The Norwegian Forest and Landscape Institute

WRB FIELD EXCURSION IN NORWAY 2010

Field guide

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Cover photo: Agricultural land in the municipality of Dovre, Photo: Siri Svendgård-Stokke, The Norwegian Forest and Landscape Institute

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Foreword

The Norwegian Forest and Landscape Institute is pleased to welcome you to the WRB field excursion, 13th -17th of September 2010.

Main topics at the excursion:

Soils with a high content of clay and silt, and with low water permeability cover a large area of the most important cultivated land in Norway. These soils have stagnic and/or gleyic colour patterns, and have been artificially drained for cultivation. Discussions at sites 1, 2, 3, 4 and 5.

Some soils with a high content of clay and silt are covered by coarse material having an abrupt textural change within 100 cm of the soil surface, for example shore deposits covering marine silt and clay. Are these Planosols? Discussions at sites 1 and 3.

In order to be able to use heavy machinery in steep and hilly areas, large areas of agricultural land were levelled during the 1960s and the 1970s. These were mainly marine deposits. Where in WRB do these fit? Discussions at sites 11 and 12.

The Norwegian Forest and Landscape Institute is using an adjusted version of the WRB in the ongoing soil survey. Two methods will be shown, detailed mapping 1:15 000 and general mapping 1: 50 000, sites 6 and 9.

The field guide

The first part of the field guide deals with background information on Norway in general, climate at the sites, geology, agriculture, classification of agricultural soils in Norway, soil survey and land levelling. In part two, each site is presented with location maps, soil maps and pictures, together with profile descriptions, analytical data and subjects for classification discussions. Classification is done according to WRB 2006, First update 2007 (except for sites 2 and 4). Three appendixes are included: Using WRB as basis for soil mapping units in detailed soil mapping in Norway, methods of soil analysis and micro photos showing Albeluvisol development in southern Norway. In addition, four handouts are distributed in the beginning of the WRB field excursion:

- Reshaping the old seabed – river erosion and clay slides. Extract from (pages 544-547): "The making of a land – Geology of Norway", Ramberg, Bryhni, Nøttvedt & Rangnes (Eds), 2008. Publisher: Geological Society of Norway, ISBN: 978-82-92394-42-7 http://www.geologi.no/cgi-bin/geologi/imaker?id=11579&visdybde=1&aktiv=11579
- Hofgaard, A. 2006. Monitoring of palsa peatlands. Initial investigation in Dovre 2005: Haukskardmyrin and Haugtjørnin. NINA Rapport 154
- Sauer, D. et al., Albeluvisol development with time in loamy marine sediments of southern Norway, Quarternary International (2008), doi: 10.1016/j.quaint.2008.09.007
- Sperstad, R. Unpublished

Agricultural land in the county of Østfold, the municipality of Dovre and in the county of Sør-Trøndelag (all photos: Siri Svendgård-Stokke)

Ås, August 2010

Siri Svendgård-Stokke

CONTENT

1. BACKGROUND INFORMATION

1.1. ARTICLE from Britannica World Data

Official name	Kongeriket Norge (Kingdom of Norway)
Form of government	constitutional monarchy with one legislative house (Storting, or Parliament [169])
Head of state	King
Head of government	Prime Minister
Capital	Oslo
Official languages	Norwegian; Sami (locally)
Official religion	Evangelical Lutheran
Monetary unit	Norwegian krone (pl. kroner; NOK)
Population estimate	(2009) 4,828,000
Total area (sq mi)	148,7181
Total area (sq km)	385,1791

1Includes Svalbard and Jan Mayen.

Country, western Scandinavian Peninsula, northern Europe.

Area (including Svalbard and Jan Mayen): 148,718 sq mi (385,179 sq km). Population (2009 est.): 4,828,000. Capital: Oslo. Most of the people are Norwegian, though there are several ethnic minorities, including some 30,000 to 40,000 Sami (Lapps). Languages: Norwegian, Sami (official). Religion: Christianity (predominantly Evangelical Lutheran [official]). Currency: Norwegian krone. Norway is among Europe's largest countries. It is a mountainous land with extensive plateau regions in its southwestern and central parts. Traditionally a fishing and lumbering country, it greatly increased its mining and manufacturing activities since World War II. It has a developed economy largely based on services, petroleum and natural gas production, and light and heavy industries. Literacy is virtually 100%. Norway is a constitutional monarchy with one legislative house; its head of state is the king, and the head of government is the prime minister. Several principalities were united into the kingdom of Norway in the 11th century. It had the same king as Denmark from 1380 to 1814, when it was ceded to Sweden. The union with Sweden was dissolved in 1905, and Norway's economy grew rapidly. It remained neutral during World War I, although its shipping industry played a vital role in the conflict. It declared its neutrality in World War II but was invaded and occupied by German troops. Norway maintains a comprehensive welfare system and is a member of NATO. Its citizens rejected membership in the European Union in 1994.

Norway is a country of northern Europe that occupies the western half of the Scandinavian peninsula. Nearly half of the inhabitants of the country live in the far south, in the region around Oslo, the capital. About two-thirds of Norway is mountainous, and off its much-indented coastline lie, carved by deep glacial fjords, some 50,000 islands.

Indo-European peoples settled Norway's coast in antiquity, establishing a permanent settlement near the present capital of Oslo some 6,000 years ago. The interior was more sparsely settled, owing to extremes of climate and difficult terrain, and even today the country's population is concentrated in coastal cities such as Bergen and Trondheim. Dependent on fishing and farming, early Norwegians developed a seafaring tradition that would reach its apex in the Viking era, when Norse warriors regularly raided the British Isles, the coasts of western Europe, and even the interior of Russia; the Vikings also established colonies in Iceland and Greenland and explored the coast of North America (which Leif Eriksson called Vinland) more than a thousand years ago. This great tradition of exploration by such explorers as Leif Eriksson and his father, Erik the Red, continued into modern times, exemplified by such men as Fridtjof Nansen, Roald Amundsen, and Thor Heyerdahl. Weakened by plague and economic deterioration in the late Middle Ages and dominated by neighbouring Denmark and Sweden, Norwegians turned to trading in fish and lumber, and modern Norway, which gained its independence in 1905, emerged as a major maritime transporter of the world's goods as well as a world leader in specialized shipbuilding. In the 1970s the exploitation of offshore oil and natural gas became the major maritime industry, with Norway emerging in the 1990s as one of the world's leading petroleum exporters.

