Climate Cange Adaptation Tools for Environmental Risk Mitigation of Acid Sulfate Soils

CATERMASS

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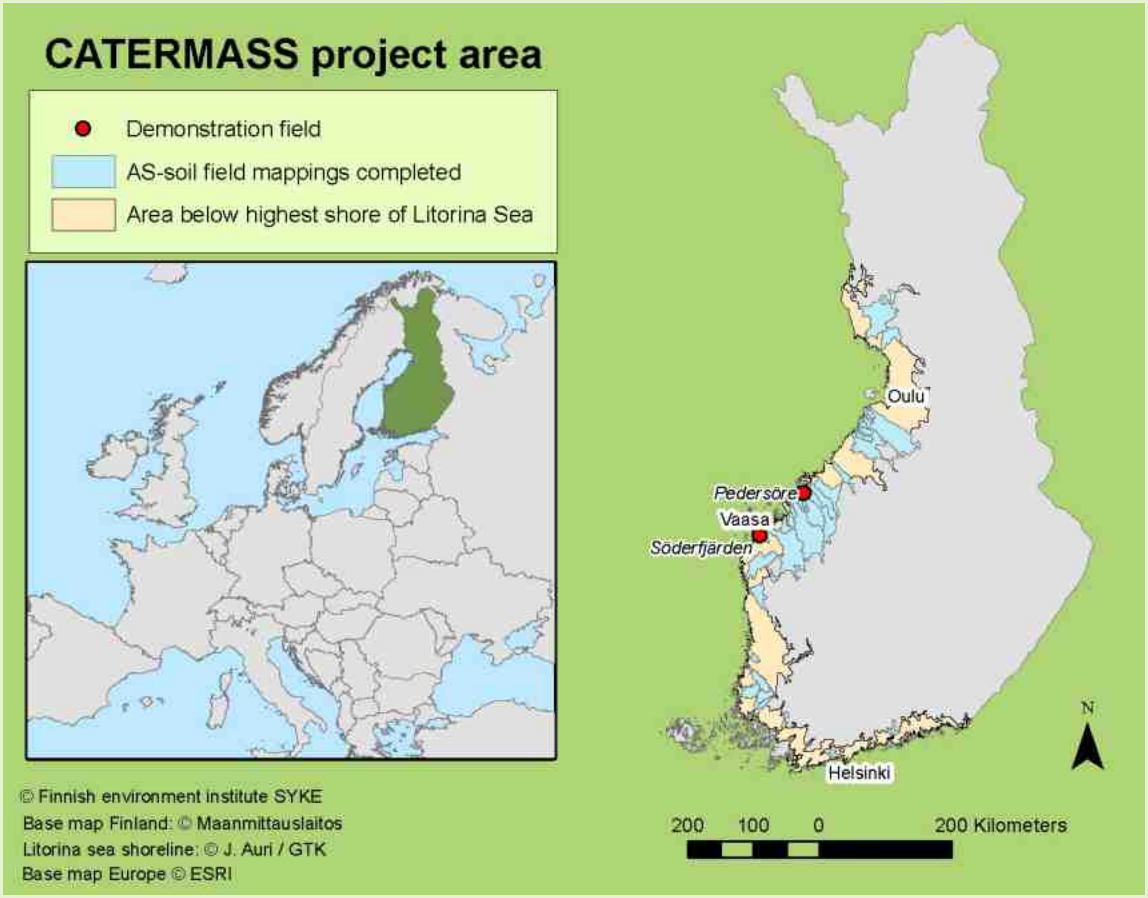
Layman´s Report


CATERMASS project area
Demonstration field
AS-soil field mappings completed
Area below highest shore of Litorina Sea
Oulu
Pedersöre
Vaasa
Söderfjärden
Helsinki
N
© Finnish environment institute SYKE
Base map Finland: © Maanmittauslaitos
Litorina sea shoreline: © J. Auri / GTK
Base map Europe © ESRI
200 100 0 200 Kilometers

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The CATERMASS-project

Climate change may dramatically increase leaching of metals and acidity from geochemical soil anomalies having naturally high sulfur- and metal storages. In boreal river basins acid sulfate soils originating from sulfidic sediments starting to deposit during an early stage of the Baltic Sea (the Litorina Sea) about 8.000 years ago, are such anomalies. These soils cover up to 3 000 km2 of the coast of Finland mainly in low-lying agricultural and peat areas. Sulfidic sediments are still forming today along our coast.

