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FRESHABIT A2 Task 4: Assessment of freshwater ecosystem services in the Koitajoki Catchment in North Karelia with associated land use changes and restoration

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Contents

List of tables

List of Figures

List of maps

Summary

Task 4 of the FRESHABIT LIFE A2 is the evaluation of land use on ecosystem services in the Koitajoki catchment in North Karelia. Land use changes and their effects on ecosystem services of mires and freshwater systems are a central aspect of A2 Task 4, together with the effect of restoration on ecosystem services.

The task has been processed by mapping of available ecosystem service indicators to express the potential supply of specific ecosystem services as well as visualizing connections and networks. Statistics were used to refer to trends of the last years, particularly for natural resources. Key ecosystem services investigated are water purification, biodiversity and recreation. Results show that the main land use forms forestry, peat extraction and mining have a great impact on ecological functioning and hence, on ecosystem service provision. A slight increase of natural resource management areas can be found within the recent years according to available data. Further, water purification can be enhanced by restoration measures that improve peatlands natural buffer function to retain pollutants and sediments before entering the river. River restoration has a high potential to create spawning habitats for endangered species and migration routes along Koitajoki. Mapped results of available data show a clear distribution of conservation areas and mining and peat extraction areas, forming a green network and natural resource management belt. This suggests a possible co-existence of both extreme land use forms, for which further analyses need to be conducted in order to determine core zones of competitive ecosystem services.

1. Introduction

Land use determines the stock of ecosystem services, from which human benefit in many ways. Ecosystems are exposed to a variety of disturbances and their degradation is followed by massive changes in ecological functioning often caused by intensive land uses. The consequences are imbalances of ecological functions altering ecosystem services. Restoration is a method to restore ecological functioning and hence, the state of many ecosystems. The River Koitajoki and its catchment in the North Karelia Biosphere Reserve serves as an example of ecosystem (services') restoration of peatlands and adjacent freshwater systems and emphasizes the sustainable interaction of natural resource management and ecosystem services.

The Koitajoki catchment is characterized by its large share of peatlands representing a landscape pattern of various wetland types and a high share of forests growing on drained peatlands. Natural resource management and restoration actions are from high relevance, as forestry activities, peat extraction and other mining activities are altering ecosystems in the catchment. Often associated with "undisturbed nature", the Koitajoki catchment area in North Karelia is facing trade-offs between economic targets and nature conservation for the maintenance of biodiversity. The FRESHABIT project has chosen the Koitajoki catchment in the North Karelia Biosphere Reserve to assess the current situation and future development of the area, which arise the following research questions:

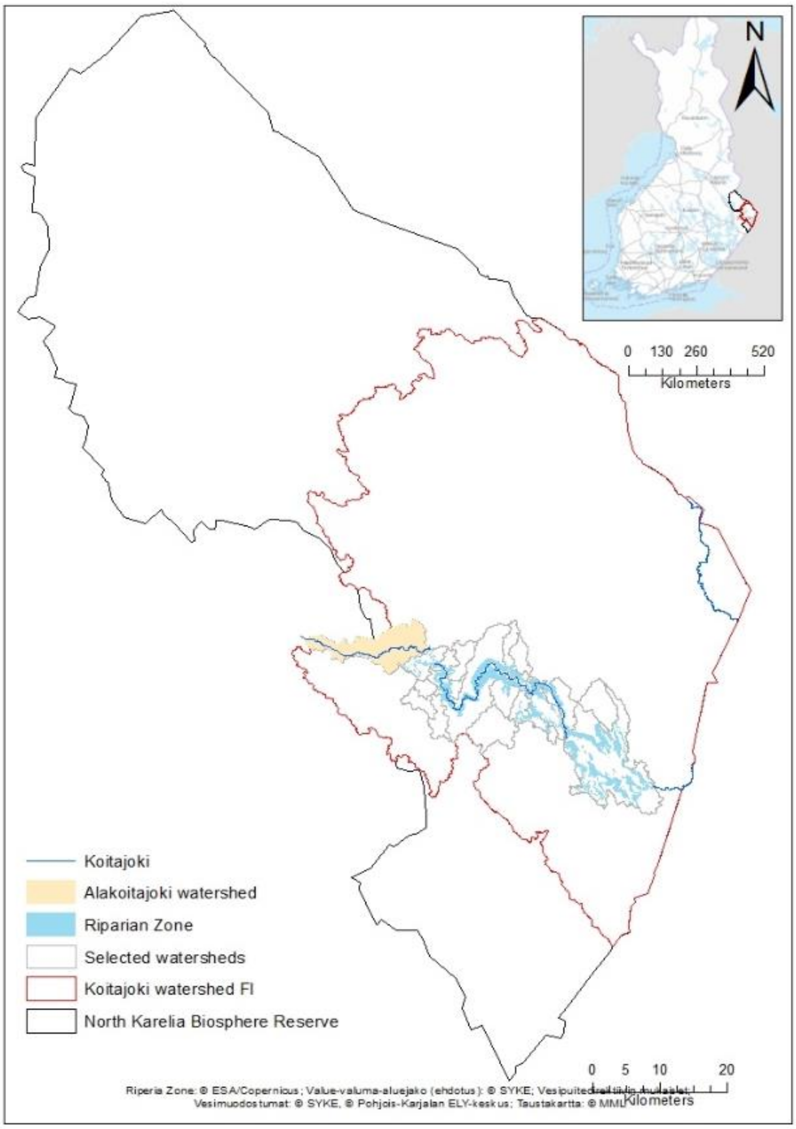
1) How did land use changes affect the provision of ecosystem services in the catchment?
2) What are the effects of peatland and river restoration on ecosystem services?
3) How can natural resource management take biodiversity and ecosystem services of peatlands and freshwaters into account for sustainable decision-making?

2. Study Area

The Koitajoki catchment is situated in the North Karelian Biosphere Reserve (Picture 1) which is part of the UNESCO's Man and the Biosphere Programme (MAB) with the aim to promote wellbeing of local economy and environment through research, education and other cooperation of sustainable development.

The Biosphere Reserve, established in 1992, includes the cities Lieksa and Ilomantsi and Tuupovaara (part of Joensuu) and comprises an area of 8000 km^2 and is home to approx. 17000 people with sparse settlements.

The catchment area of the River Koitajoki (6600 km^2), which is mainly located in the Biosphere Reserve and partly across the Russian border, is one target area of practical restoration measures as a part of the FRESHABIT-project.



Map 1: Outline of the North Karelia Biosphere Reserve and the Koitajoki catchment. Within the catchment, slected sub-catchments and the riparian zone, Koitajoki river within are marked. Highlighted is the Ala-Koitajoki watershed. The report will refer to selected areas in the following.

The Biosphere Reserve and the Koitajoki catchment are situated in a special placement as they are located in a transition zone of middle and south boreal forests and thus it exhibits valuable patterns created by climatic and vegetational gradients visible in the terrain by for example raised bogs and aapa mires. Features of the landscape within the study area are the high number of lakes, peatlands and ponds and geomorphological relicts such as moraines and drumlins. In addition, the region is characterised by its Karelian culture.

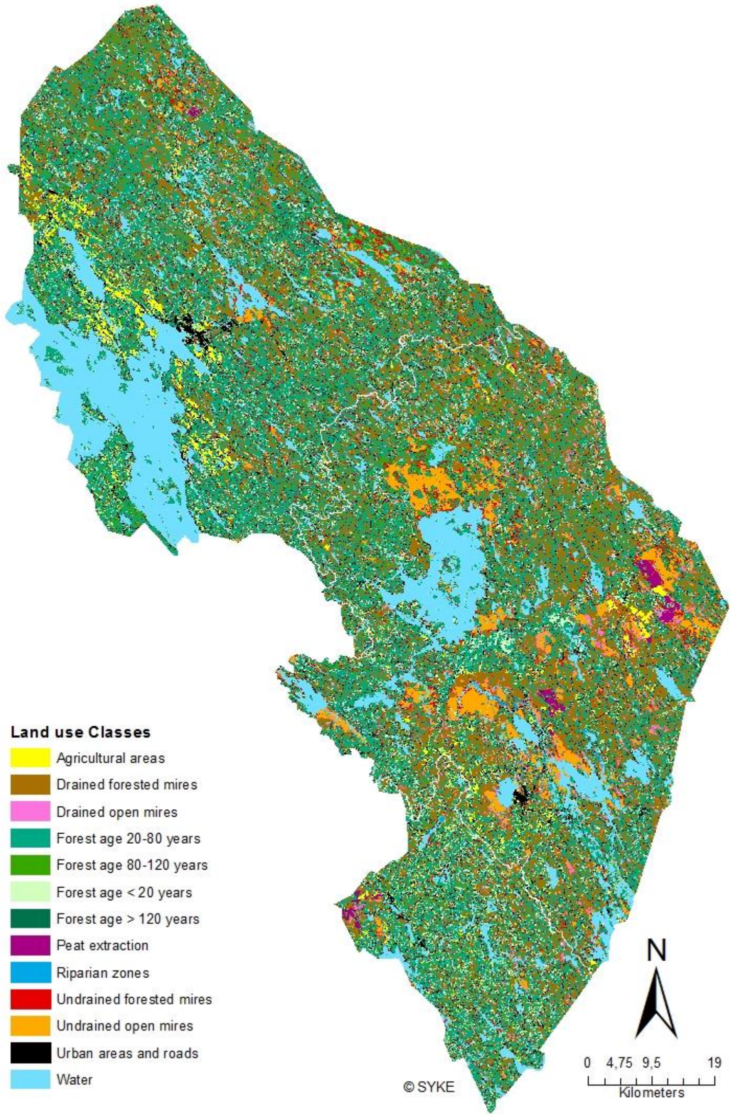
2.1 History of Land Use

The anthropogenic history is strongly related and influenced by this division of vegetation zones for it roughly delineates the most Northern border of the commonly practiced extensive swidden (slash-and-burn) agriculture (until latter half of 19th century) and also represents the border of the Saimaa district of tar burning, which was practiced from the 16th century, peaking in 1870's and declining shortly afterwards. These two exploitation methods had a great impact on the landscape and forest ecosystems as well as on the settlement development. For both practices were restricted in the transition zone, some old-growth forests remained undisturbed within the area that is nowadays the Biosphere Reserve indicated by so called *Kelo*-trees.

Within the 1950's the large-scale logging of forests also affected the areas that were so far undisturbed. Forestry became an important for the economy but also lead to clear cuts and drainage of peatlands. In addition, the use of peat soil increased in the 1970's as a consequence of higher energy demand. In Möhkö, at the Finnish-Russian border, iron huts were built. The raw material was lake iron ore, which was found in lakes and rivers in Ilomantsi and Tuupovaara. In addition, the owners of ironwork had to dig two canals to lead water from River Koitajoki to blast furnaces (SIMOLA 1995)

2.2 Current Land Use

The history of land use underlines the role of natural resources in the study area already back in time and still, it is an important factor nowadays. The North Karelia Biosphere Reserve and Koitajoki catchment are characterised by the large share of forests and wetlands (in particular peatlands). Open mires can be found throughout the entire study area; however, a majority has been drained for forestry purpose (and peat mining) even after the increased peat use for energy in the 1970s.



Map 2: Land use classes in the North Karelia Biosphere Reserve

Table 1: Land use shares within the NKBR in %.

Land Use	Share of area
Forest on mineral soil	57 %
Forest on peat soil	24 %
Water bodies	14 %
Mires	5 %
Agricultural area	2 %
Constructions	1 %
Peat extraction area	0,4 %

Thus, main land use forms are forestry and peat extraction, whereas agricultural areas are only available at a small scale. Hence, the main livelihoods are still related to the use of natural resources focussing on forestry and (peat) mining industry. In addition, the tourism sector gains more and more interest due to the Karelian landscape and the demand for nature tourism.

2.3 Natural resources and management

The high share of peatlands and forests enables the production and use of peat, timber and other natural resources such as ore. As a result, natural resource management plays a key role in local development and is an integral part of local economy. Big companies owning and executing operations regarding natural resources are Vapo Oy, Tornator Oy and Endomines Oy. Besides, Vattenfall (Pamilo Oy) owns a hydroelectric power station fed by

Lake Koitere and Koitajoki River. The use of water is present by Pamilo hydro power plant in Ala-Koitajoki, which is Vattenfall's biggest power plant in Finland.

Competitive land use forms provide different ecosystem services. Thus, land use conversion, which is the case of peatland drainage, leads to the provision of otherwise not available services. Trade-offs are the result of co-existence of various land use forms and their supply and demand of ecosystem services need to be investigated.

2.3.1 Forestry

The wet conditions in the study area require drainage of peatlands for forestry purposes. Thus, the underlying soil of forests stands in the Koitajoki catchment are peat and mineral soil and varies between coniferous forest stands, mixed forest stands and scarcely forested areas. However, draining peatlands does not mean that forests growths and economical benefit is ensured.

Table 2: Forest types on peat soil (2018, left column) and land cover of forested wetlands (rel. 2016/17), right column) within Koitajoki catchment.

