Vulnerability assessment of ecosystem services for climate change impacts and adaptation (VACCIA)

Action 8: Vulnerability and adaptation of catchment areas and lakes for climate change impacts

Ilpo Hakala

Report on environmental variables available in the region

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EU:n LIFE+ -ohjelmaan kuuluva VACCIA-hanke (Luonnon tarjoamien palveluiden haavoittuvuusarviointi ja sopeutuminen muuttuvaan ilmastoon) alkoi tammikuussa 2009. Työpaketti 8 tehtävänä on Lammin LTER alueelta kerättyjä lyhyt- ja pitkäaikaisia seuranta-aineistoja analysoimalla arvioida valuma-alueiden ja järvien herkkyyttä ilmastonmuutoksen vaikutuksille, sekä pyrkiä löytämään valuma-alueille ja järville toimivia hoito- ja sopeutumistapoja.

Lammin LTER alueella pitkäaikaista ekologista tutkimusta on tehty useilla eri alueilla ja paikoilla. Evon metsä- ja järvialue on alueista suurin. Kotisten luonnonsuojelualueella sijaisteva Valkea-Kotinen järvi on ollut pitkään intensiivisen tutkimuksen kohteena. Toinen monipuolisesti ja pitkään tutkituista alueista on Lammin Pääjärvi valuma-alueineen.

Lammin Pääjärvi on Suomen neljänneksi syvin järvi (maksimisyvyys 85 m). 1950-luvulla alkaneesta rehevöitymisestä ja veden korkeasta humuspitoisuudesta huolimatta järven ekologinen tila on hyvä. Suurin osa järven valuma-alueesta on metsien ja soiden peittämää, mutta alueella harjoitetaan myös maa- ja metsätaloutta. Pääjärveä ja sen valuma-aluetta on tutkittu intensiivisesti 1960-luvulta lähtien. Tästä ansiosta Pääjärven alueesta on olemassa ainutlaatuinen pitkäaikainen seuranta-aineisto.

Evon alue on yksi Etelä-Suomen suurimmista yhtenäisistä havumetsäalueista. Alueen sisään jää yli 100 pientä järveä ja lampea, joista suurin osa on humuspitoisia (mm. Valkea-Kotinen on humusjärvi). Järvien lisäksi lukuisat pienet purot ja joet yhdistävät alueen vesistöjä. Valkea-Kotinen järveä ja sen valuma-aluetta on tutkittu intensiivisesti 1980-luvun lopulta lähtien, jolloin ympäristön yhdennetty seuranta (YYS) käynnistyi Kotisen alueella. Lisäksi Evon alueella on seurattu systemaattisesti yli 30 järven ja lammen vedenlaatua 1970-luvun lopulta lähtien.

Jatkossa tärkeimmistä seuranta-aineistoista tullaan tekemään metadatakuvaukset, jotka sisältävät yksityiskohtaisemmat kuvaukset tärkeimmistä ympäristömuuttujista, näytteenottopaikoista, käytetyistä menetelmistä sekä mm. aineiston haltijan yhteystiedot. Kyseisiä lyhyt- ja pitkäaikaisia seuranta-aineistoja tullaan käyttämään hyödyksi arvioitaessa valuma-alueiden ja järvien herkkyyttä ilmastonmuutoksen vaikutuksille. Tärkeimmät tulokset tullaan välittämään alueellisille ja paikallisille toimijoille sekä yleisölle seminaareissa. Lisäksi tietoja julkaistaan tulevissa raporteissa sekä muissa yleisölle suunnatuissa viestimissä.

1. Introduction

In the boreal zone terrestrial and lake ecosystems are sensitive in respect to changes in climatic conditions. According to climate scenarios made by the Finnish Meteorological Institute (FMI) climate change increases temperatures and precipitation in Finland especially in wintertime. In warmer climate the productivity of terrestrial and lake ecosystems may increase because of longer growing season. Nutrients turn-over times and leaching may also change due to higher production. Predicted higher precipitation in wintertime intensifies water transport out of the catchments as well as nutrient loadings and may lead several consequences on aquatic ecosystems such as eutrophication and cascading food web responses.