After the last ice-age Finland's coastal zone was covered by the Litorina Sea. In many places fine-grained, muddy, and sulfur-bearing sediments were deposited in the water. Broad land areas rose from the sea due to isostatic land uplift, and now they are utilized for varying land-use and drainage practices. Intensified agricultural drainage, especially subsurface drainage, has exposed sulfur-rich sediments to atmospheric oxygen, which leads to the formation of sulfuric acid in the soil, which in turn dissolves metals from the surroundings. This creates highly acidic and metal-rich runoff water, causing ecological degradation of water bodies especially in western Finland. The requirements of EU's Water Framework Directive cannot be met in this region the by the year 2015 because of the acid sulfate soils.

Climate change is likely to widen the affected area and increase environmental damages unless targeted mitigation measures are developed. High peak concentrations of toxic compounds occur especially after long dry periods and subsequent heavy rainfalls. As a result of climate change, these hydrological extremes are expected to become much more common and affect especially river basins with small lake-area and rapidly fluctuating discharges. For aquatic ecosystems and fish stocks this means increased probability for exposure to toxic metal compounds.

The objective of the CATERMASS -project, funded by EU's Life+ program, was to find tools for improving water protection in acid sulfate soil areas. The project aimed at developing methods for mitigating environmental impact of acid sulfate soils and adapting land use and water protection to changing climate conditions. Mitigation of damages to water systems, fish stocks and nature required gathering information about the distribution and quality of acid sulfate soils, changes in acidity and metal exposure, nature of environmental risks and priorities for environmental protection, existing pollution abatement methods, and the validity of these methods under changing climate conditions in Finland.

Juha Riihimäki

Acid sulfate soils: what and where

Acid sulfate soils are soils with elevated contents of sulfur and consisting of an oxidized acid horizon (actual acid sulfate soil) and/or below it a non-oxidized (reduced) sulfide-bearing horizon (potential acid sulfate soil). Acid sulfate soils are usually gyttja-bearing fine-grained soils (clay or silt), but sand can in places develop acidity, too.

Actual Acid Sulfate Soil:

- Field pH < 4.0 as a result of oxidation of sulfides and measured directly from the sample of oxidized mineral sediment or gyttja (not peat).
- If pH is 4.0 - 4.4 and there is no observation of underlying sulfide, further determinations are required (incubation or sulfur content).

Potential Acid Sulfate Soil:

- Sulfur in the form of sulfides (reduced, not oxidized)
- Typically pH > 6.0
- Total Sulfur $S_{(tot)} \geq 0.2\%$ (>0.01% in sand)
- Incubated pH ≤ 4.0 and drop of more than 0.5 units compared to field pH

Sulfide = iron - sulfur mineral (FeS2, FeS)
Incubation = sample is oxidized 8-16 weeks, after which, the pH is measured

The main activities and products include:

- An efficient method to map and identify acid sulfate soils in Finnish conditions was developed. Existing data is used for preliminary interpretation and for planning field observations, measurements and sampling for chemical analysis.
- The results obtained are used to compile catchment-specific or regional maps at a general scale (1:250.000) presenting the probability for acid sulfate soils to occur.
- Maps and other products will be available on GTK's website (www.gtk.fi) in the beginning of 2013.
- By clicking the data points of the maps, the background information and results, such as field pH, incubation pH, sulfide depth, soil types, and sulfur content can be displayed.
- We have created a Finnish definition of acid sulfate soils. The definition differs from the international definitions due to different origin, natural conditions and land use.
- A risk classification of Finnish acid sulfate soils was created. It is based on the depth of the sulfide layer, minimum pH and sulfur content.
- Simple guides describing the areas where acid sulfate soils can be found and help for identification of these soils are also found on GTK's website.