Forest types on peat soil (Corine Land Cover 2018)	Area in ha	Land cover of forested wetlands (2016/17)	Area in ha
Decidious forest on peat soil	306	**Low-forested wetland**	2204
Coniferous forest on peat soil	85835	**Forested wetland**	6681
Mixed forest on peat soil	10926	**Low forested/open shore**	104
Scarcely forested area on peat soil cc 10-30%	17853	**Forested shore**	1

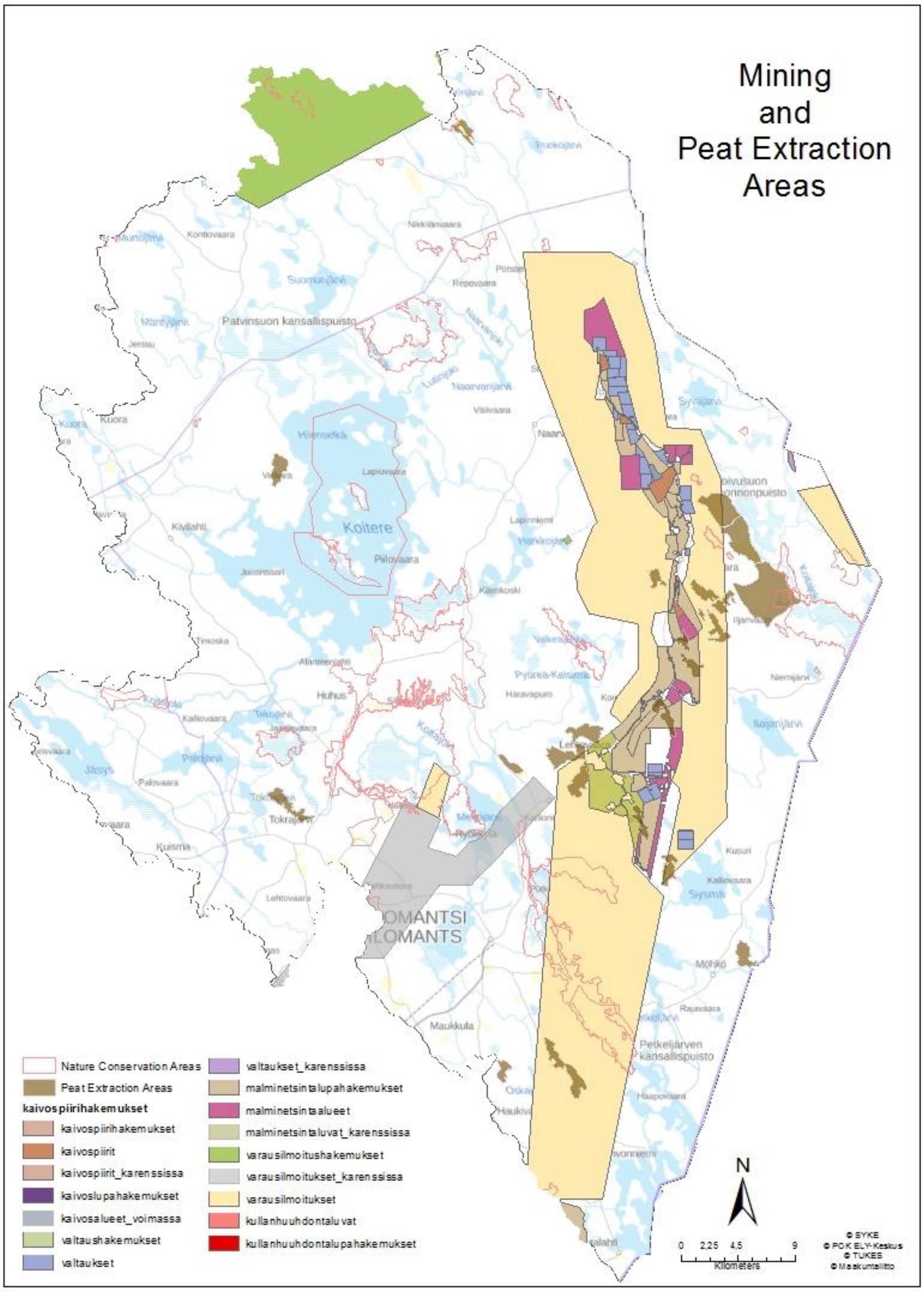
Generally, the profitability of forests stands is, as always, site specific but especially the economic value of drained, forested peatlands differs greatly.

While forests provide their own important ecosystem services ranging from recreational activities over provisioning services (e.g. timber) to regulating services (C-storage) and offer forest-specific biodiversity, it is crucial to distinguish between the different forest types and their management. These determine not only the production of ecosystem services of forest ecosystem services, but at the same time their management can have a great impact on adjacent ecosystem services. In this case, the drainage of peatlands to grow forests and the subsequent (intensive) forest operations quite likely affects peatland and freshwater ecosystems. On the other side, drained peatland for forestry purposes provide material in form of biomass for different purposes (e.g. timber, industrial round wood), that could not have been provided without drainage. At the same time, natural forested peatlands are also present often forming transition zones, which makes it even more difficult to clearly distinguish between these different types in terms of ecosystem provision.

2.3.2 Peat extraction and mining

Peat production in North Karelia has started in the 1970s in the wake of the global energy crisis, which resulted in the rapid shift from nature conservation to using peat on an industrial scale for energy production. Peat production in Ilomantsi started in 1974 during a time when the environmental permits did not yet exist, and the emissions to the effected rivers, like Koitajoki, were much greater. While the emissions from peat production are these days strictly regulated, the combined effects from previous and current production are long-term (Mustonen & Mustonen 2018). Regarding the current state of peat production, during 2000s there has been between 15-17 production areas in use in North Karelia, the average area of extraction ranging from 5100 to 5900 hectares, with some of the largest sites located near the Koitajoki river. While some of the areas will be removed from use during the 2010s, new production is being planned, as evident by the 14 pending peat production permits at the end of 2013 (SYKE, 2014). In contrast to forestry, peat extraction does not offer co-production of other ecosystem services than the extracted peat for energy or horticulture.

Other mining activities in the Koitajoki catchment are gold mining and ore mining. Mining areas (including mining claims and application for permissions) form of a south-north exposed “belt”, located at the height of Patvinsuo National Park but closer to the Russian border. Its central point with ongoing mining is in Hattuvaara, a 296ha gold mine opened in 2011 by Endomines (Mustonen & Mustonen 2018), and come to a stop with only reservation notification areas at the Southern border of the Koitajoki catchment.



Map 3: Mining and peat extraction areas. The map considers all mining exploration districts, including the areas of ongoing mining activities.

2.3.3 Hydro energy

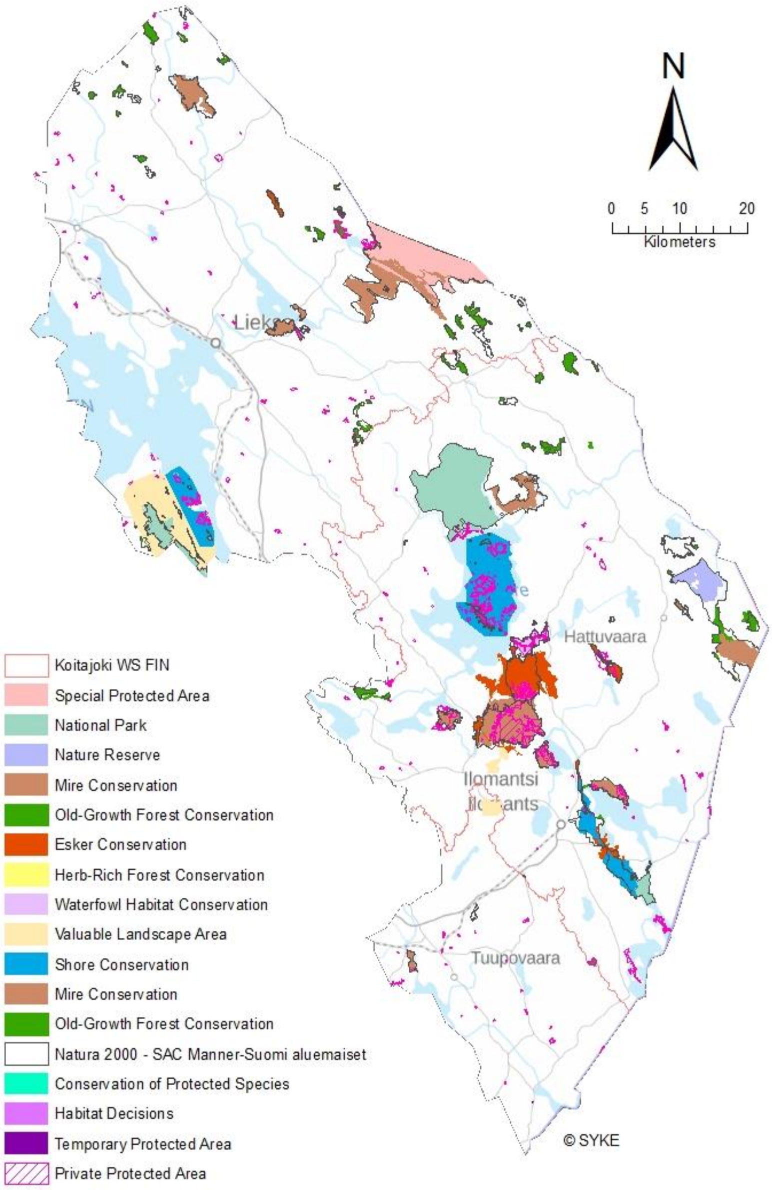
Hydro energy is complementing the list of renewable energies obtained within North Karelia, being famous for it's high share of renewable energies. The Pamilo hydro power plant is located at the Southern-West end of the Lake Palojärvi and regulating the water table of Lake Koitere. Its construction required the dam in Hiiskoski and the regulation of water affecting Ala-Koitajoki river. Palojärvi and Tekojärvi are artificial lakes connecting with Lake Koitere. While hydro power is providing energy services, water regulation can provide many other ecosystem services, such as freshwater provision and flood control but remains an interference into natural river course and flow conditions. In 2016, the energy consumption of renewable energies has been 1471 GWh, which makes a share of 63,9 % from North Karelian energy consumption of renewable energies. Pamilo states, its overall power 84 megawatts, which makes it Finland's 12. most powerful hydro plant and produces an average of 265 000 MWh per year (VATTENFALL, w.y.)

2.4 Nature Conservation

The grounds for protection and conservation are based on the Forest Law, the Land Use and Building Act and the Land Act, and areas in the Koitajoki catchment are protected under various nature conservation programmes. There are six nationwide nature conservation programmes for bogs, birds, esker, herb-rich forests, shores and old-growth forests. In addition, the European Union's Natura 2000 network, established 1996 to prevent biodiversity loss with the focus on birds, is represented by several Natura 2000 protection areas. Moreover, the protection of forest biodiversity is promoted through the METSO programme by promoting private landowners' involvement in voluntary protection through state financial assistance. Throughout the entire study area, private protected areas are situated. Further, the study area has two national parks: Petkeljärvi National Park (1956-) and Patvinsuo National Park (1982-). The Koivusuo Strict Nature Reserve was established in 1982 and some parts of Nature Reserve Kesonsuo were protected starting 1976.

Table 3: Shares of conservation and protected areas within the North Karelia Biosphere Reserve NKBR, (left column) the Koitajoki catchment (right column) in hectares.

	NKBR	Koitajoki catchment
National Park	13279,43	11205,36
Private protected area	7211, 73	5892,89
Conservation area for peatlands	4504,31	3267,77
Nature Park	2206,41	2206,41
Conservation area for old-growth forest	371,93	371,93
Habitat decisions	16,07	1,11
Particular conservation areas for protected species	7,84	0,64
Total	34954,69	22946,11



Map 4: Conservation and protection areas in the North Karelia Biosphere Reserve. The Koitajoki catchment boundary is highlighted with a red line.

2.5 Culture and tourism

A special feature of the North Karelia Biosphere Reserve and the Koitajoki catchment is the "Runon ja Rajan" route via Karelia passing the Eastern border of Finland. Cultural values along the route are given by pilgrim routes with orthodox churches, the iron museum in Möhkö and memorial sites of war. Paateri church, the home of the famous artist Eeva Ryynänen, lies on the Lake Pielinen in Vuonislahti. Following the Finnish-Russian border via Lieksa up to the North, the Runon and Rajan route passes historical sites and ancient relicts giving and inside into traditions, for example the large open-air Pielisen museum.

The history of North Karelia provides interesting targets for tourism but the special location of the Biosphere Reserve and the Koitajoki river course through the reserve offer special spots for particularly nature tourism. Patvinsuo and Petkeljärvi National Park, located in the Koitajoki catchment, offer information on landscape along marked trails though the national parks. Besides, the area has several nature parks and reserves attracting also bird watchers with popular bird watching sites and towers, for example in Kesonsuo. The river Koitajoki is a popular target for adventurers enjoying canoeing and kayaking or simply enjoying the Karelian nature with its silence. The high amount of lakes and rivers provide suitable conditions for recreational fishing.

