Late Holocene Erosion and Transport from an Agrarian Landscape into a small Lake in Southeastern Norway: A Catchment Study

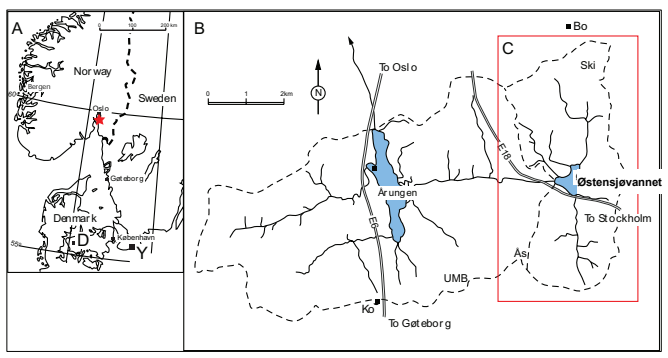
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Introduction

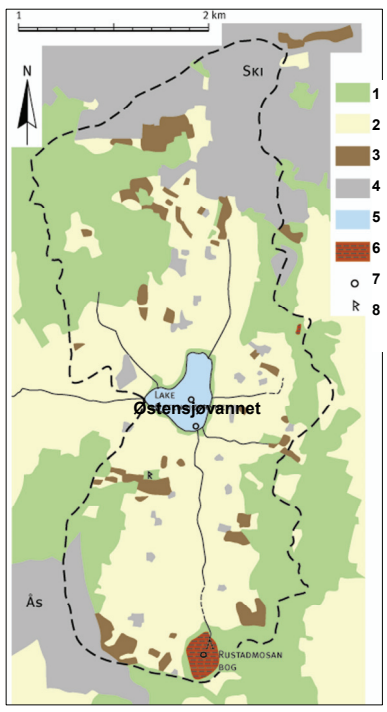
The six authors comprise a research-group within the project Ecology and economy of agriculture in a changing climate (www.umb.no/eacc) financed by the Norwegian Research Council. We focus on the effects of the agricultural expansion on the landscape over the last 4500 years, by studying sediment cores in the lake Østensjøvannet in southern Akershus county, and a full Holocene section from a peatbog within the catchment.

Location Maps



The study area is located in southeastern Norway (Map A). The catchment of Lake Østensjøvannet (Map C) is part of the Lake Årungen catchment (Map B), where several research projects were carried out in the nineteen seventies and eighties (NLVF 1979), and where a new project has been initiated this year (Krogstad 2006). Several sedimentological and biostratigraphical studies have been carried out within, and in the vicinity of the Lake Årungen catchment (Nybakken 1985, Sørensen 1990, Abrahamsen et al. 1995)

Present Land Use

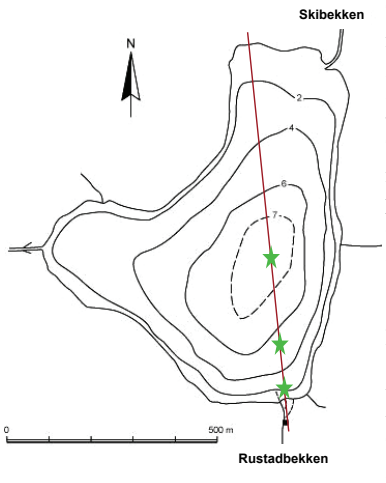


The catchment, has a total area of 13.8 km^2:

1. Forest areas (ca 30%);
2. Cultivated land (ca 53%)
4. Urban areas and farmyards (ca. 15%)
5. Lake area (2.4 %); and
6. Bog areas (ca. 1 %).
7. Coring sites

No. 3 on the legend is ***umbrisols*** and complexes containing umbrisol. They are almost exclusively found on top of the ice-marginal ridges and are developed in beach sediments. They represent most likely old permanently cultivated fields where cow-dung and other organic materials have been added regularly.

The Lake



The depth of the lake has been measured on a 100 x 100 m grid, from the ice, located with a GPS. Coring of sediment-unit **D** was done at same time. The main coring sites are marked on the map, and a profile (see column 2, above) cross the lake show the assumed distribution of sediment units. The lake surface area is 0.33 km^2. Maximum depth is 7.1 m (measured March 2005), and the lake volume is estimated to be 1.33 mill m^3. The hydraulic retention time is approximately 72 days.