The mapping process developed in this project and all the work done has significantly increased our knowledge of the occurrence and the properties of acid sulfate soils in Finland. The observations were made 30 to 40 times denser than in the old data. A user-friendly and reliable database was created for use in e.g.:

- National, regional and local planning and decision-making (ministries, regional councils, municipalities, regional administration, consultants)
- Agriculture and forestry sector (farmers, farmers union, farmers advisory organisations, Forest Centres, drainage companies)
- Peat industry, earth works and construction
- In the future, for example when making decisions of EU subsidies.


Juha Riihimäki

Environmental impact of acid sulfate soils

We demonstrated the ecological risks of acid sulfate soils in the Finnish surface water bodies and constructed risk maps characterizing effects on fish stocks and ecological status of water bodies under different climate scenarios.

Existing monitoring results and data on environmental impacts from the national databases were supplemented those by field surveys covering less studied areas and seasons to analyse duration and timing of acid and metal peaks, and to compile exposure and effect profiles.

Ecological risk maps are constructed by integrating ecological risk assessment, hydrological and cartographic modelling.

The ecotoxicological risk classification for 14 estuary areas yielded bad status in 5 sites, passable/fair in 6 of them, and good in only 3 of the studied estuary areas.

A climate model constructed for the Finnish climate and environment was applied to estimate past and future metal discharges in River Kyrönjoki. The modelling indicated increased metal discharge at autumn when the flushing of the acid sulfate soils is at its highest and decreased discharge in spring and summer.

The response of fish species to acid loads varies largely, the salmon fishes typically being most sensitive, while species like perch and pike can tolerate more acid conditions. When pH falls low enough, to pH 4-4.5, all Finnish fish species disappear. In order to clarify ecological impacts of acid sulfate soils, 22 rivers and about 100 study sites were selected, covering a wide range in frequency of acid sulfate soils. Response of biota to differences in water quality and other environmental parameters were analyzed and the ecological status of rivers was assessed.

Fish assemblages indicated strong response to pH. Acid-intolerant fish species, e.g. bullhead, brown trout, and grayling were usually not caught at sites with average pH < 6. Perch and pike indicated high tolerance to low pH. The most acidified rivers appeared to be totally empty of fishes.


Seija Virtanen


Rainer Rosendahl


Rainer Rosendahl


Rainer Rosendahl

Lowering the environmental risks of acid sulfate soils by raising the groundwater level

We aimed to reduce the acidity of runoff and metal emissions from cultivated acid sulfate soils by raising the ground water level so high that the sulfide soil layers would be covered by groundwater. The groundwater level was kept high enough also during the summer, when the demonstration field was control drained and additional water was pumped into the drainage pipes from a nearby ditch. A plastic film extending to the sulfide layer was installed to prevent water flowing out of the lower edge of the field.

Controlling the groundwater level and its environmental impacts were studied on barley and wheat crops in the Söderfjärden demonstration field and on grass crops at the Pedersöre field near Vaasa. Three different drainage methods were tested in Söderfjärden: i) conventional drainage, ii) controlled subsurface drainage and iii) controlled subsurface drainage combined with additional pumping of water in the summer. Moreover, impacts of the water level on the soil, on chemical composition of soil water and on canary reed stands were also studied by using a 1 meter high acid sulfate soil monolith in controlled experimental conditions.

In Söderfjärden, acid sulfate soils were fertile and grain yields in excess of the average crop yields in Finland. The acidity caused leaching of metals, but metal concentrations measured from the soil and harvests were within the adequate range. However, aluminium concentrations (5–20 mg/l) measured from the drainage water exceeded the limit for household water by 20 to 100 times. So far the results from the field experiments show that raising the groundwater level increases gradually pH in drainage water and decreases leaching of aluminium. These effects were even clearer in the controlled experimental conditions.

The nitrate-nitrogen concentrations of the drainage water (22–26 mg/l) from cultivated acid sulfate soils of Söderjärden were generally 2-fold compared to the maximum allowed concentration for household water. During spring-time runoff the amount of nitrate-nitrogen leaching was estimated to be 20–30 kg/ha. High nitrogen leaching may be due to high nitrogen resources in the subsoil of acid sulfate soils. Emissions of nitrous oxide (20–30 kg/ha) from acid sulfate soils were also found to be up to 2-3 times higher than the corresponding emissions from organic soils, but the level of ground water did not affect the emissions. The results were similar in controlled conditions.