EU Life+ funded project Vulnerability assessment of ecosystem services for climate change impacts and adaptation (VACCIA) started in January 2009. Part of the project Action 8 focuses on the vulnerability of catchment areas and lakes to climate change impacts, and related adaptation measures. Analyses are based on short-term and long-term data sets from Lammi LTER area, which is one site of the Finnish Long-Term Socio-Ecological Research Network (FinLTSER).

The aim of this report is to list all the important environmental variables available in the region. Another aim of report is to describe and characterize the case study areas from where these environmental data sets are collected. More detailed descriptions of the environmental data sets, methods used and the main results will be published in forthcoming reports.

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2. Lammi LTER area

The Lammi LTER area in southern Häme consists of several core sites and areas (Figure 1). The Evo Forest and Lake Area (EVO) is the largest one of the areas and has a special value in terms of long-term ecological studies. One of the core sites of the Evo is Kotinen nature reserve area and the intensively studied Lake Valkea-Kotinen therein. Lake Pääjärvi and its catchment area in the southern parts of the Lammi LTER area is another one of the intensively studied areas.

2.1 Lake Pääjärvi area

Lake Pääjärvi is the fourth deepest lake in Finland with maximum depth of 85 meters. Its surface area is 13.4 km^2 and together with its drainage basin its area is 230 km^2. Lake Pääjärvi is mesotrophic and humic water lake. Slow eutrophication of the shallow bays of the lake and descendent river deltas was noticed already in 1970's. Nevertheless the ecological status of the Lake Pääjärvi is good. Most of the large catchment area is covered by the forests and peatlands, but Lake Pääjärvi is also influenced by the human activity e.g. agriculture and forestry.

2.2 Evo forest and lake area (EVO)

The EVO area in uplands between two major river basins, i.e. rivers Kokemäenjoki and Kymijoki, is among the largest coniferous forest areas in southern Finland. The number of small lakes in this patchy landscape is > 100 most of which are humic, brown-water acidic lakes typical of boreal zone. The intensively studied Lake Valkea-Kotinen is one of above mentioned brown water lakes with an area of 0.04 km^2 and maximum and mean depth of 6.5 m and 2.5 m respectively. However, due to the last glaciation, which retracted ca. 11 000-12 000 years ago, there are some eskers and sandy areas where spring and ground water lakes with crystal clear water appear. Besides lakes the freshwater ecosystems include small streams and rivers connecting the water bodies.

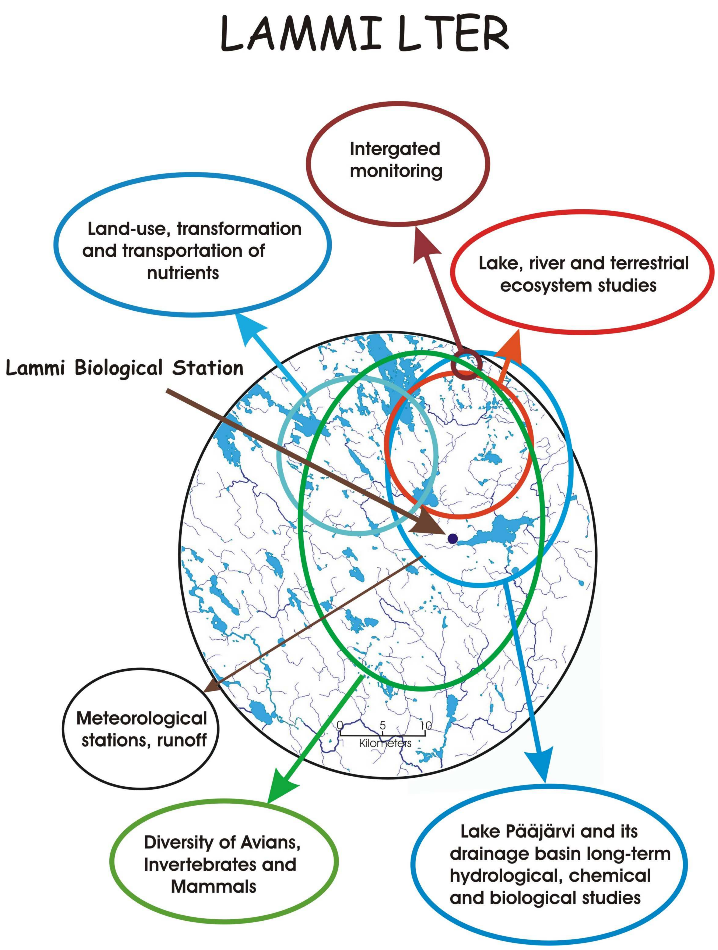

Figure 1. Map of Lammi LTER area and core sites of ecological studies.