Lying on the northern outskirts of the European continent and thus avoiding the characteristics of a geographic crossroads, Norway (the "northern way") has maintained a great homogeneity among its peoples and their way of life. Small enclaves of immigrants, mostly from south-eastern Europe and South Asia, established themselves in the Oslo region in the late 20th century, but the overwhelming majority of the country's inhabitants are ethnically Nordic. The northern part of the country, particularly the rugged Finnmark Plateau, is home to the Sami (also called Lapps or Laplanders), a Uralic people whose origins are obscure. Life expectancy rates in Norway are among the highest in the world. The main political division reflects differing views on the importance of free-market forces; but the socialists long ago stopped insisting on nationalization of the country's industry, and the non-socialists have accepted extensive governmental control of the country's economy. Such evident national consensus—along with abundant waterpower, offshore oil, and peaceful labour relations—was a major factor in the rapid growth of Norway as an industrial nation during the 20th century and in the creation of one of the highest standards of living in the world, reinforced by a comprehensive social welfare system.

Norway's austere natural beauty has attracted visitors from all over the world. The country has also produced many important artists, among them composer Edvard Grieg, painter Edvard Munch, novelists Knut Hamsun and Sigrid Undset, and playwright Henrik Ibsen. Of his country and its ruminative people, Ibsen observed, "The magnificent, but severe, natural environment surrounding people up there in the north, the lonely, secluded life—the farms are miles apart—forces them to…become introspective and serious.…At home every other person is a philosopher!"

Land

With the Barents Sea to the north, the Norwegian Sea and the North Sea to the west, and Skagerrak (Skager Strait) to the south, Norway has land borders only to the east—with Sweden, Finland, and Russia.

Norway occupies part of northern Europe's Fennoscandian Shield. The extremely hard bedrock, which consists mostly of granite and other heat- and pressure-formed materials, ranges from one to two billion years in age.

RELIEF

Glaciation and other forces wore down the surface and created thick sandstone, conglomerate, and limestone deposits known as sparagmite. Numerous extensive areas called peneplains, whose relief has been largely eroded away, also were formed. Remains of these include the

Hardanger Plateau—3,000 feet (900 metres) above sea level—Europe's largest mountain plateau, covering about 4,600 square miles (11,900 square km) in southern Norway; and the Finnmark Plateau (1,000 feet [300 metres] above sea level), occupying most of Finnmark, the northernmost and largest county of Norway.

From the Cambrian through the Silurian geologic period (i.e., from about 540 to 415 million years ago), most of the area was below sea level and acquired a layer of limestone, shale, slate, and conglomerate from 330 to 525 feet (100 to 160 metres) thick. Folding processes in the Earth then gave rise to a mountain system that is a continuation of the Caledonian orogenic belt. Norway has an average elevation of 1,600 feet (500 metres), compared with 1,000 feet (300 metres) for Europe as a whole.

Rivers running westward acquired tremendous erosive power. Following fracture lines marking weaknesses in the Earth's crust, they dug out gorges and canyons that knifed deep into the jagged coast. To the east the land sloped more gently, and broader valleys were formed. During repeated periods of glaciation in the Great Ice Age of the Quaternary Period (i.e., about the last 2.6 million years), the scouring action of glaciers tonguing down the V-shaped valleys that were then part of the landscape created the magnificent U-shaped drowned fjords that now grace the western coast of Norway. Enormous masses of soil, gravel, and stone were also carried by glacial action as far south as present-day Denmark and northern Germany. The bedrock, exposed in about 40 percent of the area, was scoured and polished by the movements of these materials.

There are four traditional regions of Norway, three in the south and one in the Arctic north. The three main regions of the south are defined by wide mountain barriers. From the southernmost point a swelling complex of ranges, collectively called Lang Mountains, runs northward to divide eastern Norway, or Østlandet, from western Norway, or Vestlandet. The narrow coastal zone of Vestlandet has many islands, and steep-walled, narrow fjords cut deep into the interior mountain region. The major exception is the wide Jæren Plain, south of Stavanger. An eastward sweep of the mountains separates northern Østlandet from the Trondheim region, or Trøndelag. Northern Norway, or Nord-Norge, begins almost exactly at the midpoint of the country. Most of the region is above the Arctic Circle, and much of it is filled with mountains with jagged peaks and ridges, even on the many islands.

DRAINAGE

The Glåma (Glomma) River, running south almost the entire length of eastern Norway, is 372 miles (600 km) long—close to twice the length of the two other large drainage systems in southern Norway, which meet the sea at the cities of Drammen and Skien. The only other long river is the 224-mile- (360-km-) long Tana-Anarjåkka, which runs northeast along part of the border with Finland. Norway has about 65,000 lakes with surface areas of at least 4 acres (1.5 hectares). By far the largest is Mjøsa, which is 50 miles (80 km) north of Oslo on the Lågen River (a tributary of the Glåma).

SOILS

In the melting periods between ice ages, large areas were flooded by the sea because the enormous weight of the ice had depressed the land. Thick layers of clay, silt, and sand were deposited along the present coast and in large areas in the Oslo and Trondheim regions, which rise as high as 650 feet (200 metres) above sea level today. Some very rich soils are found below these old marine coastal regions. In the large areas covered by forests, the main soil has been stripped of much of its mineral content, and this has created poor agricultural land.

In the interior of the Østlandet region, farms are located along the sides of the broad valleys, the bottoms of which contain only washed-out deposits of soil. With rich glacier-formed soils, exceptionally mild winters, long growing seasons, and plentiful precipitation, the Jæren Plain boasts the highest yields of any agricultural area in Norway.

CLIMATE

Although it occupies almost the same degrees of latitude as Alaska, Norway owes its warmer climate to the Norwegian Current (the north-eastern extension of the Gulf Stream), which carries four to five million tons of tropical water per second into the surrounding seas. This current usually keeps the fjords from freezing, even in the Arctic Finnmark region. Even more important are the southerly air currents brought in above these warm waters, especially during the winter.

The mean annual temperature on the west coast is 45 °F (7 °C), or 54 °F (30 °C) above average for the latitude. In the Lofoten Islands, north of the Arctic Circle, the January mean is 43 °F (24 °C) above the world average for this latitude and one of the world's greatest thermal anomalies. Norway lies directly in the path of the North Atlantic cyclones, which bring frequent gales and changes in weather. Western Norway has a marine climate, with comparatively cool summers, mild winters, and nearly 90 inches (2,250 mm) of mean annual precipitation. Eastern Norway, sheltered by the mountains, has an inland climate with warm summers, cold winters, and less than 30 inches (760 mm) of mean annual precipitation.

PLANT AND ANIMAL LIFE

Norway has about 2,000 species of plants, but only a few, mainly mountain plants, are endemic to Norway. Thick forests of spruce and pine predominate in the broad glacial valleys up to 2,800 feet (850 metres) above sea level in eastern Norway and 2,300 feet (700 metres) in the Trondheim region. Even in the thickest spruce woods the ground is carpeted with leafy mosses and heather, and a rich variety of deciduous trees—notably birch, ash, rowan, and aspen—grow on even the steepest hillsides. The birch zone extends from 3,000 to 3,900 feet (900 to 1,200 metres) above sea level, above which there is a willow belt that includes dwarf birch.