Figure 1: Runon ja Rajan route via Karelia. Source: Kotimaassa.

3. Restoration

Restoration takes place in freshwater ecosystems. Restoration measures and targets depend on the area to be restored. For peatlands it means that restoration measures depend also on drainage status and if the site is forested or has been forested or extracted. Common restoration measures for peatlands and rivers, that also apply for the case study, are listed in table 4 below.

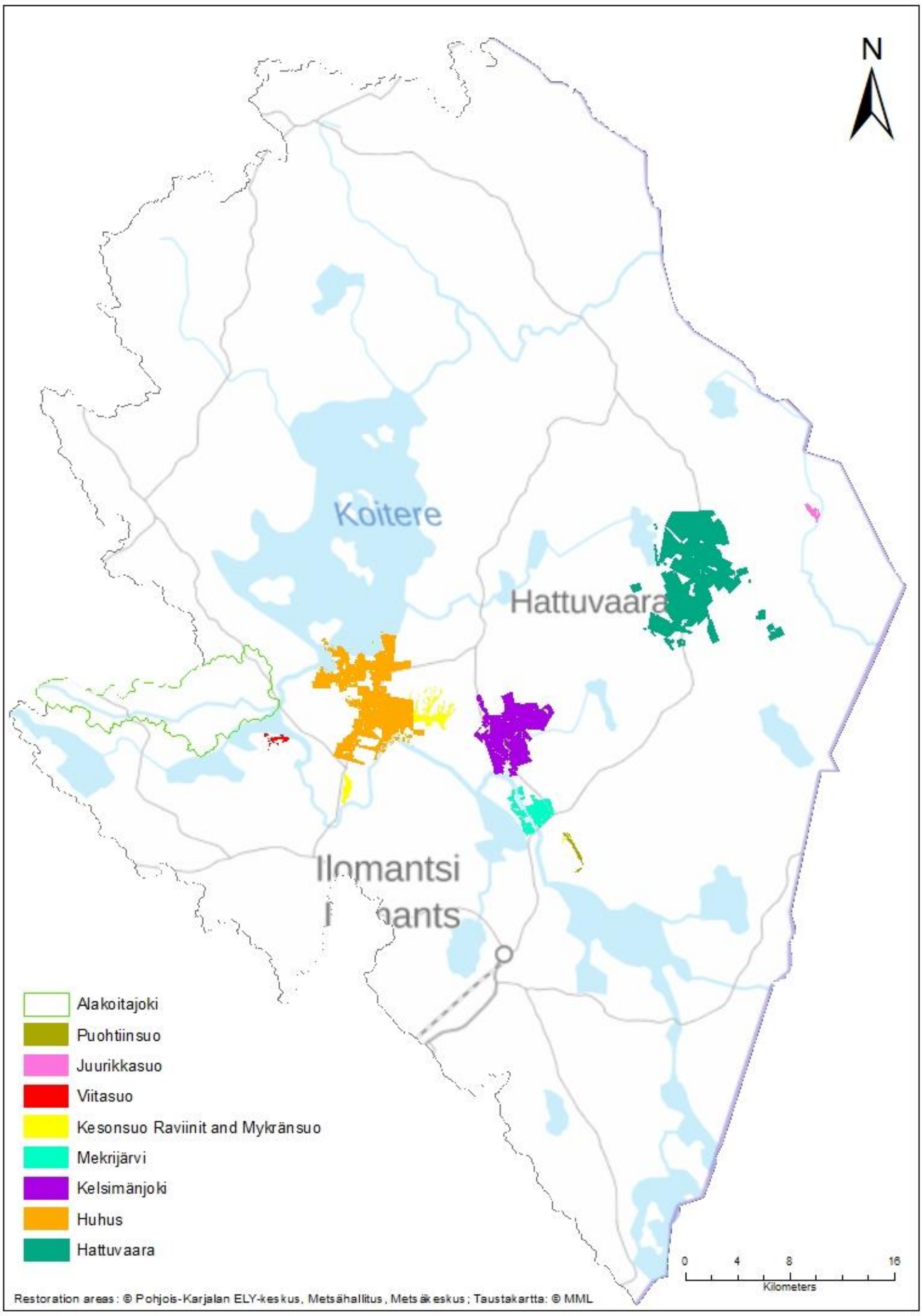
Table 4: List of restoration measures for peatland and river ecosystems

Peatland restoration measures	**River restoration measures**
Blocking of ditches: water table increase	Improvement of river condition (rapids) and spawning grounds
Damming: sediment retention and vegetation re-growth	Restoring artificially cleared current and stream sections
Sedimentation pits: sediment retention	Habitat restoration and creation
Peat bunds: water storage, surface water retention	Promoting and spreading of aquatic plants: Biodiversity increase, shelter provision, access to food
	Creating migration routes for fish

Restoration of ecosystems promotes recovering of ecological functions within a system. Peatland restoration outcomes may vary due to the following reasons: spatial scale (catchment, sub-catchment), target, succession of plant communities, stage of ecosystem destruction and ability to recover. The improvement of ecological functioning is often not (immediately) visible and takes several years up to decades (Bonn et al. 2016). In addition, restoration measures are often associated with a great interference into ecosystems, which means, that sediment and nutrient load can temporarily increase.

The effects of restoration on ecosystem service provision depend on the above-mentioned factors as well. Restoration generally decreases forest-related ecosystem services and peat provision for energy. On the other hand, improvement of ecological functioning is promoting the provision of other ecosystem services listed in Chapter 4. As the process of restoration passes through various stages, also the ecosystem services might alter in quantity and quality. That is, for example, because of the vegetation succession and regrowth. The vegetation of an afforested peatland under restoration embracing forest plant species might slowly be replaced by peatland plant species due to the increase of water table and thus, the provision of berries varies among berry species, quantity and quality (Bonn et al. 2016). It also needs to be mentioned, that climate regulating ecosystem services, such as carbon sequestration and storage indicated by peat accumulation is a very slow process and difficult to measure. At the same time, it is highly discussed to what extent forests growing on drained peatlands would replace the function by sequestering carbon in forest biomass.

In the Freshabit-LIFE project, the forestry center Metsäkeskus makes private forest owners plans for water protection in the following areas: Hattuvaara, Huhus, Kelsimänjoki and Mekrijärvi. Implementations take place through integration projects but depend on the willingness of landowners to be involved.



Map 5: Restoration areas within the Koitajoki catchment, actions are in all stages, implemented, ongoing and in planning.

4. Ecosystem Services and Biodiversity

Ecosystem Services are the benefits human obtain from ecosystems and promote human wellbeing. They can be classified into regulating and maintenance services, provisioning and cultural services. The ecosystem service approach connects supply (ES provided by an ecosystem) and demand (need for specific ES of society), by quantifying both sides biophysically and economically.

This task is focussing on the supply side, that is measurement of ecosystem structures and functions through biophysical quantification, for instance, the quantity of water abstracted from a lake. The measurement of ecosystem services can be divided into direct measurement and indirect measurement. The first measures and quantifies stock or flow values and is very accurate. Whereas the use of direct measurements and primary data involves field observations and surveys mostly applicable only at site-level and not for all ecosystem services, the indirect measurement allows to quantify ecosystem services on a larger scale, e.g. via remote sensing. Unfortunately, indirect measurements are prone to errors but cost efficient. If neither direct nor indirect measurements can be used for the quantification, modelling as a form of simulation can be applied.

The measurement of services can be done by ecosystem service indicators. These indicators allow quantifications of services in physical units or units that require further interpretation (models), which can be subsequently used for statistics and mapping purposes.

For this report, direct and indirect measurements were used to analyses and assess ecosystem services.

For ecological functioning is the basis of all services provided, quantifying ecosystem services via indicators can be quite complex and not all ecosystem services can be measured. One challenge is the quantification of cultural ecosystem services, as they are embracing mostly non-material services as landscape aesthetic or experiences. An ecosystems' capacity to provide certain ecosystem services is restricted and depends on land use (management). Therefore, ecosystems cannot necessarily provide a broad range of services but sometimes focuses on the provision of only one specific services (mostly related to provisioning services, e.g. timber) and often trade-offs are the result of land use conflicts.

There is much discussion about how biodiversity and the provision of ecosystem services are connected. The tendency is to assume, that a higher biodiversity is likely to increase the range of ecosystem services as well. However, it does not necessarily mean that the quantity of ecosystem services increases with increasing biodiversity. Biodiversity rather covers a broad range of services, where the provision of some services is more pronounced than others.

Further, the results of the SuoEko workshop from 2012 show clearly, that the definition of ecosystem services remains in some cases controversial, as for example peat might be seen as an ecosystem service for energy production but at the same time, its provision implies the destruction of an ecosystem and thus, supressing the provision of other services. In addition, the benefits obtained from an ecosystem might vary depending on the scale (regional/local).

4.1 Regulation and maintenance services

Regulation and maintenance services are often less obvious, as they are embracing ecosystem processes such as nutrient cycle and pollination. They are the basis of all other services and therefore support better living conditions. In Finland, carbon cycle and water purification are among the crucial regulating services.

4.2 Provisioning services

For the economy, provisioning ecosystem services have always been vital, with wood as Finland's most important provisioning service. Berries, mushrooms and game count also to this class, but their economic value is not so easy to estimate. However, together with fish, they also reflect on Finnish traditions and history. In addition, bioenergy from forest resources has always been very important.

4.3 Cultural services

Cultural services are usually non-material, as these are the benefits people obtain via recreational activities and experiences. Thus, recreation is often the term in the foreground and opens the doors to tourism. Further, cultural services can be strongly connected to provisioning services as berry and mushroom picking has a high recreational value.

4.4 Freshwater ecosystem services

In the following, ecosystem services of peatlands and freshwaters are regarded for the Koitajoki catchment. The list below gives an overview of the most important peatland and river ecosystem services with adjustment according to boreal landscapes and Koitajoki's meandric, braided river course. Indicators available and used are marked with red under each service. Sources for the ES are *biodiversity.fi*, *Soiden ja turvemaiden ekosyteemipalvelujen tunnistaminen ja arvottaminen- Työpajaraportti* (AAPALA et al. 2012), *TEEB* (KETTUNEN ET AL. 2012), *Linking ecosystem services, rehabilitation, and river hydrogeomorphology (*THORP et al. 2010).

The case study area embraces peatland with different drainage status and land use conversion. These peatlands can be divided into drained, extracted, drained and afforested, undrained open mires and undrained forested mires (the last two can also be classified as pristine mires). The different peatland classification according to their drainage status were taken into account during the entire analysis and assessment and will be referred to in the result and discussion part.

In addition, it is also important to notice, that drained peatlands for forestry purposes and to some extent also undrained forested peatlands host besides peatland ecosystem services also forest ecosystem services, which therefore cannot be neglected completely. However, the focus is not set on forest ecosystem services.

Table 5: Peatland and river ecosystem services and indicators (red). The * is placed on services that are even emphasised by meandric rivers and corresponding floodplains, flood forests and riparian zones.

	Peatland	River
Regulation and Maintenance Services	Water purification (indicator: drainage status)	Water purification (*) (indicator: water quality, chemical status)
	Climate regulation	Climate regulation, water regulation
	Water regulation and flow	Predator-prey relationship/foodweb
	Flood prevention	Flood prevention *
	Erosion control	Erosion control
	Habitat provision (Conservation areas, important bird areas)	Habitat provision * (Spawning and larvae habitats, conservation areas)
Provisioning Services	Berries (Survey, SuoEko workshop)	Water for non-consumptive use (for generating power/transport)
	Game	Water for consumptive use (drinking, agriculture, industry)
	Peat (Indicator: Area (ha) Extraction area, use for energy)	Fish and other aquatic organisms
	Energy wood	
	Timber and pulpwood	
Cultural Services	Hunting, berry picking	
	Landscape aesthetic and beauty (Indicator: Conservation areas)	Landscape aesthetic and beauty * (Indicator: Conservation areas, water quality)
	Recreation (bird watching, hiking)	Recreation (fishing, canoeing, swimming) (Indicators: statistics)

5. Methods

Methods to assess the effects of land uses and ecosystem restoration on mire and freshwater ecosystem services in the Koitajoki catchment required intensive gathering of GIS-data on land cover, biodiversity and other remote sensing and GIS data sets of ecosystems provided by SYKE and other partners.