3. Environmental variables available in the region

3.1. Environmental variables in the Lake Pääjärvi area

Lake Pääjärvi together with its drainage basin has been studied intensively since 1960's, when monitoring of lake physics, chemistry and biology started (Ruuhijärvi 1974a and 1974b, Arvola et al. 2006). Thus, today there is a unique uninterrupted data set on specific habitats, ecosystems and processes. These include e.g. local meteorology (since 1964), hydrology (since 1972), lake chemistry and biology (since 1963), lake physics (since 1968), and drainage chemistry (since 1993). These available long-term environmental variables and data sets are presented in Table 1.

Table 1. Long-term environmental data-sets available in the Lake Pääjärvi area and the importance of the variable for assessment of climate change impacts.

Environmental Variable	Sampling Period	Importance	Environmental Variable	Sampling Period	Importance
Meteorology			Water column stability (J m^{-2})	1961-->	High
Mean air temperature (°C)	1964-->	High	Heat content (MJ m^{-2})	1961-->	High
Min air temperature (°C)	1964-->	Medium	Transparency	1963-->	High
Max air temperature (°C)	1964-->	Medium	Turbidity (FNU)	1965-->	Medium
Rainfall (mm)	1964-->	High	**Lake chemistry**		
Relative humidity (%)	1969-1976	Low	Oxygen (mg l^{-1})	1961-->	High
Wind speed (m/s)	1971-1987	Medium	Oxygen saturation (%)	1961-->	High
Snow cover (cm)	1964-->	High	Solid (mg l^{-1})	1965-->	Medium
Stream hydrology			pH	1961-->	Medium
Discharge (m^3/s)	1972-->	High	Alkalinity (mmol l^{-1})	1963-->	Medium
Stream chemistry			Conductivity (mS m^{-1})	1961-->	Medium
pH	2000-->	Medium	Water Colour (mg Pt l^{-1})	1961-->	High
Water Colour (mg Pt l^{-1})	1993-->	High	NH_4-N (µg l^{-1})	1967-->	High
NH_4-N (µg l^{-1})	1993-->	High	NO_3-N (µg l^{-1})	1968-->	High
NO_3-N (µg l^{-1})	1993-->	High	Total N (µg l^{-1})	1965-->	High
Total N (µg l^{-1})	1993-->	High	PO_4-P (µg l^{-1})	1972-->	High
PO_4-P (µg l^{-1})	1993-->	High	Total P (µg l^{-1})	1965-->	High
Total P (µg l^{-1})	1993-->	High	TOC (mg l^{-1})	1968-->	High
TOC (mg l^{-1})	1993-->	High	CODMn (mg l^{-1})	1961-->	High
K (mg l^{-1})	1993-->	Low	K (mg l^{-1})	1965-->	Low
Na (mg l^{-1})	1993-->	Low	Na (mg l^{-1})	1965-->	Low
Ca (mg l^{-1})	1993-->	Medium	Ca (mg l^{-1})	1963-->	Medium
Mg (mg l^{-1})	1993-->	Low	Mg (mg l^{-1})	1963-->	Low
Mn (mg l^{-1})	1993-->	Low	Mn (mg l^{-1})	1965-->	Low
Fe (mg l^{-1})	1993-->	Low	Fe (mg l^{-1})	1963-->	Low
Cl (mg l^{-1})	1993-->	Medium	Cl (mg l^{-1})	1963-->	Medium
SO_4 (mg l^{-1})	1993-->	High	SO_4 (mg l^{-1})	1969-->	High
Lake hydrology			**Lake biology**		
Ice season (days)	1910-1930,	High	Chlorophyll *a* (µg l^{-1})	1972-->	High
	1971-->		Phytoplankton species composition	1963-->	High
Ice thickness (cm)	1965-->	Medium	Phytoplankton Biomass (g ww m^{-2})	1971-->	High
Water level (m)	1973-->	Low	Primary Production (mg C m^{-2} d^{-1})	1972-1982	Medium
Lake physics			Zooplankton	1963	Medium
Water temperature (°C)	1961-->	High		1993-->	