In western Norway conifers and broad-leaved trees abound in approximately equal numbers. The largest forests in Norway are found between the Swedish border and the Glåma River, east of Oslo. About half of the Østlandet region is forested. The region also has about half of Norway's total forest resources and an equivalent share of the country's total area of fully cultivated land. Nearly one-third of the area of Trøndelag is forested. North of the Arctic Circle there is little spruce, and pine grows mainly in the inland valleys amid their surprisingly rich vegetation. Wild berries grow abundantly in all regions; they include blueberries and cranberries of small size as well as yellow cloudberries, a fruit-bearing plant of the rose family that is little known outside Scandinavia and Britain.

Reindeer, wolverines, lemmings, and other Arctic animals are found throughout Norway, although in the south they live only in the mountain areas. Elk are common in the large coniferous forests, and red deer are numerous on the west coast. Just 150 years ago large animals of prey were common in Norway, but now the bear, wolf, and lynx are found only in a few areas, mainly in the north. Foxes, otters, and several species of marten, however, are common, and in many areas badgers and beavers thrive.

Most of the rivers and lakes have a variety of fish, notably trout and salmon. The latter are found in at least 160 rivers, often in an abundance that attracts anglers from throughout the world.

Of the large variety of birds, many migrate as far as Southern Africa for the winter. In the north people collect eggs and down from millions of seabirds, and, as far south as Ålesund, small cliff islands often are nearly covered by several hundred thousand nesting birds. Partridges and several kinds of grouse are common in the mountains and forests and are popular game birds.

People

ETHNIC GROUPS

In most parts of Norway the nucleus of the population is Nordic in heritage and appearance. Between 60 and 70 percent have blue eyes. An influx of people from southern Europe has been

strong in south-western Norway. Nord-Norge has about nine-tenths of the estimated 30,000 to 40,000 Sami—the country's first inhabitants—living in Norway. Only a small number of them still practice traditional reindeer herding on the Finnmark Plateau. The Sami arrived in Norway at least 10,000 years ago, perhaps from Central Asia. Formerly subject to widespread, even official ethnic discrimination, the Sami are now legally recognized as a distinct culture and have been granted some measure of autonomy through the Sami Parliament.

LANGUAGES

The Norwegian language belongs to the North Germanic branch of the Germanic language group. The Norwegian alphabet has three more letters than the Latin alphabet—æ, ø, and å, pronounced respectively as the vowels in bad, burn, and ball. Modern Norwegian has many dialects, but all of them, as well as the Swedish and Danish languages, are understood throughout all three of these Scandinavian countries. Until about 1850 there was only one written language, called Riksmål, or "Official Language," which was strongly influenced by Danish during the 434-year union of the two countries. Landsmål, or "Country Language," was then created out of the rural dialects. After a long feud, mostly urban-rural in makeup, the forms received equal status under the terms Bokmål ("Book Language") and Nynorsk (New Norwegian), respectively. For more than four-fifths of schoolchildren, Bokmål is the main language in local schools, and it is the principal language of commerce and communications. In daily speech Bokmål is predominant in the area around Oslo and the eastern Norwegian lowland, while Nynorsk is widely spoken in the mountainous interior and along the west coast.

More than 15,000 Norwegians, mostly in scattered pockets of northern Norway, speak North Sami as a first language. A Uralic language, Sami has been granted semi-official status even as it has rapidly lost ground to Norwegian.

Almost all educated Norwegians speak English as a second language. Indeed, so widespread is its use that some commentators have voiced concern that English may displace Norwegian in commerce and industry.

RELIGION

About nine-tenths of all Norwegians belong to the Evangelical Lutheran national church, the Church of Norway, which is endowed by the government. The largest groups outside this establishment are Pentecostals, Roman Catholics, Lutheran Free Church members, Jehovah's Witnesses, Methodists, and Baptists. As a result of Asian immigration, there also are small groups of Muslims and Buddhists.

SETTLEMENT PATTERNS

Østlandet contains more than half of Norway's population, most of whom live in the metropolitan area of the national capital, Oslo, and in the many industrial cities and urban agglomerations on both sides of Oslo Fjord. With the lion's share of the national wealth in mining and manufacturing and the concentration of economic activity around Oslo Fjord, Østlandet has the highest average income per household of Norway's traditional regions.

Norway has never had the agricultural villages that are common elsewhere in Europe. The more densely populated areas of the country have grown up around crossroads of transportation, from which people have moved to the cities and suburbs. Thus, there is actually little borderline between the rural and urban populations. For many years Oslo has attracted settlers from throughout the country, becoming a national melting pot surrounded by the most important agricultural and industrial districts of Norway. The coastline facing Denmark across the Skagerrak passage, stretching from Oslo Fjord to the southern tip of Norway, is densely populated and contains many small towns, coastal villages, and small farms. Centred on the city of Kristiansand, this area is sometimes set apart as a fifth region: southern Norway, or Sørlandet. In Vestlandet the industrial city of Stavanger has attracted large numbers of settlers and has continued to expand

as Norway's oil capital. Bergen, the capital of Vestlandet and Norway's largest city from the Hanseatic period in the mid 19th century, is a centre for fish exports. Trondheim, the third largest city in Norway and for long periods the national capital, dominates Trøndelag. Tromsø is the capital of Nord-Norge and is a hub for various Arctic activities, including fishing, sealing, and petroleum exploration.

DEMOGRAPHIC TRENDS

Largely as a result of a significant increase in the proportion of the population over age 80, the population of Norway continued to grow slowly but steadily at the end of the 20th century. The birth rate fell slightly during the 1990s—to about half the world's average—but so did the death rate, as life expectancy (about 75 years for men and about 81 years for women) was among the highest in Europe.

Migration from rural to urban areas slowed in the 1980s, but movement away from Nord-Norge increased. At the beginning of the 21st century, about three-fourths of the population lived in towns and urban areas. Norway has a small but varied population of foreign nationals, the great majority of them living in urban areas. Of these, more than half are from other European countries—primarily Denmark, Sweden, and the United Kingdom, with small groups from Pakistan and North and South America (primarily the United States). Since the 1960s Norway has practiced a strict policy concerning immigrants and refugees. Emigration—of such great importance in Norway in the 19th and early 20th centuries—ceased to be of any significance, although in most years there is a small net out-migration of Norwegian nationals.

Economy

The Norwegian economy is dependent largely on the fortunes of its important petroleum industry. Thus, it experienced a decline in the late 1980s as oil prices fell, but by the late 1990s it had rebounded strongly, benefiting from increased production and higher prices. In an effort to reduce economic downturns caused by drops in oil prices, the government in 1990 had established the Government Petroleum Fund (renamed the Government Pension Fund), into which budget surpluses were deposited for investment overseas. Norway reversed its negative balance of payments, and the growth of its gross national product (GNP)—which had slowed during the 1980s—accelerated. By the late 1990s Norway's per capita GNP was the highest in Scandinavia and among the highest in the world. The Norwegian economy remained robust into the early 21st century, and Norway fared much better than many other industrialized countries during the international financial and economic crisis that began in 2008.