Due to data limitations, the report includes three different approaches to analyse the relationships:

a) via ecosystem service indicators
b) via Expert assessment from SuoEko workshop 2012
c) via causal relationships

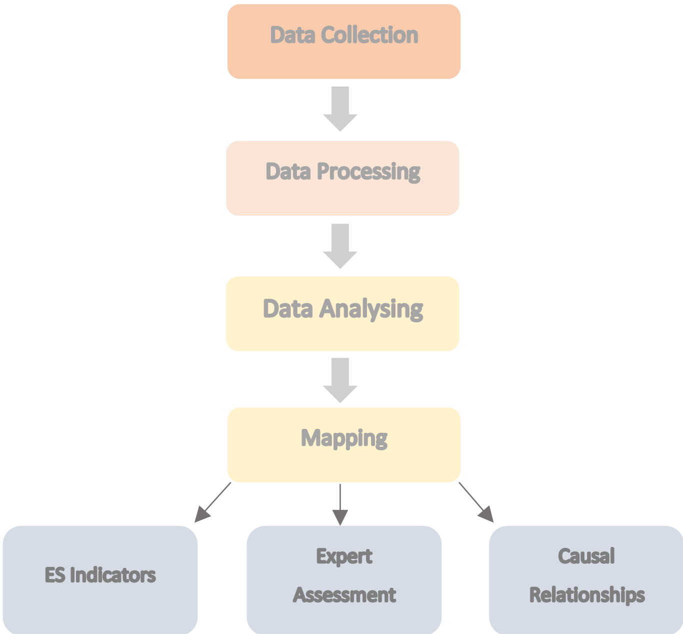


Figure 2: Mapping ecosystem service relationships. Own creation.

Ecosystem service indicators used were data on ecological surface water quality and chemical state as well as data on the usability of water bodies in the catchment. Spawning areas of the endangered whitefish and salmon, as well as important bird habitats, (mire) conservation areas, mire vegetation zones and mire types were used to estimate habitat provision and underline biodiversity. Historical sites and holiday accommodation distribution were analysed considering their density. The merging of Corine land use information and forest-related information of tree composition and age resulted in new land use classes, for which the potential berry distribution was evaluated in the SuoEko workshop in 2012. Land use classes, land use changes, land cover of wetlands, drainage status, peat extraction and mining areas were used to discuss relationships and to extract area values. For the clear cut areas of 2012-2018, hot spot analysis was used to identify accumulation areas. Watersheds and the riparian zone outline of *Copernicus* served as an

approximation where land use can affect most likely. For special occasions, a smaller spatial scale was regarded a land use information was extracted for four different areas: Koitajoki watershed, a watershed cut-out along the Koitajoki river from Nuorajärvi to Ala-Koitajoki, the riparian zone according to Copernicus for the latter named watershed assemblage and for the sub-watershed Ala-Koitajoki. A list of used data can be found in the Appendix.
Data accuracy of Copernicus for the riparian zone along the Koitajoki river is not confirmed yet, however, the designation was only used as an approximation. Further, the Corine Land Cover changes for 2012-2018 for the class forest clear cuts might contain miner amounts of thinning areas.

6. Preliminary Results

6.1 Land use changes and current state

Land use information was available from Corine Land Cover of the years 2000, 2006, 2012 and 2018 and associated land use changes from 2000/06, 2006/12 and 2012/18. The drainage status of peatlands with peat extraction areas was compiled in 2008 and thus provided information of former peat extraction locations.

Table 6: List of land use classes based on Corine Land Cover information 2006, drainage status information 2008 and National Forestry Inventory data 2013.

Land use Classes 2006	Koitajoki catchment	Koitajoki Watersheds Nuorajäarvi-Alakoitakoitajoki	Ala-Koitajoki	Riparian Zone (Nuorajärvi-Alakoitajok)
Forest age < 20 years	48037	2797	573	208
Forest age 20-80 years	280444	15352	3217	2001
Forest age 80-120 years	42643	1345	402	221
Forest age > 120 years	6941	201	54	69
Drained open mires	14293	1354	46	602
Undrained open mires	33230	6670	115	3616
Drained forested mires	167768	12083	1168	1981
Undrained forested mires	29099	2266	324	805

In the Koitajoki catchment, there are no changes in the main land use forms visible with the available data. The compiled land use classes from 2006 show a clear majority of drained forested peatlands, except for the riparian zone. A high percentage of drained forested mires can be seen especially for the Ala-Koitajoki watershed. The category forest age 20-80 is the most present one in all analysed regions, underlining the importance and presence of silviculture (compare table 6). The total area of drained mires and clear cuts within the time frame 2000-2018 can be obtained from the table below. It is assumable, that no major additional drainage of peatland has been done after 2008, when the available information on peatland drainage status has been released. Despite, quantity of land use types has changed, for instance, peat extraction areas have been expanded and have become more numerous (compare table 7) and clear cut areas have increased within 2000-2018 (see table 8). While the extrication area in Mekrijärvi shifted slightly, a decrease in peat extraction areas in Hattuvaara is present. A new extraction site is located in Möhkö. For further consideration of natural resource management, it is evident, that no peat extraction site is located in the Ala-Koitajoki watershed and not immediately within the riparian zone, although extraction is practised adjacent.

Table 7: Extracted information on drainage status and peat extraction sites for different locations.

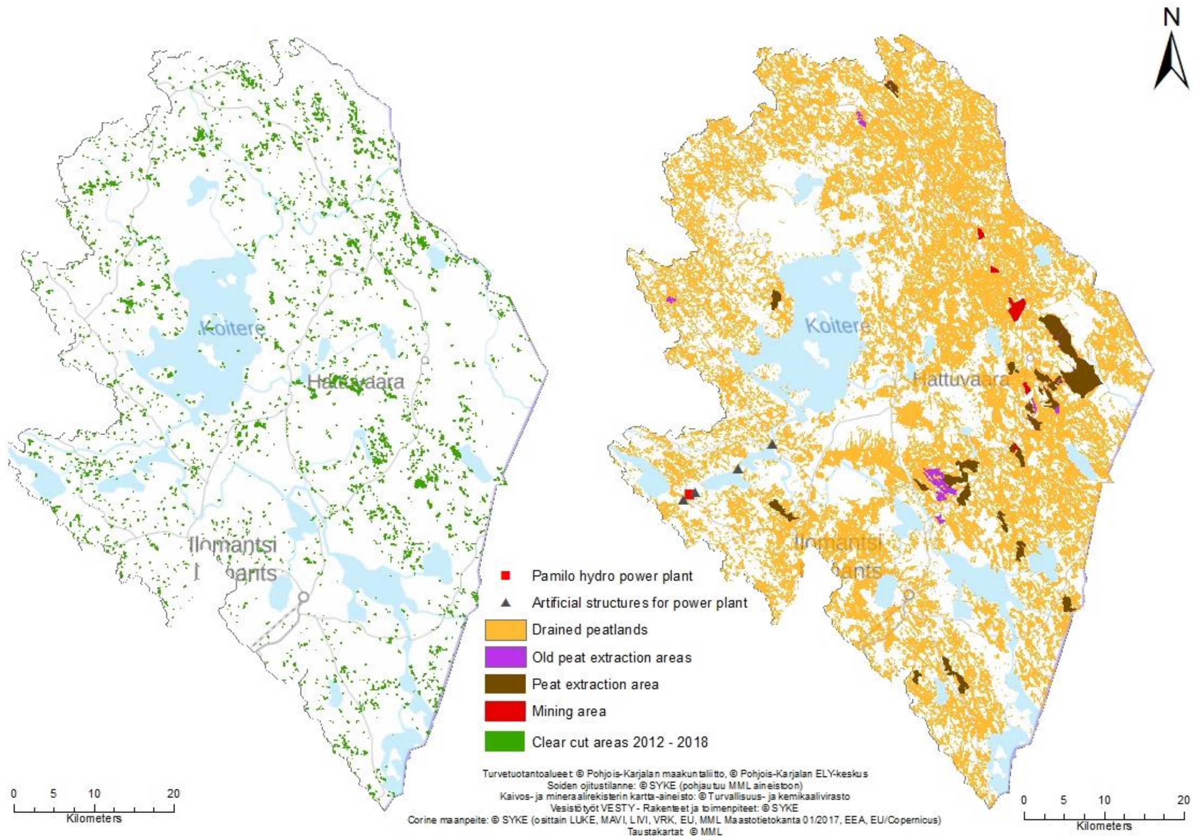
	Koitajoki catchment	Koitajoki (Nuorajäarvi-Alakoitakoitajoki)	Ala-Koitajoki	Riparian Zone (Nuorajärvi-Alakoitajok)
Undrained peatland (in ha)	39966	9014	447	4461
Drained peatland (in ha)	94494	13685	1247	2668
Peat extraction (in ha)	2326	80	0	0 (adjacent)
Current Peat Extraction (in ha)	6276	792	0	0 (adjacent)

The total hectare number of clear cut areas has increased and clear cut areas have been shifting from 2000 until 2018 within the catchment as a natural consequence of forest practise, but a distancing is also visible from protection areas. Hot Spot Analysis of clear cut areas between 2012-18 show the accumulation of clear cuts in Hattuvaara area. Other changes indicated via Corine Land Cover Changes, such as agricultural land, are very small and neglectable.

Table 8: Information on clear cut area bas on Corine Land Cover changes within 2000-2018.

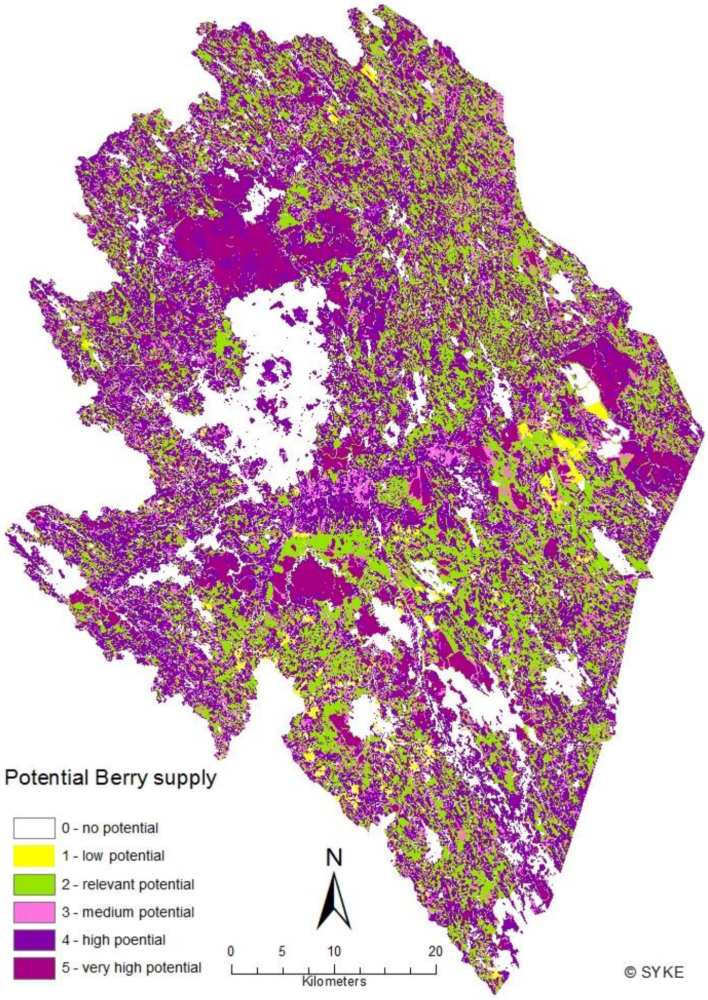
	Koitajoki catchment	Koitajoki (Nuorajäarvi-Alakoitakoitajoki)	Riparian Zone (Nuorajärvi-Alakoitajok)
2000-2006 Clear cut area in ha (total)	6368	1004	50
2006-2012 Clear cut area in ha (total)	8015	1283	103
2012-2018 Clear cut area in ha (total)	11697	1267	119

The findings of land use changes and current land use derived by land use information means the following for the provision of ecosystem services. Changes in the provisioning ecosystem services can be seen the easiest, as they present a measurable service often revealed in statistics and surveys. The increased area of peat extraction emphasised the continuous provision of peat, belonging to an important provisioning ecosystem service for energy purposes in North Karelia. At the same time, the provision of forest-related



Map 6: Natural resource management in Koitajoki catchment, left clea cut areas from 2012-2018 and right drained mires (orange), old peat extraction areas (purple), current extraction sites (brown) and ore mining (red). Pamilo Hydro Power Plant and its artificial structures located in the Western part.

ecosystem services remains ensured and enhanced by drainage. Undrained forested peatlands and unprofitable afforested peatlands also provide energy wood; the areas of the latter cannot be identified with the used information. In addition, Pamilo hydro power plant, as the biggest one of Vattenfall in Finland and located in Ala-Koitajoki, still provides energy