3.2. Environmental variables in the Evo forest and lake area

Lake Valkea-Kotinen together with its catchment area has been studied intensively since late 1980's, when the integrated monitoring of the Kotinen site started (Keskitalo & Salonen 1995, 1996, 1997 and 1998, Keskitalo et al. 1995 and 1998). In addition an extensive lake monitoring programme in more than 30 forest lakes nearby has been carrying out since late 1970´s (Järvinen et al. 2002). These data sets include e.g. local meteorology (since 1964), hydrology (since 1990), lake physics and chemistry (since 1977) and lake biology (since 1990). These available long-term environmental variables and data sets are presented in Table 2.

Table 2. Long-term environmental data-sets available in the Evo forest and lake area and the importance of the variable for assessment of climate change impacts. VK = Lake Valkea-kotinen.

Environmental Variable	Sampling Period	Importance	Environmental Variable	Sampling Period	Importance
Meteorology			Ca (mg l^{-1})	1985-->	Medium
Mean air temperature (℃)	1964-->	High	Mg (mg l^{-1})	1985-->	Low
Min air temperature (℃)	1964-->	Medium	Mn (mg l^{-1})	1983-->	Low
Max air temperature (℃)	1964-->	Medium	Fe (mg l^{-1})	1982-->	Low
Rainfall (mm)	1964-->	High	Cl (mg l^{-1})	1985-->	Medium
Snow cover (cm)	1964-->	High	SO_4 (mg l^{-1})	1985-->	High
Lake physics (>30 lakes)			**Lake hydrology (VK)**		
Water temperature (℃)	1977-->	High	Ice season (days)	1990-->	High
Lake chemistry (>30 lakes)			Ice thickness (cm)	1983-->	Medium
Oxygen (mg l^{-1})	1977-->	High	**Lake physics (VK)**		
pH	1977-->	Medium	Water temperature (℃)	1983-->	High
Alkalinity (mmol l^{-1})	1977-->	Medium	Water column stability (J m^{-2})	1990-->	Medium
Conductivity (mS m^{-1})	1977-->	Medium	Heat content (MJ m^{-2})	1990-->	Medium
Water Colour (mg Pt l^{-1})	1977-->	High	Transparency	1985-->	Medium
Total N (µg l^{-1})	1977-->	High	**Lake chemistry (VK)**		
Total P (µg l^{-1})	1977-->	High	Oxygen (mg l^{-1})	1983-->	High
CODMn (mg l^{-1})	1977-->	High	Oxygen saturation (%)	1983-->	High
K (mg l^{-1})	1977-->	Low	pH	1983-->	Medium
Na (mg l^{-1})	1977-->	Low	Alkalinity (mmol l^{-1})	1983-->	Medium
Ca (mg l^{-1})	1977-->	Low	Conductivity (mS m^{-1})	1983-->	Medium
Mg (mg l^{-1})	1977-->	Low	Water Colour (mg Pt l^{-1})	1983-->	High
Mn (mg l^{-1})	1977-->	Low	NH_4-N (µg l^{-1})	1987-->	High
Fe (mg l^{-1})	1977-->	Low	NO_3-N (µg l^{-1})	1985-->	High
Stream hydrology (VK)			Total N (µg l^{-1})	1983-->	High
Discharge (m^3/s)	1990-->	High	PO_4-P (µg l^{-1})	1987-->	High
Stream chemistry (VK)			Total P (µg l^{-1})	1983-->	High
Oxygen (mg l^{-1})	1982-->	High	TOC (mg l^{-1})	1986-->	High
Oxygen saturation (%)	1982-->	High	CODMn (mg l^{-1})	1983-->	High
Solid (mg l^{-1})	1982-->	Medium	K (mg l^{-1})	1985-->	Low
pH	1982-->	Medium	Na (mg l^{-1})	1985-->	Low
Alkalinity (mmol l^{-1})	1982-->	Medium	Ca (mg l^{-1})	1985-->	Low
Conductivity (mS m^{-1})	1982-->	Medium	Mg (mg l^{-1})	1985-->	Low
Water Colour (mg Pt l^{-1})	1982-->	High	Mn (mg l^{-1})	1984-->	Low
NH_4-N (µg l^{-1})	1982-->	High	Fe (mg l^{-1})	1983-->	Low
NO_3-N (µg l^{-1})	1985-->	High	Cl (mg l^{-1})	1985-->	Low
Total N (µg l^{-1})	1982-->	High	SO_4 (mg l^{-1})	1985-->	Low
PO_4-P (µg l^{-1})	1982-->	High	**Lake biology (VK)**		
Total P (µg l^{-1})	1982-->	High	Chlorophyll *a* (µg l^{-1})	1989-->	High
TOC (mg l^{-1})	1988-->	High	Phytoplankton Biomass (g ww m^{-2})	1990-->	Medium
CODMn (mg l^{-1})	1982-->	High	Primary Production (mg C m^{-2} d^{-1})	1990-->	Medium
K (mg l^{-1})	1985-->	Low	Zooplankton	1990-->	Medium
Na (mg l^{-1})	1985-->	Low	Fish community	1992-->	Medium