Only about one-fifth of Norway's commodity imports are food and consumer goods; the rest consists of raw materials, fuels, and capital goods. The rate of reinvestment has been high in Norway for a number of years. This is reflected in the relatively steady employment in the building and construction industry. Rapid growth, however, has been registered in commercial and service occupations, as is the case in most countries with a high standard of living.

Fewer than 5 percent of the industrial companies in Norway have more than 100 employees. Nonetheless, they account for half of the industrial labour force and for more than half of production. The smaller companies are usually family-owned, whereas most of the larger ones are joint-stock companies. Foreign interests control companies accounting for about 10 percent of total production. Only a few larger concerns are state-owned, and even these are usually run with almost complete independence. However, the government traditionally has had a significant ownership control over major economy sectors, such as oil, telecommunications, power, and transport, but from the end of the 1990s many such companies were partially or fully privatized.

Citation:

"Norway." Encyclopædia Britannica. 2010. Encyclopædia Britannica Online. 16 Jun. 2010 http://www.britannica.com/EBchecked/topic/420178/Norway

1.2. Climate at the sites

Table 1 Mean monthly temperature, 1961 – 1990 normals (˚C) (The Norwegian Meteorological Institute)

Site - municipality	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual (˚C)
1 Nes	-6.9	-6.6	-1.5	3.5	9.9	14.3	15.3	14.1	9.8	5.2	-1.1	-5.3	4.2
2 Trøgstad	-6.2	-6.0	-1.7	3.1	9.6	13.8	14.9	13.8	9.3	5.4	-0.4	-4.5	4.3
3 Moss	-2.3	-2.8	0.3	4.6	10.5	15.0	16.6	15.8	11.9	7.8	2.6	-0.8	6.6
4 Sarpsborg	-3.0	-3.0	0.2	4.9	10.6	14.8	16.7	15.6	11.6	7.5	2.4	-1.1	6.4
5 Råde	-3.7	-3.5	0.0	4.7	10.5	14.5	16.5	15.4	11.4	7.1	1.8	-1.5	6.1
7 Ringsaker	-7.4	-8.1	-3.1	2.2	8.5	13.6	15.2	14.0	9.6	5.1	-0.8	-5.3	3.6
8 Dovre	-9.0	-7.9	-4.0	0.3	6.5	10.7	12.0	11.1	6.6	2.2	-4.1	-7.4	1.4
10 Dovrefjell	-10.3	-9.5	-7.0	-2.9	3.8	8.4	10.0	8.9	4.4	0.4	-5.7	-8.6	-0.7
11, 12 Melhus	-6.0	-5.0	-2.0	2.5	9.0	12.5	14.0	13.2	9.5	5.0	-2.0	-4.0	3.9

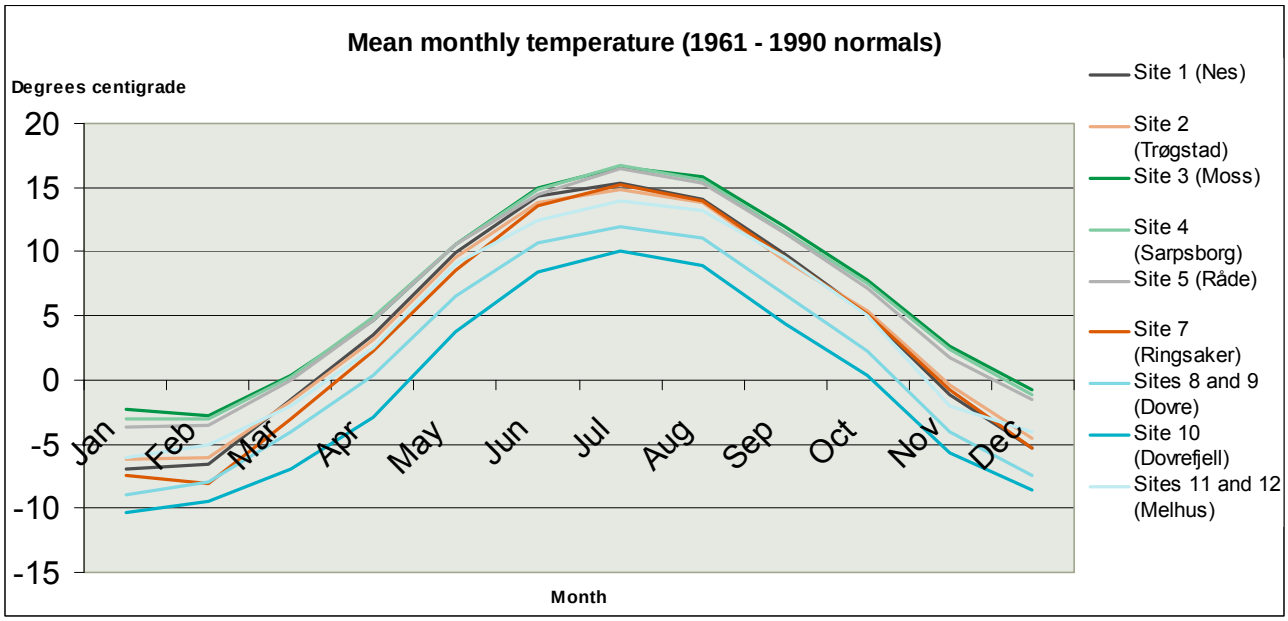


Figure 1 Mean monthly temperature (1961 – 1990 normals)

Table 2 Mean monthly precipitation, 1961 – 1990 normals (mm) (The Norwegian Meteorological Institute)

Site - municipality	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual (mm)
1 Nes	40	34	37	36	48	64	71	75	78	76	63	48	670
2 Trøgstad	52	42	48	44	57	71	79	85	91	101	83	57	810
3 Moss	51	38	51	42	59	58	69	86	90	99	81	55	779
4 Sarpsborg	55	45	50	40	55	65	70	80	85	100	85	60	790
5 Råde	56	42	51	40	55	61	69	83	86	101	85	61	790
7 Ringsaker	36	29	27	34	44	59	66	76	64	63	50	37	585
8 Dovre	33	25	23	14	27	51	57	49	40	43	35	33	430
10 Dovrefjell	34	26	28	17	28	55	61	52	42	42	33	32	450
11, 12 Melhus	64	54	55	50	44	60	81	72	101	91	77	81	830