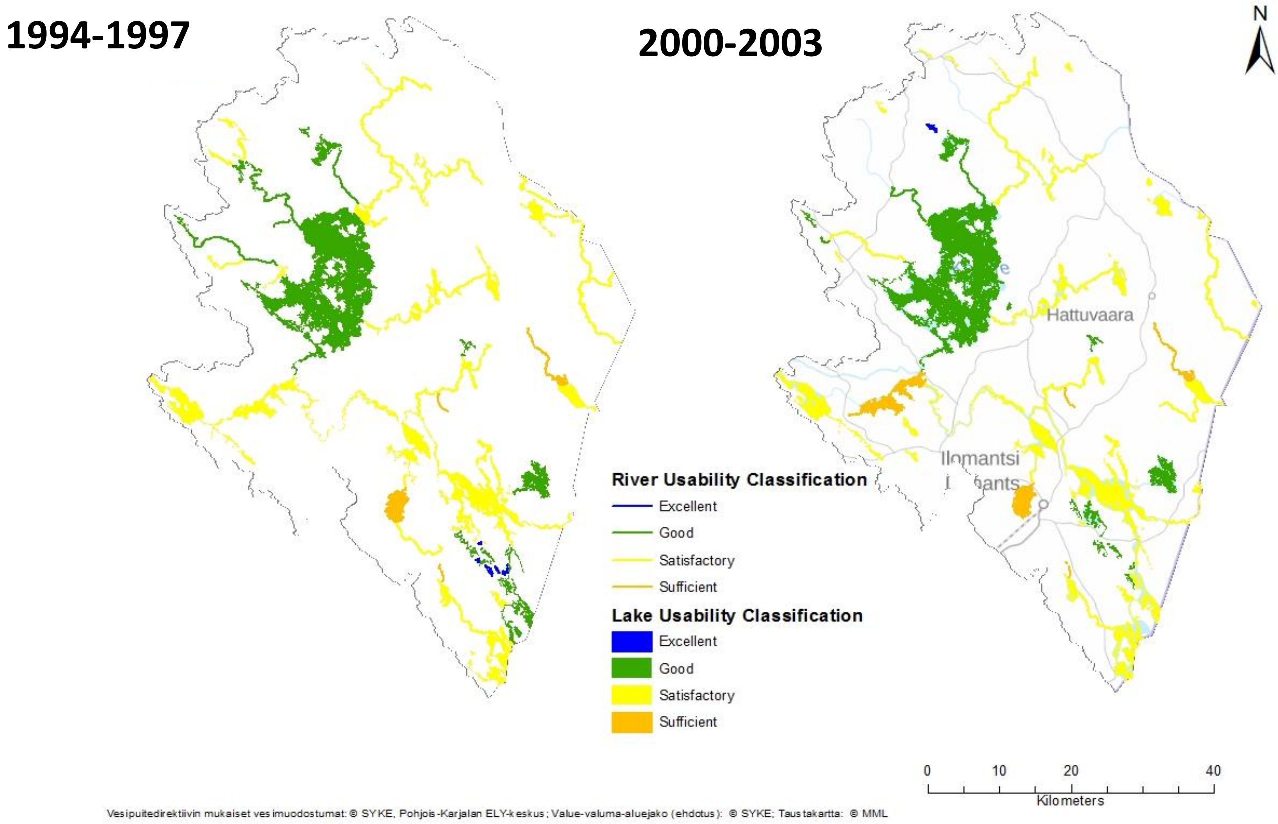


to the region (see chapter 2.3.3). Computed land use classes, for which the potential berry distribution was evaluated in the SuoEko workshop in 2012, showing that the highest potential of berry occurrence lies within undrained peatlands.

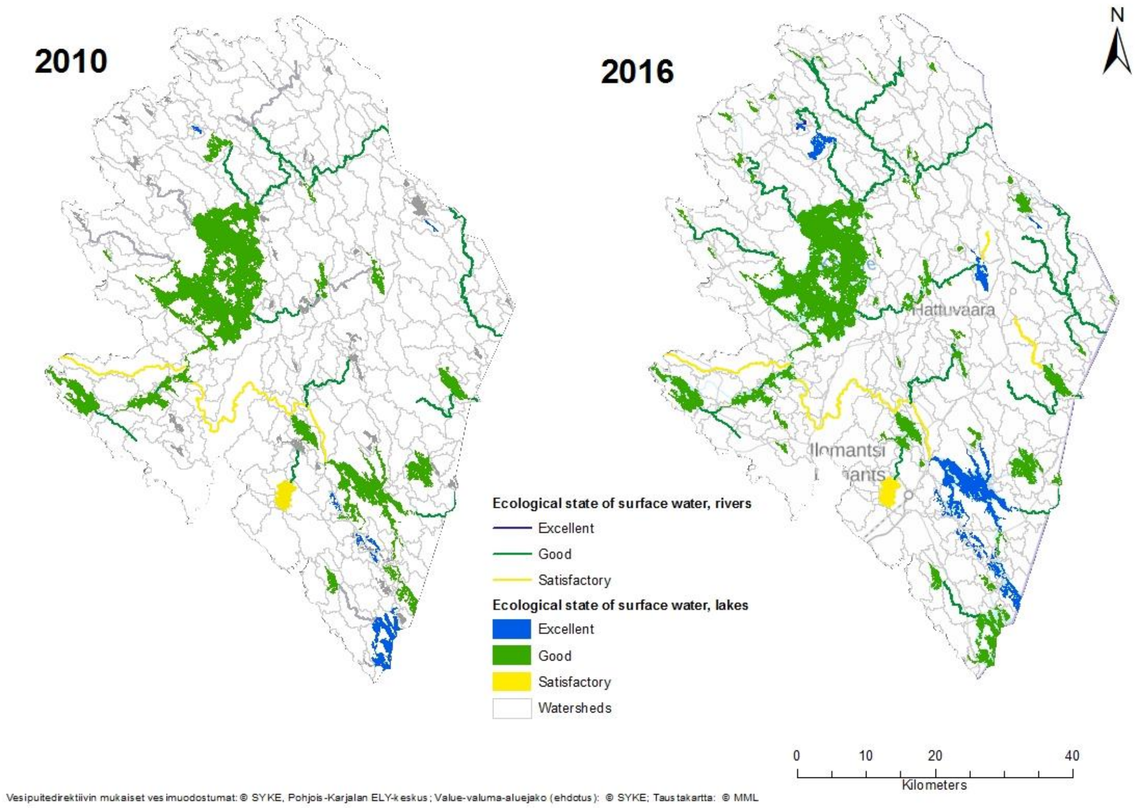
Changes in provisioning ecosystem service, that are related to land use changes and not

Map 7: Potential berry distribution within the catchment according to SuoEko results 2012.

visible on maps due to data restriction is the decrease of fish species, such as the decrease of endangered *Salmo salar*. m. Sebago and the endangered *Coregonus lavaretus pallasi.* While no salmon has been caught between 1998 and 2017, 11 European Whitefish have been caught in 1998, while its number decrease to 4 in 2002, 2 in 2006 and 1 in 2012. 2017 records three European whitefish (LUKE 2018) As ecosystem services are all interconnected and depended on ecological functioning, the decrease of fish stock and species might be explained with the regulation and maintenance ecosystem services. For those, changes can be arrived at some extent by the changes in ecological state of surface water in the Koitajoki catchment.



Map 8 & 9: Changes in usability of rivers and lakes (above) within the Koitajoki catchment for 1994-1997 and 2000-2003 and changes of ecological state of surface waters for river and lakes within the catchment for 2010 and 2016 (below).

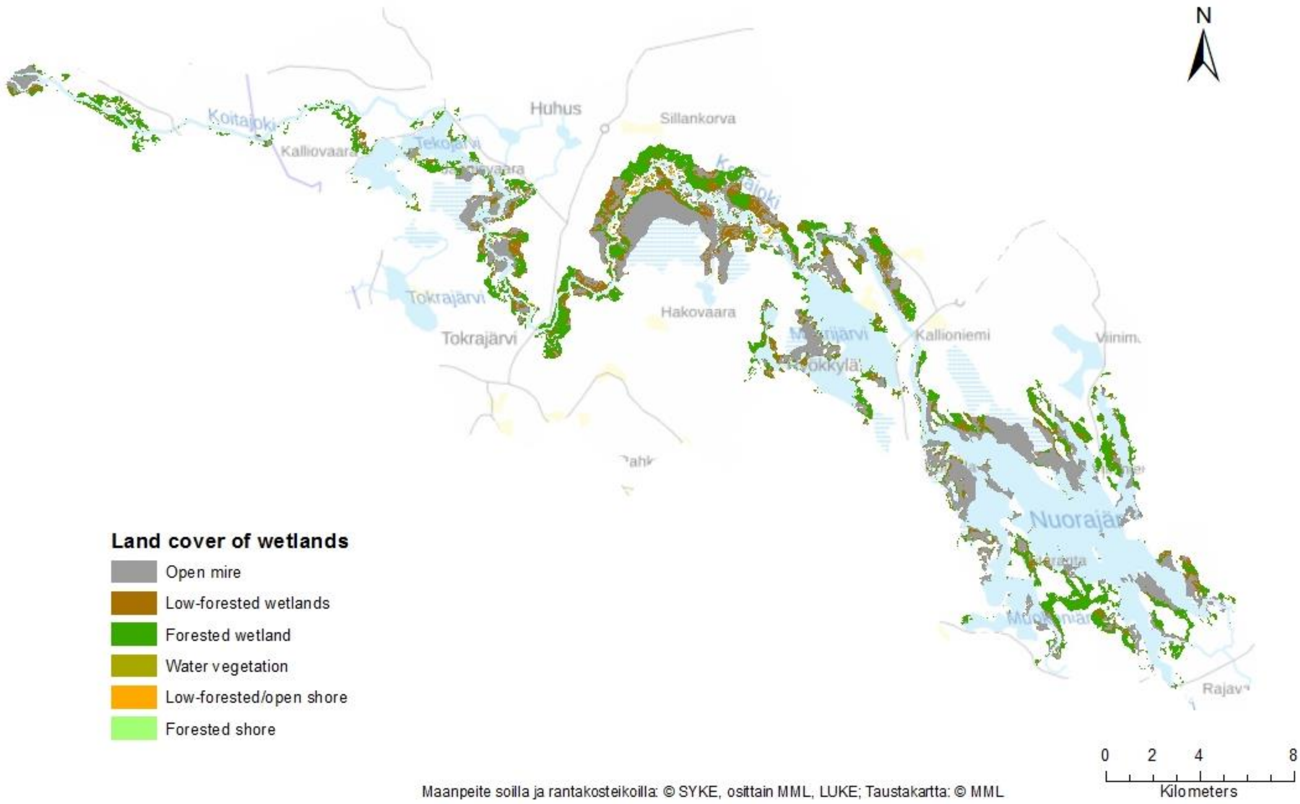


Within the time period 1994-1997 and 2000-2003, the usability of river bodies was investigated. Among the parameters used for these classifications are oxygen content, water colour (humus content), visibility, amount of nutrients and algea (*SYKE, 2015*). The conditions of river and lakes became worse between these time periods. Tekojärvi was reclassified from "satisfactory" to "sufficient", as well as rivers north of Lake Koitere. Further, excellent status from lakes South of Nuorajärvi changes to good status. The ecological state of surface waters from 2010 and 2016 provides a broader spectrum of variables and has generally a larger emphasise on biological quality indicators, such as plankton algae, water plants, fish and other aquatic organisms. Parameters included also in the usability classification from the earlier years are among other the amount of nutrients, pH and visibility are taken into account. Another emphasis is set on artificial altering, such as dams and water regulation (MONONEN ET AL. 2016). Between 2010 and 2016, ecological state has positively changed, especially for Lake Nuorajärvi. Ecological surface water quality is indicated with "sufficient" at Ilajanjoki connecting Hattavaara and Ilajanjärvi, where the largest peat extraction area is located between Hattuvaara and Koivusuo Nature Park. Ecological state of surface water appears to be the most problematic along Koitajoki river course starting from Nuorajärvi on until catchment border of Ala-Koitajoki ("sufficient"). Ala-Koitajoki is heavily modified due to the dam in Hiiskoski and channel alteration for the Pamilo power plant. However, chemical status of surface water shows that some waters classified as "good" ecological surface water have an insufficient chemical status, confirmed also by various studies about the mercury level in Koitajoki (PARVIAINEN 2014; MONONEN ET AL. 2016). Comparing these two classifications of water bodies within the catchment to create a timeline, it is not certain of the positive changes between 2003 and 2010 results from different parameters included in the classification or if the ecological state has become indeed better. Due to that, no assumptions will be made in the discussion part.

For the provision of ecosystem services, it means that water purification of adjacent peatlands and freshwater systems might is restricted. Land use affecting the ecological state of the water surface are in accordance to present land use classes a combination of forestry operations, peat extraction and mining as well as artificial structures for hydro power.

Point sources from settlements and houses, such as waste water, is not contributing as a major impact, as settlement are too scarce in the catchment. Discharge points of the watersheds are located so, that impacts of nearby peat extraction and forestry activities would emerge in the as “satisfied” classified river segment. Further, the river passes the artificial lake Tekojärvi and the dam in Hiiskoski due to the Pamilo power plant regulating the water table in Ala-Koitajoki and Lake Koitere. Regardless, potential habitats for endangered fish species can still be found in Nuorajärvi and downstream including the old river segment Ala-Koitajoki, where old habitats for Salmons are situated.

As additional information, riparian zone data from ESA/Copernicus was used as an approximation for a “buffer zone”, which might be periodically flooded and thus being the transition zone of terrestrial and aquatic ecosystems. The information was used on smaller scale, applied for the river part that has potential habitats for endangered fish species from Mekrijärvi to Ala-Koitajoki.