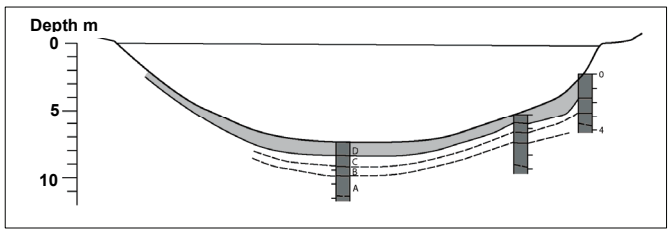
Lake Østensjøvannet



The catchment is located in a landscape that has been affected by man for more than 5000 years (Sørensen 1990). A detailed map over a greater part of the catchment dated 1887-88, show that the cleared area (agricultural fields and pastures) was almost identical to the present, with the exception of the parts around Ski and Ås centres which has been urbanised after the establishment of the railroads in 1887. The catchment is located in one of the most productive agricultural regions of Norway.

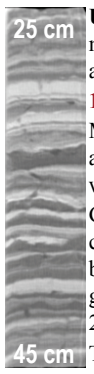
Sediment Units

Based on visual description of the cores, four sediment units have been identified. X-ray tomography and magnetic analyses have confirmed this subdivision, with small adjustments of unit boundaries. The lower unit **A** is finely laminated – possibly with annual lamina. Unit **B** is transitional – with disturbed lamina. Unit **C** contains considerably more organic matter than the units below and above, and contain 'gas-escape' structures. Unit **D** represents the last 400-500 years of sedimentation and erosion from an expanding agriculture.



The Lake Sediments

Depth **Unit Description:**



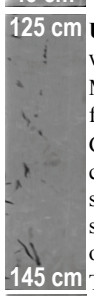
Unit D – upper part, representing modern agricultural management, with strong erosion, and pollution from both farms and urban areas.

137Cs-date = 1963 - 64

Maximum loading of sediments and pollution. Black layers (FeSx) are common, indicating frequent anoxic conditions in the bottom waters.

Grain-size distribution: ca 2 % sand, 35-45 % silt and 50-55 % clay. Maximum contents of available phosphorous, but minimum biogenic silica and low C/N ratios, indicate domination of blue-green algae and Pediastrum over diatoms (Meyers & Teranes 2001). Some gas (methane) production.

The section represents the timespan: AD 1980 - 1940.

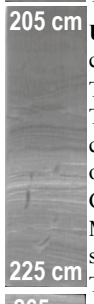


Unit C – middle part, representing Late Medieval conditions, with moderate agricultural activity and little erosion.

Massive clay gyttja (ca 13 % TOC) with traces of gas escape features (black lines in the image), and/or bioturbation.

Grain-size distribution: ca 2 % sand, 30-40 % silt, and 55-65 % clay. Moderate contents of available phosphorous, high biogenic silica indicate high diatom production. High C/N ratios indicate some terrestrial input, which coincide with maximum distribution of Norway spruce (Picea).

The section represents the timespan: AD 1180 - 940.

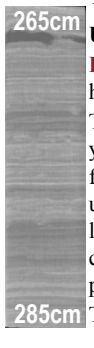


Unit B – middle part, representing Younger Iron Age, with continuous farming and cattle-grazing in the area.

The unit is transitional, changing from massive clay gyttja (high TOC but low C/N ratios) to diffuse lamination with low TOC contents. High contents of charcoal indicate that this is a period of land clearance.

Grain-size distribution: ca 2 % sand, ca 35 % silt, and ca 63 % clay. Moderate - low contents of available phosphorous and biogenic silica.

The section represents the timespan: AD 70 – 220 BC.



Unit A – upper part, representing Bronze Age and early farming.