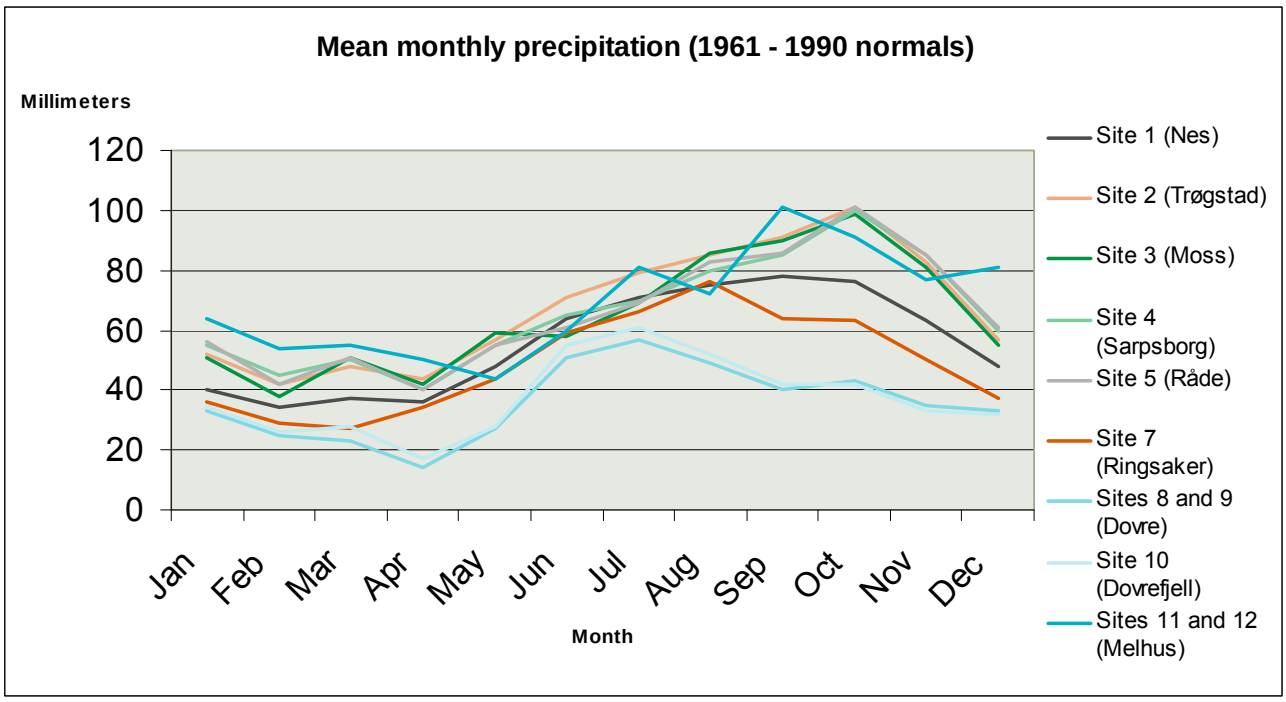


Figure 2 Mean monthly precipitation (1961 – 1990 normals)

1.3. Geology

Arriving at the Oslo airport Gardermoen your visit to Norway begin slightly above the late glacial marine limit (ML) of the area, 205 meters above the present sea level. The airport is situated on a glaciofluvial sandurdelta deposited at the margin of the inland ice 10500 years ago. To the south of this delta, the agricultural soils are developed mostly on marine sediments. To the north the parent material is dominated by till in the valley sides and fluvial deposits in the valley floor. We also find remnants of glacial lakes in the northern valleys. Some parts of the marine sediments are covered by meltwater silt and sand deposited by a "jøkulhlaup" from one of these ice-dammed lakes.

All these sediments are millions of years younger than the underlying bedrock. Fluvial and glacial erosion on the Norwegian mainland during the latest geological time periods is the main reason for this long hiatus.

1.3.1. THE BEDROCK

The Precambrian rocks in the basement of southern Norway constitute the youngest part of the **Fennoscandian Shield**. This basement is separated by the **Caledonides** in a Southern and a Western Province (fig.3). Most of the southern province was formed during the **Gothian orogeny**,1700-1550 mill. years ago (Ma), and later (1500-900 Ma) it was intruded by several generations of granitoids. In the Western Province the **Caledonian metamorphism** (490-390) was very intense in places, but also remnants of the Gothian orogeny are found here.

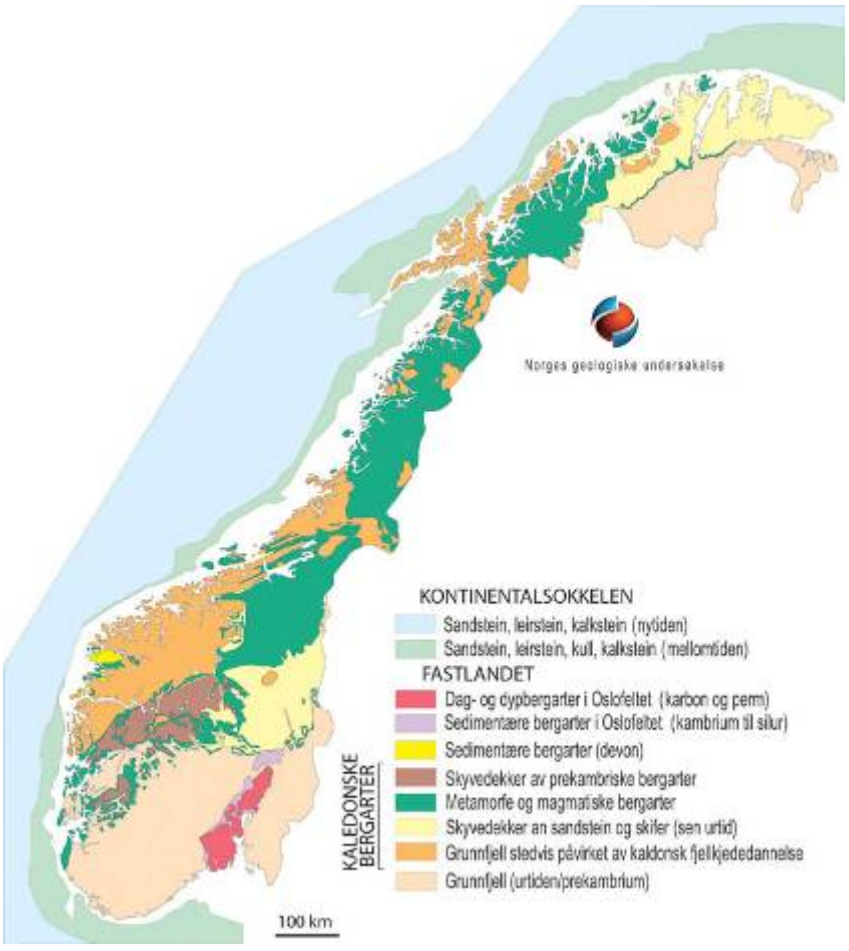


Figure 3: Simplified map of the Norwegian bedrock

The **Scandinavian Caledonides** are made up of Late-Precambrian to Silurian metamorphosed sedimentary and volcanic rocks (700-400 Ma) lying as a backbone along the whole country from south-west to the far north. In south-west nappes of Precambrian rocks are overlying younger sedimentary rocks. In south-east and north (Finnmark) folded and thrusted sandstones of Late- Precambrian age are a part of this complex.