Map 10: Wetland classes along the Koitajoki within the riparian zone.

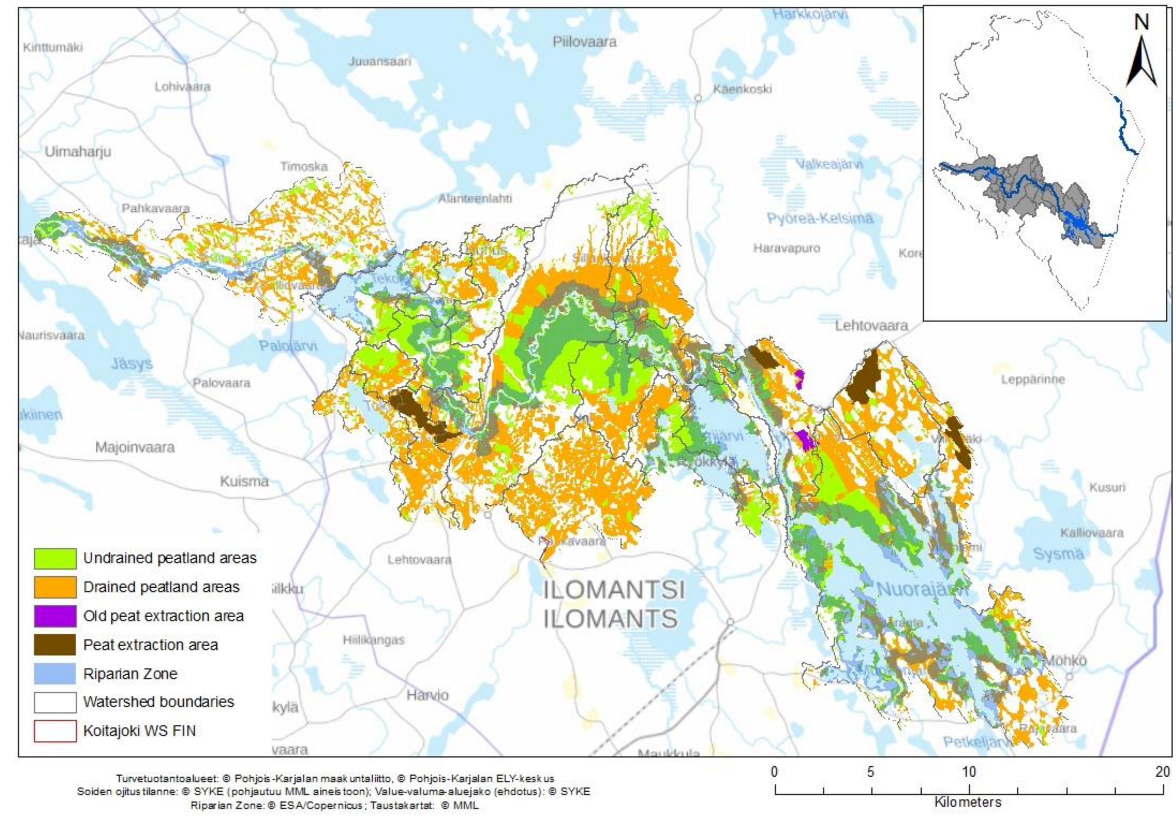
Wetland occurance is not continours within the riparian zone along the Koitajoki in the regarded river segment. Open mire classes fit to the distribution of undrained mires (see map 11). Low-forested wetlands and forested wetlands fit to the undrained peatlands shown in map 11. Low forested or open shores can be found on the island within the river course, mainly above Kesonsuo.

Table 9: Wetland class cover in hectare within the catchment and Ala-Koitajoki sub-catchment. Values for wetland classes have been extracted only within the riparian zone.

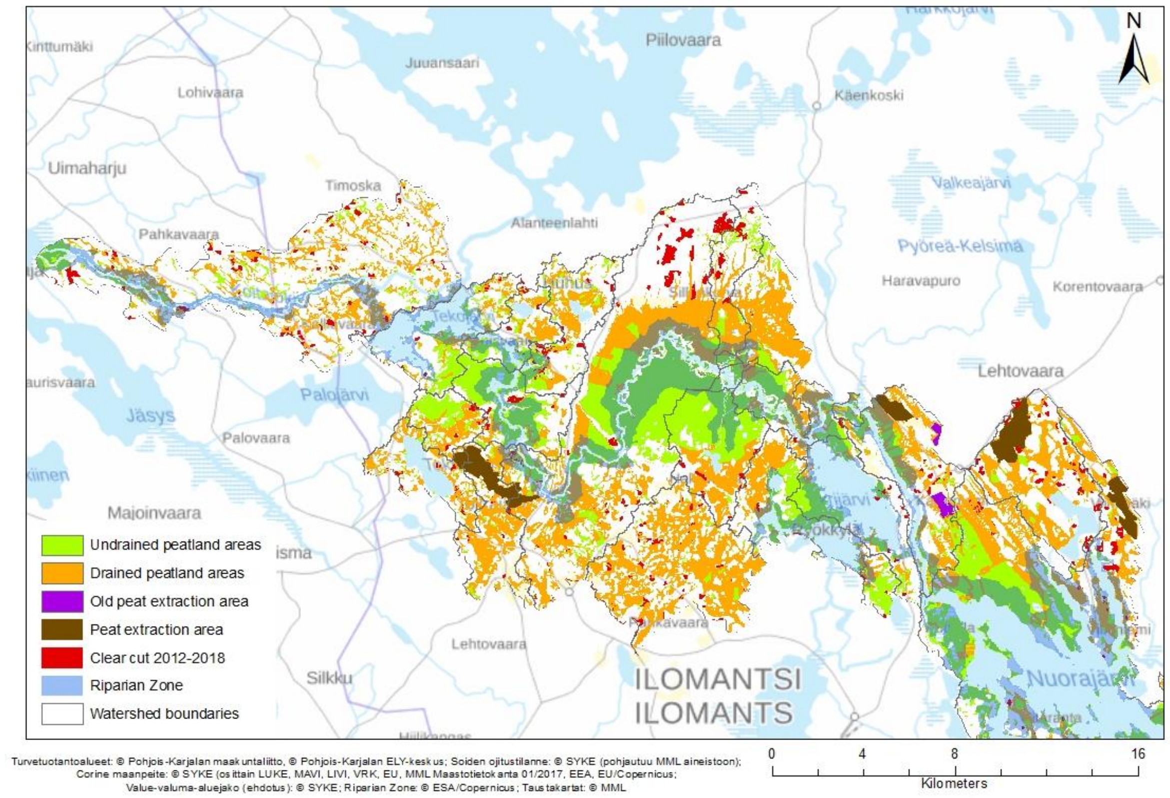
Wetland Cover Classes	Area Koitajoki catchment (in ha)	Area in Ala-Koitajoki (in ha)
Open mire	5184	9276
Low-forested mire	2204	4735
Forested mire	6681	29835
Water vegetation	1301	458
Low-forested shore	104	2
Forested shore	1	0

Within the riparian zone, land use is directly affecting the river. Continuous wetland distribution can retain leaching nutrient and sediment (see discussion), but gaps along the river within the riparian zone are loopholes for harmful substances.

Although, no larger clear cut spots within the riparian zone can be detected, it is obvious that a great share of the zone's peatlands has been drained, except for the parts located in a conservation area. However, the close distance of clear cut areas and peat extraction areas to the riparian zone is visible (see map 12).



Map 11 & 12: Draiange status and peat mining areas within selected watersheds along the River Koitajoki. Riparian zone (*Copernicus*) as overlay information. In addition, celar cut areas of 2012-2018 were added (see map 11 below).

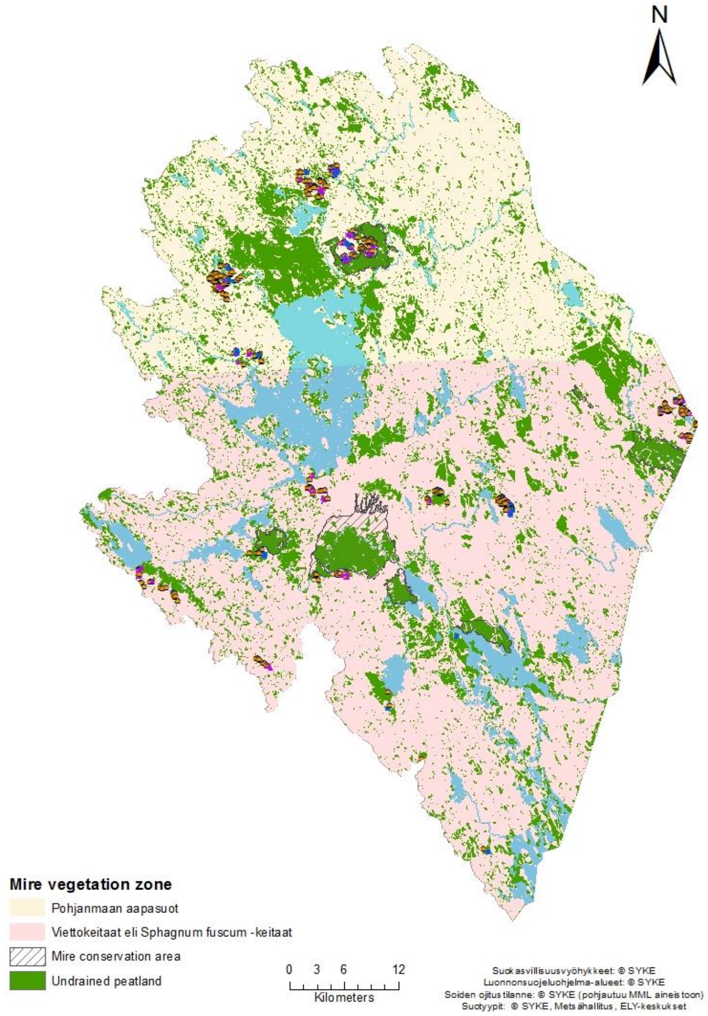


Within the delination of the riparian zone, wetland land cover was examined further showing that the connection of wetlands is not continuous. Particularly, without the forested wetlands, which are mainly located on drained peatlands.

The regulation and maintaining ecosystem services include also the provision of habitats. For this, the mire types identified in the catchment in 2016 were listed in the table below. Moreover, mire vegetation zone for the catchment were mapped together with the investigation spots of the mire types.

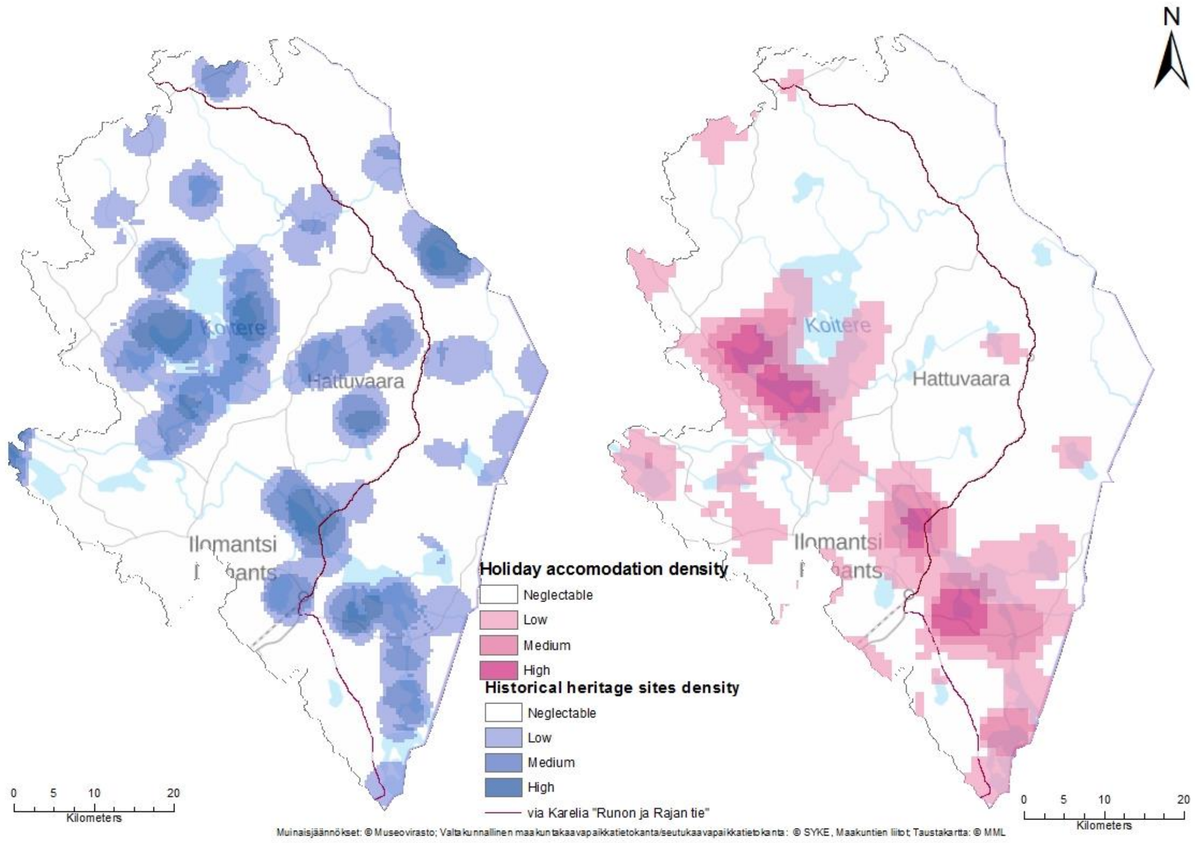
Table 10: List of mire types located in the catchment.