The results suggest that oxidation of sulfides can be diminished by controlled subsurface drainage, and the effect can be enhanced by pumping additional water from ditches into the drainage pipes. This is called subirrigation. Plastic film mounted into the ground and extending to the sulfide layer may effectively prevent water from escaping from the field. Combining these methods allow keeping sulfide layers in reduced state.


Rainer Rosendahl

Multi-criteria evaluation of measures to control acid runoff from sulfate soils

The methods available for mitigation of adverse environmental impacts of acidic and metal-rich runoff from acid sulfate soils can influence the ecological state of rivers and estuaries, but they will also raise costs and other social impacts to farmers and to the society at large. The socio-economic sub-project has evaluated the divergent impacts from different strategies to control the acid runoff from sulfate soils (Figure x), based on data from river Kyrönjoki.

Extending controlled subsurface drainage to all fields with conventional draining already installed, in river Kyrönjoki basin, would cost for the farmers around 2,7 M€ per year and controlled subsurface drainage combined with plastic film and subirrigation would cost around 3,7 M€ per year. Most of these costs come from increased labour costs for farmers. The costs for the Finnish Government from subsidies and investment support would be around 1,4 M€ and 1,8 M€, respectively. These costs can be compared with the annual agricultural subsidies of 12 M€. The costs from drainage restrictions and restoration depend on their implementation. If they are carried out through voluntary measures such as nature value trading, they can be economic solutions for some farmers. However, the farmers' attitude towards all land-use restrictions was clearly negative and they were considered to have harmful impacts on the livelihood and farmers' identity and also on the local economy. The restoration of the drainage state can also have harmful scenic impacts, if the open fields typical for Southern Ostrobothnia landscape will be forested.

The cumulative effect of mitigation methods can reduce the occurrence of harmful acidity peaks from 30 per cent to 10 per cent and raise the average pH-value from 5,7 to 6,0. As a consequence, the share of sensitive species in the fish catch will increase and the measures will enable a slow restoration of the ecological and physical-chemical condition of River Kyrönjoki. It is possible that the state of River Kyrönjoki will be improved from bad to poor in some parts, and from poor to moderate in some parts, according to the classification system by Water Framework Directive. It is also possible that the effectiveness of fish stockings will improve and hence the likelihood of catching trout will be better. Taken together, these changes will improve the conditions for recreational fishing in river Kyrönjoki and the professional fishing in the estuary.

Jaana Wallin

CATERMASS in figures

- Participants in the project: 7 institutes and universities (Finnish Environment Institute SYKE, Centre for Economic Development, Transport and the Environment of Southern Ostrobothnia, Geological Survey of Finland (GTK), Agrifood Research Finland (MTT), Finnish Game and Fisheries Research Institute (RKTL), University of Helsinki, Åbo Akademi)
- Actors involved in the project: 118 persons, 450 man months
- Duration of the project: 3 years (2010—2012)
- Project funding: 2,9 million euros

Reports and publications:

- The impact of acid sulfate soils on water bodies and fish deaths in Finland
- Mitigating environmental risks on acid sulfate soils - Guide for controlling groundwater table
- Layman's Report
- Brochures 1

Seminars and workshops:

- National Kick-off Seminar for stakeholders
- Sub-projects seminars and workshops 10
- Lectures, presentations and posters in national and international seminars and conferences 35

Presentation of results in media:

- Articles in national and regional papers 26
- Radio presentations 2
- Fairs and other public events 1
- Press and news releases in the Internet 13

Websites and portals:

• www.ymparisto.fi/syke/catermass

Homepage of the project (in Finnish)

• www.miljo.fi/syke/ catermass

Homepage of the project (in Swedish)

• www.environment.fi/syke/ catermass

Homepage of the project (in English)

• http://www.catermass.fi

CATERMASS homepage information on acid sulfate soils


Jaana Wallin

CATERMASS

Climate Change Adaptation Tools for
Environmental Risks of Acid Sulfate Soils

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2. Environmental impact assessment
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