The youngest bedrock formations on the Norwegian mainland we find in the **Oslo Graben**, a rift system developed mainly during the **Permian** (300-250 Ma), continuing from Skagerrak to the lake Mjøsa area. In this graben, sedimentary rocks of Cambro - Silurian age have survived. These rocks were folded and partly thrusted during the Caledonian Orogeny and are partly overlain by a Carboniferous to Permian sequence of volcanics and sedimentary rocks, and intruded by a series of Permian magmatic bodies. In the areas with Cambro-Silurian rocks we find some of the best agricultural soils in Norway (site 7).

1.3.2. GLACIAL GEOLOGY

Scandinavia has experienced multiple glaciations during the Quaternary period (2,6 – 0 Ma) of which the latest continental ice sheet had the greater impact on the distribution of soils and soil scapes in the northern Europe. Naturally, the superficial deposits on the main land are dominated by till, highly consolidated basal till or a heterogeneous and loosely packed ablation till. Tills with sandy material are most frequent, but in areas with bedrock of limestone and shale, loamy tills are dominating. Glaciofluvial material occurs along the former pathways of the meltwater streams, deposited as terraces along the ice margins, in meltwater tunnels in stagnated ice lobes or as glaciofluvial sandurs, fans or deltas close to the retreating margin of the melting continental ice sheet. Most of the silt and clay fractions are transported into the sea and deposited in the marine environment outside the glaciofluvial deltas.

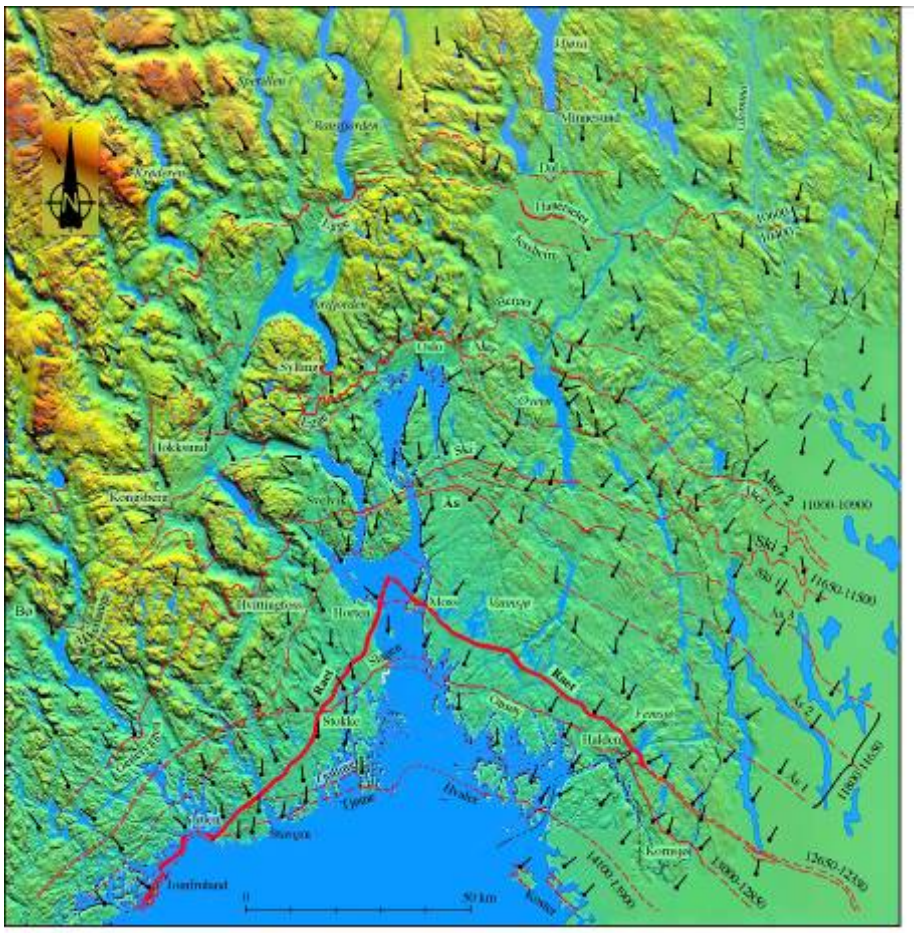


Figure 4: Marginal moraines and deglaciation pattern in the Oslofjord area

Ice retreat

During the deglaciation (15000 – 10000 years ago) powerful ice streams ended in calving bays both in the Oslofjord (south) and the Trondheimsfjord area (further north). Marginal moraines were deposited along the margin where the ice front retreated slowly or re-advanced.

The most prominent moraine in the Oslofjord area is the Ra moraine, deposited during the Younger Dryas stage, 12800 -11500 years ago, representing a climatic deterioration and a re-advance of the Scandinavian ice sheet (fig.4). A lot of moraines from smaller events can be seen in the whole area, deposited one of them at the entrance of our institute at Raveien 9 in Ås.

Late- and postglacial land uplift

Today, glaciofluvial deltas and marine clay deposited during the last deglaciation, are situated far above the present sea level. Therefore, it is obvious that a late- and postglacial land uplift has occurred in Norway. Looking at the distribution of the highest marine limits (ML) in Scandinavia, this uplift can be explained by the weight reduction due to the melting of the continental ice sheet (fig. 5). The net shore displacement since the deglaciation is 222 m in the Oslo area and 175 m in