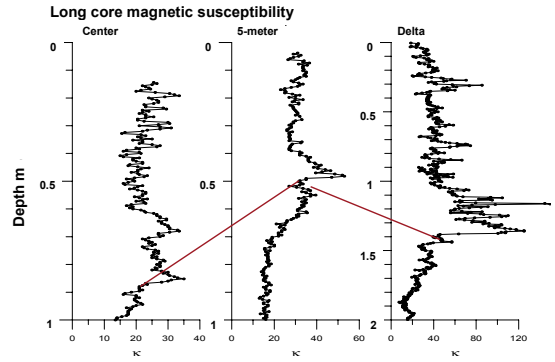
LuS 6665-B = 805 – 895 BC (macro-remains of grasses and herbs; black in image)

The first grain-growing in the region is dated back to ca. 4000 years BP but the first phase of continuous farming is recorded from ca. 3200 years BP. However, unit A represents an almost unaffected ecosystem with sedimentation rates of ca. 0.6 mm yr-1, low – oscillating contents of TOC and C/N ratios, and 65 - 70 % clay. The bottom waters must have been anoxic, preserving a possible annual lamination.

The section represents the timespan: 800 - 1170 BC.

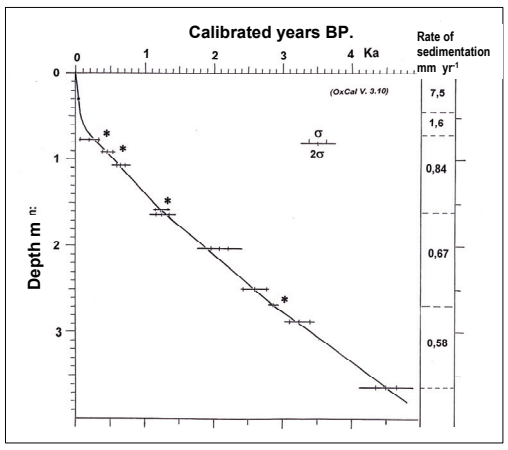
Magnetic Investigations

Long core magnetic susceptibility on the three cores from the lake has been used for correlation between the delta facies and the centre of the lake. This has been particularly useful and informative for the youngest sediment unit **(D;** *lower boundary is marked with red line*), indicating a rapid increase in erosion / sedimentation some 300 years ago. Detailed magnetic investigation on the delta and centre core has also been carried out.



Sedimentation Rates

Sedimentation rates have been calculated on the basis of nine ^{14}C-dates, and location of the Tsjernobyl and of the maximum fallout from the atmospheric bomb-testing in 1963-64 by ^{137}Cs-analysis. The ^{14}C-datings have mainly been done on the NaOH soluble fraction of bulk sediment, and an assumed reservoir-age of 425 years has been subtracted. Three datings of terrestrial macro-remains in the lake sediments, and the dated expansion of Picea in three peatbogs (correlation by pollen) in the area, have been used for estimating the reservoir-age. The radio-carbon dates have been calibrated with OxCal V. 10.3



Methods

The lake sediments were cored from ice with a 4 m long piston-corer with a diameter of 100 mm (Nesje 1992). The cores were split lengthwise, and one of the half-cylinders were described, photographed, and sub-sampled for different purposes (pollen, diatomes, LOI –TOC, TN, P, and heavy metals). The other half were sealed and placed in a cold-storage at ca. 4 °C for further analyses tomography and grain-size. The grain-size analyses were done on ca. 300 cm^3 samples taken at every 8 cm depth, except for the upper 90 cm (central core) were samples are smaller and at closer intervals. Organic matter was removed with H_2O_2. Sand was separated with wet-sieving, and the silt and clay fractions were analysed on a Sedigraph instrument. Long core magnetic susceptibility and other magnetic properties were analysed at the magnetic laboratory, Lund University. X-ray tomography was done on long cores, and on 20 cm long core segments at the University of Life Sciences, Ås.

Concluding Remarks

The time-span covered show the development of the cultural landscape from the Late Neolithic up to the present. The sedimentation rates stayed very low up to the end of Older Iron Age, and the farming activities had little effect on sediment erosion and transport into the lake. From the Viking Age up to approximately AD 1850 a slight increase in the sediment-ation rates can be recorded. During this time-span the small areas of open soil were most likely located on sandy soil with low risk of surface erosion, and the drainage lines were well protected by vegetation. Most of the cleared land was used for grazing. With the introduction of modern farm machinery around AD 1850, artificial drainage, and clearing of large tracts of poorly drained clay soils close to the lake, the sedimentation rates increased more than ten times. We will try to model the catchment erosion (ERONOR, Lundekvam 2003) for the last 130 years that we have instrumental climatic data from the area, and compare with the calculated sedimentation rate in the lake.

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