Name of mire type	Name of mire type	
Avoluhta	Mesotrofinen lyhytkorsiräme	Puolukkaturvekangas
Isovarpuräme	Mesotrofinen rimpineva	Metsäkortekorpi
Juolasarakorpi	Mesotrofinen rimpinevaräme	Mustikkakorpi
Jäkäläturvekangas	Mesotrofinen sarakorpi	Oligotrofinen rimpinevaräme
Kangaskorpi	Mesotrofinen saraneva	Oligotrofinen sarakorpi
Kangasräme	Mesotrofinen sararäme	Oligotrofinen sararäme
Keidasräme	Metsäkortekorpi	Ombrotrofinen lyhytkorsineva
Koivuluhta	Mustikkakorpi	Pajuluhta
Korpimuuttuma	Mustikkaturvekangas	Pallosararäme
Korpiojikko	Muurainkorpi	Puolukkaturvekangas
Korpiräme	Nevaojikko	Metsäkortekorpi
Kuljuneva	Oligotrofinen kalvakkaneva	Mustikkakorpi
Lehtokorpi	Oligotrofinen kalvakkaräme	Oligotrofinen rimpinevaräme
Lehtoturvekangas	Oligotrofinen lyhytkorsineva	Rahkaräme
Lettokorpi	Oligotrofinen lyhytkorsiräme	Rimpiletto
Lettoneva	Oligotrofinen rimpineva	Ruohokorpi
Letto-ojikko	Oligotrofinen rimpinevaräme	Ruohoturvekangas
Lettoräme	Oligotrofinen sarakorpi	Rämemuuttuma
Luhtaneva	Oligotrofinen sararäme	Rämeojikko
Mesotrofinen kalvakkaneva	Ombrotrofinen lyhytkorsineva	Tupasvillakorpi
Mesotrofinen kalvakkaräme	Pajuluhta	Tupasvillaräme
Mesotrofinen lyhytkorsineva	Pallosararäme	Varputurvekangas



Map 13: Mire vegetation zones and mires types.

Density analysis shows a clear distribution of holiday cottages along the nature protection network. The result of the density analysis for historical sites including terrestrial and aquatic relicts show a rather evenly distribution. Along the via Karelia “Runon ja Rajan” route, a buffer widths of 2 km to each side was used to estimate, how many historical sites are located within 4km buffer along the route showing that 44 historical sites were within the defined buffer along via Karelia through the entire watershed. However, the sites included are referred to linear distance from the main route and not considering accessibility via branching roads (actual distance via access roads might be longer).



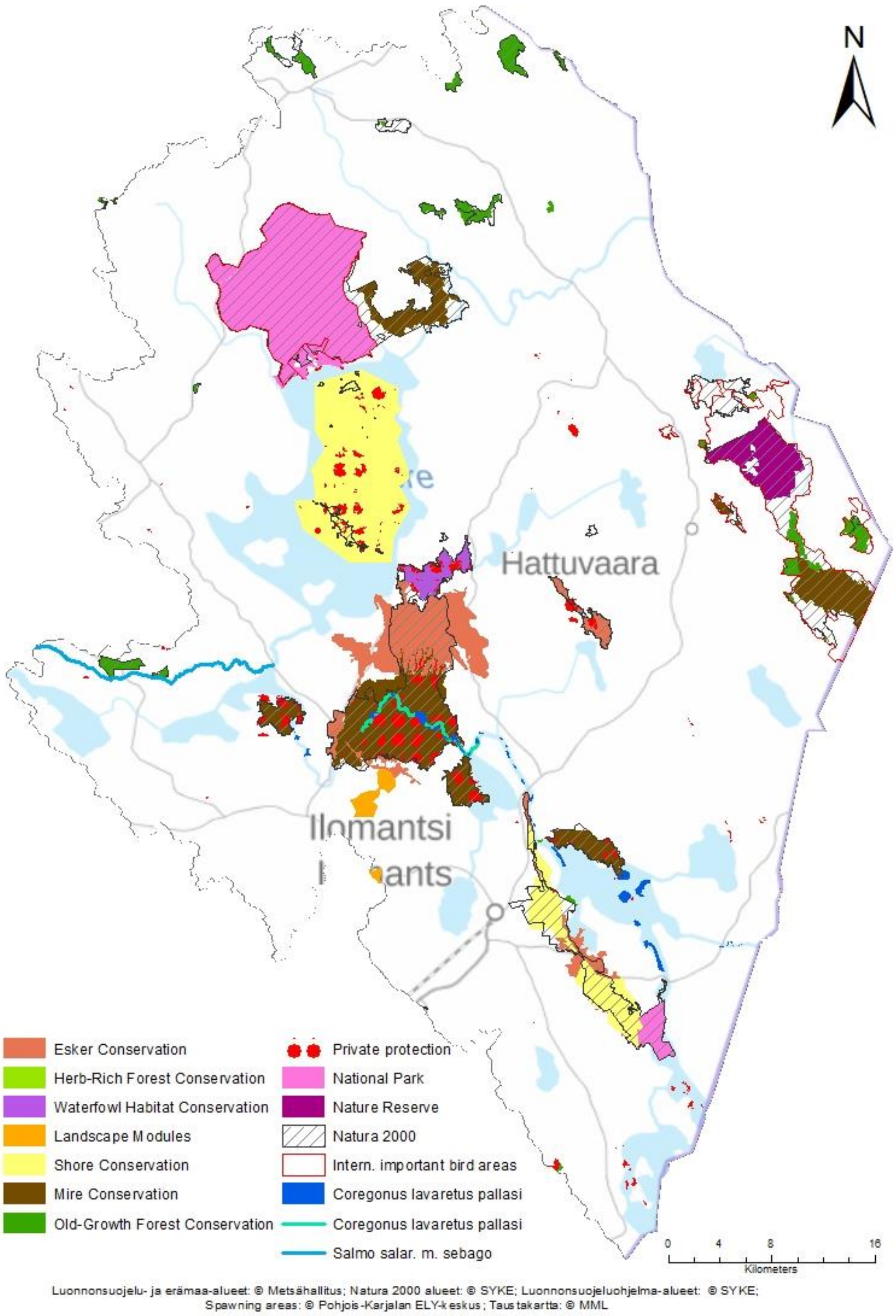
Map 14: Density analysis of Historical heritage sites (left) and holiday accomodation (right). More intensive colors show higher density.

It is worth to mention, that not only land uses have effects on ecosystem service provision, but also invisible impacts are to be mentioned as the improvement of technology and land management and changes in law. Changes in law and the defined management options is also important regarding conservation and protection areas, as well as the allocation of conservation status to new areas.

As explained in Chapter 3, biodiversity is strongly linked with ecosystem services. Biodiversity can be displayed as a complex interaction between many systems and requires well-functioning ecosystems and areas that provide shelter for endangered or rare species. Also, ecosystems under human impact and great pressure can still provide habitats or at least still have the potential to provide habitats. Therefore, a complex of different conservation and protection areas can aim to show possible habitat distribution within well-functioning ecosystems, were management is restricted. For conservation areas are titled according to conservation programmes, ecosystem services can be derived by their names.

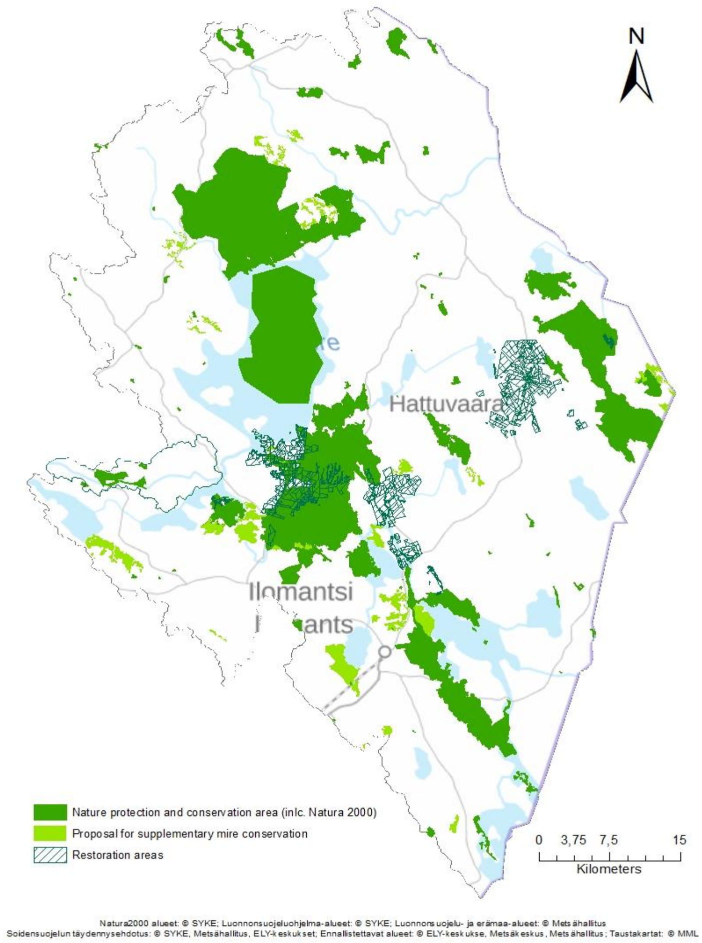
Map 13 shows the alignment of conservation areas under various programmes in addition to internationally important bird areas and potential spawning habitats for *Coregonus lavaretus pallasi* and *Salmo salar m. Sebago,* for wish special river restoration measures are taking place.

Map 15: Distribution of conservation and protection areas with different status, including Natura 2000 and private protected areas. Together with mapped internationally important bird areas and potential habiats for endangered fish species, biodiversity can be expressed.



6.2 Possible effects of Restoration

Restoration activities within the Koitajoki catchment are still ongoing and partly only in planning stage. Peatland restoration is passing through various regeneration stages and assessing if restoration target has been reached can sometimes be seen only after years. As mentioned in Chapter 3, for ecosystem services provision it means also various stages. In the following, the discussion will deal with potential effects among restoration stages further and considers ecosystem service supply after successful restoration. However, the distribution of restoration areas and conservation areas can give already a good insight on ecosystem support if restoration succeeds. The situation is a “cross network” of restoration sites and area with different kind of conservation and protection status, also Natura 2000 areas and private protected, temporary protected areas included. Together with the proposed supplementary mire conservation areas, they are almost connected and remind to ecological corridors.



Map 16: Network of protection areas and conservation areas in the catchment. In accordence with proposed supplementary mire conservation areas, good connections are visible.