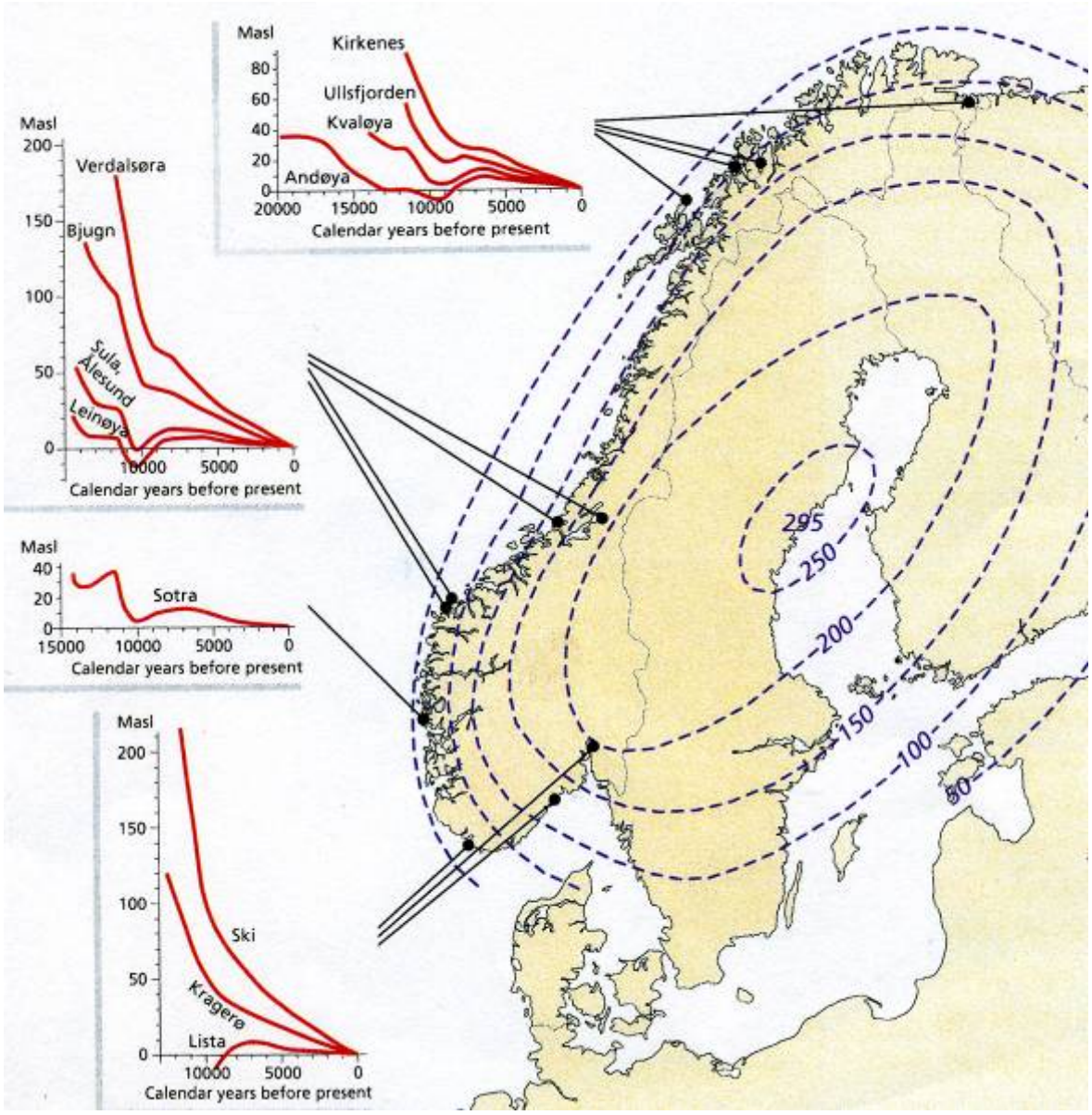


Figure 5: Shore displacement curves (red) and marine limits (ML) in Norway and Scandinavia

the Trondheim area. Below ML the agricultural areas are dominated by clay soils (Albeluvisol, Stagnosol, Gleysol) and above sandy soils developed on till and fluvial deposits are most frequent (fig. 6).

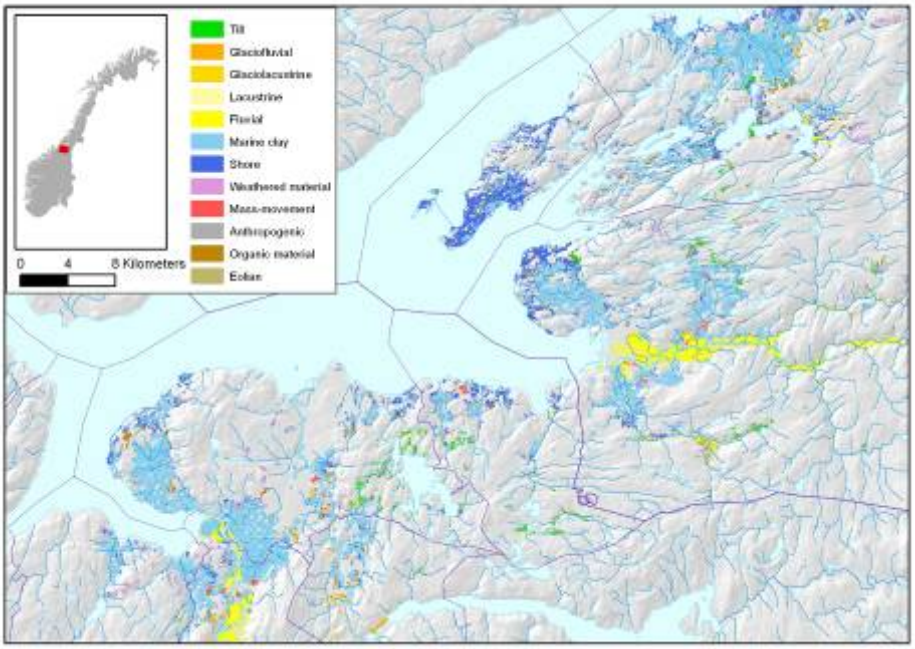
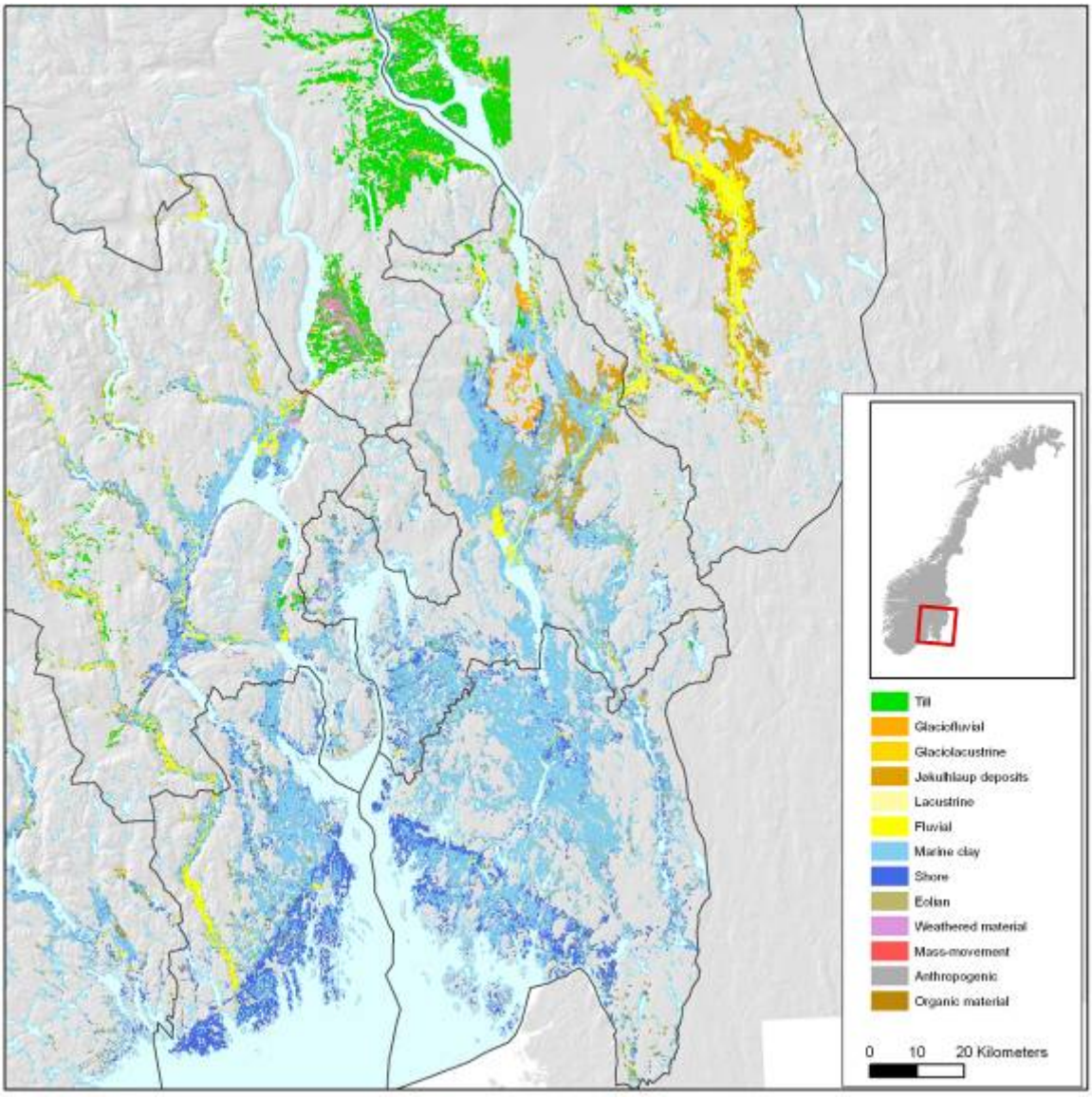


