umeå, Sweden. Available from: http://www.gret-perg.ulaval.ca/fileadmin/fichiers/fichiersGRET/pdf/Doc_generale/Stencil108.pdf (16.7.2015).

Lötjönen, T., Knuuttila, K. 2009. Pelloilta bioenergiaa –opas ruokohelven käyttäjille. Jyväskylä Innovation Oy ja Maa- ja elintarviketalouden tutkimuskeskus. Jyväskylä. Available: http://www.motiva.fi/files/4244/Pelloilta_energiaa_opas_ruokohelven_kayttajille.pdf (20.5.2016). In Finnish.

Ministry of Environment. 2015. Turvetuotannon ympäristönsuojeluohjeet (Guidelines for environmental protection in peat mining). 92 p.” Available: https://helda.helsinki.fi/bitstream/handle/10138/155221/OH_2_2015.pdf?sequence=1 (22.6.2017). In Finnish.

Mäkiranta, P., Hytönen, J., Aro, L., Maljanen, M., Pihlatie, M., Potila, H., Shurpali, N., Laine, J., Lohila, A-L., Martikainen, P.J., Minkkinen, K. 2007. Soil greenhouse gas emissions from afforested organic soil croplands and cutaway peatlands. Boreal Environmental Research 12, 159-175.

Natural Resource Institute Finland. 2015. E-yearbook of food and natural resource statistics for 2015. available: http://stat.luke.fi/sites/default/files/e-yearbook-foodandnaturalsource-2015_2_0.pdf (9.6.2017).

Oxford Dictionary. 2016. Term “wasteland”. Available: http://www.oxforddictionaries.com/definition/english/wasteland (24.2.2016).

Pahkala, K., Isolahti, M., Partala, A., Suokannas, A., Kirkkari, A-M., Peltonen, M., Sahramaa, M., Lindh, T., Paappanen, T., Kallio, E., Flyktman, M. 2005. Ruokohelven viljely ja korjuu energiantuotantoa varten. 2. korjattu painos (Farming and harvesting of reed canary grass for energy production). Maa- ja elintarviketalouden tutkimuskeskus. Jokioinen, Finland. In Finnish.

Paikkatietoikkuna. 2016. Map Window [Internet]. Available: http://www.paikkatietoikkuna.fi/web/en/map-window (17.2.2016). In Finnish.

Parviainen, T. 2007. Optimization of reed canary grass cultivation on the cutaway peatlands. The influence of geological surroundings, peat characteristics and fertilizers to the element uptake and yield of reed canary grass, PhD thesis, Faculty of Science, Department of Geosciences, University of Oulu, Finland. In Finnish with English abstract.

Picken, P. 2006. Land-use scenarios for Finnish cutaway peatlands – based on the mineral subsoil characteristics. Bull Geol Soc Finl 78, 106–19.

Salo, H., Savolainen, V. 2008. Turvetuotantoalueiden jälkikäyttö. – Opas alan toimijoille (After-use of peat production areas - A guide for stakeholders). Association of Finnish Peat Industry. Available from: http://www.turveteollisuusliitto.fi/user_files2/files/Turvetuotantoalueiden_jalkikaytto_laaja_opas_print_small.pdf. ISBN (PDF) 978-951-95397-8-2 (1.12.2015). In Finnish.

Scarlat, N., Dallemand, J-F., Banja, M. 2013. Possible impact of 2020 bioenergy targets on European Union land use. A scenario-based assessment from national renewable energy action plans proposals. Renewable and Sustainable Energy Reviews 18, 595–606.

Selin, P. 1999. Turvevarojen teollinen käyttö ja suonpohjien hyödyntäminen Suomessa. Summary: Industrial Use of Peatlands and the Re-Use of Cutaway Areas in Finland. Jyväskylä Studies in Biological and Environmental Science, No. 79, University of Jyväskylä, Jyväskylä, Finland. 239 p. In Finnish with English abstract.

Silvan, N., Hytönen, J. 2016. Impact of ash-fertilization and soil preparation on soil respiration and vegetation colonization on cutaway peatlands. American Journal of Climate Change 5, 178-192. http://dx.doi.org/10.4236/ajcc.2016.52017

Statistics Finland. 2013. Kuntien avainluvut (Basic knowledge about Finnish municipalities). Updated on 31st of December 2013. Available: http://www.stat.fi/tup/alue/kuntienavainluvut.html (1.7.2016). In Finnish.

Stoof, C., Richards, B., Woodbury, P., Fabio, E., Brumbach, A., Cherney, J., Das, S., Geohring, L., Hansen, J., Hornesky, J., Mayton, H., Mason, C., Ruestow, G., Smart, L., Volk, T., Steenhuis, T. 2015. Untapped Potential: Opportunities and Challenges for Sustainable Bioenergy Production from Marginal Lands in the Northeast USA. Bioenerg. Res. 8, 482–501. DOI 10.1007/s12155-014-9515-8

Tolvanen, A., Juutinen, A., Svento, R. 2013. Preferences of local people for the use of peatlands: the case of the richest peatland region in Finland. Ecology and Society 18(2), 19. http://dx.doi.org/10.5751/ES-05496-180219

World Energy Council. 2013. WEC Survey of Energy Resources [Internet], World Energy Resour. peat. Lond. Available: http://www. worldenergy.org/wp-content/uploads/2013/10/WER_2013_6_Peat.pdf. (7.6.2017).

Xue, S., Lewandowski, I., Wang, X., Yi, Z. 2016. Assessment of the production potentials of Miscanthus on marginal land in China. Renewable and Sustainable Energy Reviews 54, 932–943.