6.3 Natural Resource Management

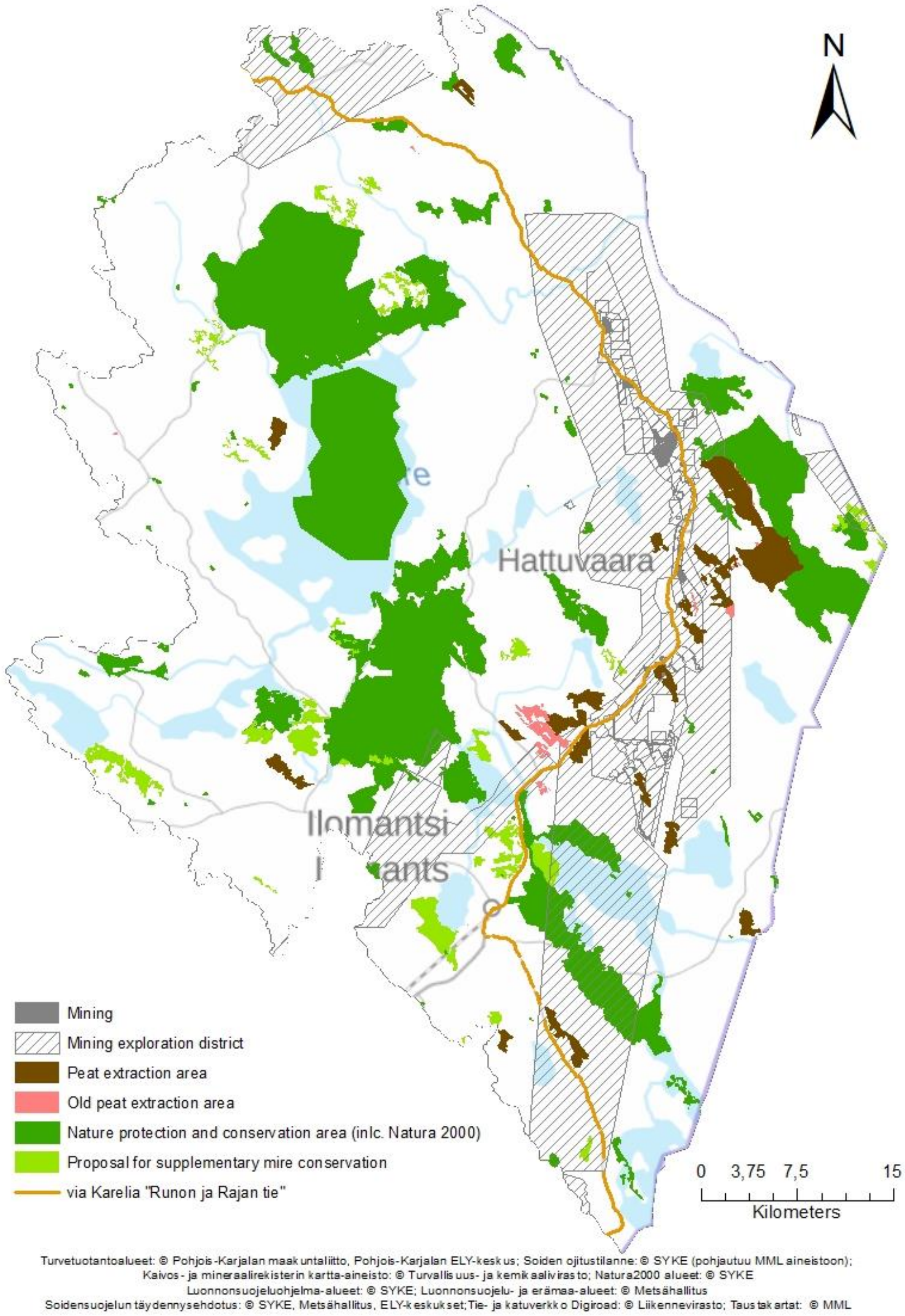
Natural resource management is practised quite intensively in the Koitajoki catchment. Drained peatland for forestry and mining activities can be found throughout the entire catchment and also along Koitajoki in nearer distance. In particular along the river course, drained peatlands and peat extraction sites are accumulated, with drained peatlands also situated in the riparian zone. Land use changes show the trend of increasing clear cut areas and peat extraction sites. While areas for natural resource management increase, statistics on energy consumption for wood energy and peat energy show fluctuations between 2008 – 2016 (see table 11 below). On the opposite, development in North Karelia shows an increase of 21,1 % from 2017 to 2018 in the sector of forestry and logging and for the same time an increase of 9,2% for mining and quarrying (TRENDIT, 2/2018).

Within peatlands, natural resource management provides only specific provisioning ecosystem services related to forestry, peat extraction, mining and hydro power and simultaneously, endangers the coexistence of regulating and cultural ecosystem services. These effects can be seen only to a limited extent, partly indicated by the ecological state of surface waters, chemical state and from aerial images visualising the scale of devastation caused predominantly by peat extraction, mining and clear cut areas. The map emphasises the clear alternating of drained and undrained peatland patches with associated land use. Thus, the derived ecosystem services of those two major initial situations alter with it.

As a result of what can be described as soft and hard land uses, a clear pattern emerges showing the concentration of conservation areas (incl. high share of undrained mires) as a green network and mining areas in form of a stripe with North-South orientation. While the cottage distribution is rather orientated towards the “green network”, the via Karelia route is passing through the stripe of mining indicating a conflicting situation

Table11: Energy consumption in North Karelia between 2008 – 2016 (*GWh*). Source: Itä-Suomen Maakuntien liitot 2016.

Energy	2008	2010	2012	2014	2016
Wood energy	4915	5948	5780	6140	5723
Turve	691	558	479	509	612



Map 17: Natural resource management vs. Nature conservation. Two extreme land use forms have to co-exist next to each other and show clear distribution patterns. The via Karelia route is situated in the mining strip and appears “out of place”.

7. Discussion

Without a doubt, the greatest impact of the supply of ecosystem services has been the process of drainage for multiple purposes. The sometimes undefinable transitions from peatland to naturally forested peatland and drained, forested peatlands make it difficult to distinguish the ecosystem border and consequently, services provided by one specific ecosystem. For that reason, it should be focussed on which process causes significant changes in ecosystem service provision for all types of peatlands and how the process drainage changes the ecosystem service provision.

Water purification is one of the most important regulation and maintenance service of peatlands and a benefit for the Koitajoki catchment that appears to be restricted and appears almost lost due to drainage. The consequences of drainage are manifold and start with a structural change of hydrological that limited potential of peatlands to act as a buffer for nutrient, pollutant and sediment retention. Simultaneously, a drained peatland does not only release more organic matter but also the land use practised on the drained peatlands and adjacent land parcels increases the impacts on freshwater systems. Starting with forestry, not only clear cut areas cause an increase in sediment load and nutrient leaching (phosphorus, nitrogen, iron and indirectly mercury) into discharging water, also other forestry operations add pollutants to the drainage network, for example caused by saw dust (VUORI & LUOTONEN, 2003). Soil preparation and the use of fertilizer add up to that a change the ecosystem's capacity for water purification. The magnitude of forestry impacts however vary and depend on the distance to drainages and discharge points. Larger clear cut areas increase the leaching input. In the Koitajoki catchment, forestry operations are ubiquitous and for economic reasons, inevitable. Nonetheless, it is obvious that forestry-induced pollutant and sediment load exacerbate ecological conditions of freshwater systems and thus, require better management options and restrictions. One options is to adjust forestry management to the direction of continuous cover forestry, being over long time economically advantageous, providing different vegetation structures within a stand and thus, increases biodiversity. Positive results are to be expected in the provision of ecosystem services and also in the retention of nutrients and sediments.

Peat extraction areas make up a big share in the catchment, especially along the Koitajoki river and discharge into it. Despite best available technology (HEIKKINEN ET AL. 2017), impacts on freshwater systems become intensified ranging from changes in groundwater level, solid and nutrient load due to extraction (and operation dust), humus and iron leaching. Effects of other mining activities are supplement by the creation of artificial lakes with high concentration of heavy metals and remaining stones masses. The effects of hydro power in the heavily modified Ala-Koitajoki are similar, because the regulation of the water table causes erosion and sediment input (MONONEN ET AL. 2016). Here, the addition is that the river course needed to be modified and damned affecting the spawning and migration possibilities for fish species.

In short, all the actions within the catchment done by "hard" land uses lead to an increase of pollutants, nutrients, heavy metals, sediment, organic matter in freshwaters with varying extent according to drainage network, catchment size, land use size and intensity.
Those actions release a chain reaction with enormous consequences for all ecosystem services, that rely on the functions provided by undrained peatlands and unmodified rivers and lakes, or regulation and maintenance ecosystem services, respectively. It explains the decrease of breeding and spawning habitats, alterations in the food-web and decrease of ecological state of surface water, (visible in the Map 9) classified as "sufficient" and finally, explains the regression of fish stock (LUKE Statistics, 2018). This is just a brief summary on land use effects and does not consider for instance services, that are introduced by forest growth due to peatlands drainage, because the effects on freshwater ecosystems is in the foreground. It needs to be considered, to which extent peat for energy purposed and wood-energy from drained peatlands will continue to play an important role in economics.
It becomes clear, that maximising one ecosystem service (timber, peat, ore) happens at the expense of other services and in the case of drainage, leads the drastically decline in ecosystem functioning. While the role of regulation and maintenance services becomes only more obvious after some explanations provisioning ecosystems are relatively easy to understand due to measurability and statistics. The same counts for cultural services, because their non-material focus shifts the attention to landscape aesthetic and recreation and provides potential for tourism. Provisioning ecosystem services are sometimes part of the cultural services as well, in North Karelia berry picking, fishing and hunting for example. Peatlands and other freshwater systems are a part of North Karelia and with it, the traditions, culture and recreation activities are have developed. Peatlands offer spots for

hunting and berry picking and bird watching. Especially the meandric and braiding Koitajoki with its adjacent lakes and mires contains a high potential for cultural service supply. On the other side, the catchment is strongly managed and modified and it is easy to spot the devastation and traces of (peat) mining, clear cuts and even-aged forests. It also easy to detect the humus content within the lakes and rivers floating as a brown stipe in the waters. Studies have shown that people prefer clear waters for fishing, boating or swimming. Recreational activities are expected to increase with better water conditions for local people and tourists (VESTERINEN ET AL. 2010; POLIZZI ET AL. 2015).

To what extent can restoration improve the current state? The restoration areas are not only located along Koitajoki, but also within the catchment (e.g. Hattuvaara). It ensures, that the ecological state regenerates from upstream to downstream. Peatland restoration with eater table increase by ditch blocking can improve ecological functioning in a way, that vegetation succession towards peatland species provides new (or old) habitats again and that water purification (sediment retention) can be enhanced. Water becomes filtered again before entering rivers and lakes and improves the ecological state of freshwaters. It therefore also increases the provision of aquatic habitats and conditions. River restoration is adding measures to establish better river conditions and migration routes for fish by transferring aquatic plants and structuring the river bed. A big step for the attempt to increase the fish stock (provisioning ecosystem and supporting service: gen material) is the increased water discharge at the Pamilo power plant in Ala-Koitajoki (MONONEN ET AL. 2016).

It becomes clear, that natural peatlands and unmodified rivers and lakes provide more ecosystem services than drained peatlands and that the Karelian landscape has a high potential for economic benefits not only with natural resource management.

In fact, current land use management is facing the challenge to integrate tourism into natural resource management. The supply of cultural values is applicable to the demand of tourism and leads to the challenge of coexistence between natural resource management and tourism. An important factor is the via Karelia route passing historical sides and beautiful scenery. However, this route also leads through the core of mining districts. It needs to be contemplating, if it is more worthy to keep landscape scenery or to dig for small amounts minerals with a huge amount of stone left overs.

8. Conclusions

The ecological structures and functioning of ecosystems is providing always certain ecosystem services, but the question is in what quantity and quality. Here it is important to consider the corresponding land use forms, as they are giving the decision-making weight into the provision. Land use information was available for this task, however, the biophysical quantification is lacking sufficient information. Main land use forms, that alter ecological functioning greatly are in the Koitajoki catchment case forestry, peat extraction and mining, complemented by hydro power in Ala-Koitajoki. Ecological functioning is the basis of all ecosystem services and the spatially limited execution of processes within undisturbed ecosystems and the alteration of functions within managed ecosystems lead to a chain reaction. It can restrict and endanger the co-production of ecosystem services besides provisioning services targeted on by natural resource management. Mixed landscape patterns of drained mires and undrained mires, peat extraction, mining areas, forest activities sites and conservation areas hinder the provision of regulation and maintenance services on a bigger scale, also for the future. As a part of the chain reaction, this landscape mosaic might repress the success of habitat provision, especially with regard to fish species, and future options for fishing economy and old traditions. Restoration success can help to promote ecological functioning in the Koitajoki catchment by solving the mosaic step by step. A “green netwok“ of restoration and conservation areas can provide the chance for a sustainable improvement of ecosystems and ecological state of freshwater systems on catchment scale and thus, also for the provision of ecosystem services, and should be considered in planning.

Advancing technology and adapted management of natural resource management might mitigate impacts to a certain extent, but nevertheless, focussing on the supply of provisioning ecosystem services always reduces the provision of other services. For the provision of cultural services and tourism options, a compromise must be found in order to integrate or consider the high potential of nature tourism in North Karelia. Economic benefits from the use of natural resources must be contemplated against the promotion of tourism.

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Appendix

List on used GIS-data

- SuoEko assessment, 2012
- Corine maanpeite: © SYKE (osittain LUKE, MAVI, LIVI, VRK, EU, MML Maastotietokanta 05/2012; 01/2017, EEA, EU/Copernicus
- Soiden ojitustilanne: © SYKE (pohjautuu MML aineistoon)
- Vesistötyöt VESTY – Rakenteet ja toimenpiteet: © SYKE
- Kaivos- ja mineraalirekisterin kartta-ainesto: © Turvallisuus- ja kemikaalivirasto
- Taustakartat: © MML
- Turvetuotantoalueet: © Pohjois-Karjalan maakuntaliitto, © Pohjois-Karjalan ELY-keskus
- Vesipuitedirektiivin mukaiset vesimuodostumat: © SYKE, Pohjois-Karjalan ELY-keskus
- Munaisjäänökset: © Muesovirasto
- Natura 200 alueet: © SYKE
- Luonnonsuojeluohjelma-alueet: © SYKE
- Luonnonsuojelu- ja erämaa-alueet: © Metsähallitus
- Ennallistettavat alueet: © Pohjois-Karjalan ELY-keskus, Metsäkeskus, Metsähallitus
- Riparian zone: © ESA/Copernicus
- Maanpeite soilla ja rantakosteikoilla: © SYKE, osittain MML, LUKE