4. Most important environmental variables

The most important environmental variables were selected for the basis of important role in the assessment of climate change impacts on catchment areas and lakes.

4.1. Air temperature

Air temperature strongly impacts the conditions in the terrestrial catchment areas. It controls the length of the growing season and production in terrestrial catchment areas. It also impacts on lakes via water temperature. Air temperature also controls the length of ice-free season and thus the growing season of phytoplankton.

4.2. Rainfall

Rainfall is an important driver of hydrology. Precipitation controls runoff which regulates nutrient transport out of the catchment areas. Predicted higher precipitation in wintertime may lead several consequences on lakes. Thus the rainfall plays an important role in the assessment of climate change impacts on lakes.

4.3. Ice season

In Lammi LTER area lakes are frozen in winter and the ice season lasts 4-6 months. Ice cover restricts effectively the exchange of heat and gases between the atmosphere and the water. Length of the ice season determines partially the length of the growing season. Ice break-up date determines indirectly the onset of reproduction of many fish species. Thus the ice season plays a major role in the seasonal dynamics of boreal lakes. Ice covered lakes are also used for many recreational purposes by local people.

4.4. Water temperature

Water temperature depends directly on the air temperature and controls the length of the growing season of phytoplankton. Changes in the water temperature and consequent changes in thermal stratification may influence lake biota and their metabolic processes. Distribution of many aquatic species depends directly or indirectly on water temperature. Thus climate change may also affect species distributions.

4.5. Oxygen concentration

Oxygen concentration depends on the water temperature and biological processes. The higher the water temperature is the lower is oxygen concentration. Oxygen concentration also determines the ecological status of the lake. In large and deep oligotrophic lakes the oxygen concentration stays high round year, whereas oxygen deficit may appear in shallow and eutrophic lakes in wintertime resulting poor winter survival of fish.

4.6. Total phosphorous (P-tot)

Total phosphorous concentration describes the trophic level and productivity of the lake. It also depends on the soil composition and land use in the terrestrial catchment area. Phosphorous is also the minimum nutrient that restricts the primary production in most of the lakes.

4.7. Total nitrogen (N-tot)

Total nitrogen concentration also describes the trophic level and productivity of the lake. It depends on the land use in the catchment area but also atmospheric deposition affects nitrogen loads to the lakes. In some cases nitrogen is the minimum nutrient that restricts the primary production in lakes.

4.8. Dissolved organic carbon (DOC)

Most of the dissolved organic carbon (DOC) in lakes is originating from the decomposition of organic matter in terrestrial catchment areas e.g. peatlands. Brown water lakes have generally high concentration of DOC and thus terrestrial organic matter plays important role in the lake food webs.

4.9. Chlorophyll-*a*

Chlorophyll-*a* concentration describes the abundance of phytoplankton and depends directly on the biomass of algae. Chlorophyll-*a* concentration also determines the trophic level and primary production of the lake.

5. Summary and further aspects

This report introduced and characterized the case study areas in the Lammi LTER area from where the environmental data is gathered. All the important environmental variables available in the region were also listed. Further the most important environmental data sets for Action 8 will be described as a metadata. The more detailed metadata descriptions will include a description of the key variables, sampling sites, methods used, length of data sets and some other characteristics such as the owner of the data. These short-term and long-term environmental data sets will be used for the assessment of climate change impacts on catchment areas and lakes. The key results will be delivered for all participants and public in the workshops, seminars and forthcoming reports.

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