Figure 6: Parent material of the agricultural soil in the Trøndelag area (left) and in the south-eastern part of Norway (below). Soils on marine clay are dominating below the marine limit (ML).



Glacial lakes and "jøkulhlaup" deposits

Jøkulhlaup is a massive flood initiated by a sudden breach of an ice-dammed lake. In Iceland, such events have been common in the recent past. The largest known jøkulhlaup in Norway happened towards the end of the last deglaciation. The ice divide of the Scandinavian ice sheet was situated far to the south and east of the water divide. During the deglaciation ice-dammed lakes developed between the two divides. (On site 8 we can study the sediments deposited in one of these glacial lakes, developed in the northern part of the Gudbrandsdalen.) The ice-dammed lake in the Østerdalen, the Nedre Glomsjø, contained up to 100 km3 of water, and was larger than the currently largest lake in Norway, the lake Mjøsa (fig.7). Initially, the jøkulhlaup started when water forced its way beneath the ice sheet and carved out the great Jøtulhogget canyon. Flood water surged southwards below the ice and reached the sea. As a result, the sea level rose by 30 - 40 meters and a sequence of silt loam known as "Romeriksmjele" was deposited upon older sediments (Fig. 6, Jøkulhlaup deposits). In Site 3 we will have a closer look to this sediment type.

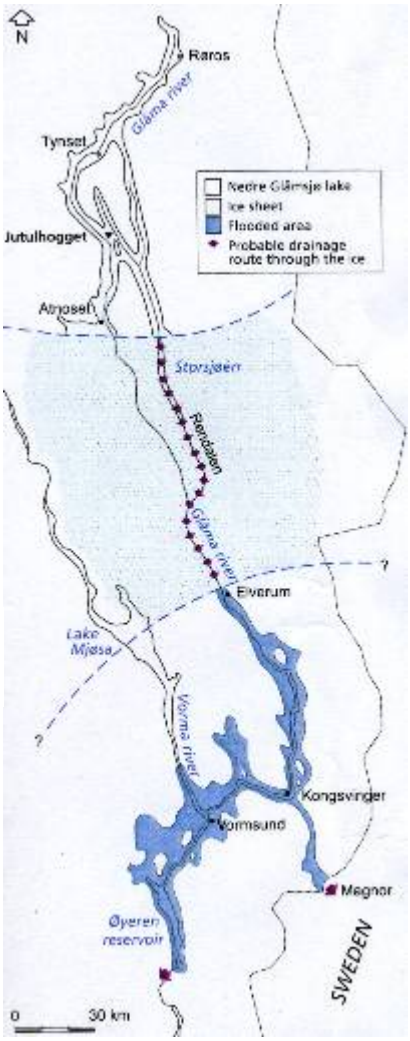


Figure 7: The late glacial jøkulhlaup in the Østerdalen, south-eastern Norway

1.3.3. POSTGLACIAL DEVELOPMENT

The Holocene period is caracterized by **river erosion and deposition** in the valleys, especially along the largest rivers. In the steep mountain and valley sides mass movements (rock fall, mud flows, slides, and solifluction) are frequent.

At the coast the result of **wave erosion and deposition** can be found as erosion scarps or marine shore deposits in all height levels between ML and the present sea level (fig.5). The postglacial uplift is still going on with rates of 3-4 mm/year in areas with the highest MLs in Norway.

In an appendix to this guide you can read more about development of thixotropic clays and the threats of large clay slides in the marine clay areas in Norway.

Further reading and link: The Making of a Land - Geology of Norway

http://books.google.com/books?id=rMVNE0F2SckC&printsec=frontcover&dq=the+making+of+a+land&source=bl&ots=pYjnPIsL9z&sig=Ls_6xljV70zWRQaPHSrLKny25jQ&hl=no&ei=MAI3TMnUIIa6OM266bME&sa=X&oi=book_result&ct=result&resnum=3&ved=0CCQQ6AEwAg#v=onepage&q&f=false

1.4. Agriculture

1.4.1. AGRICULTURAL AREA

In many parts of Norway climate conditions restrict the possibilities for agriculture. A short growing season combined with relatively low average temperatures reduces the possibilities to grow a large variety of crops. Due to climate and terrain conditions only a minor part of the country is suitable for agriculture. Table 3 shows the most important land uses (2009) (figures from Statistics Norway: http://www.ssb.no/english/).

Table 3 Land use in Norway in 2009 (figures from Statistics Norway)

Land use	%
Agriculture	3.4
Production forest	24.4
Other	69.4

The group “Other” consists off mountains and mountain plateaus (vidde), fresh water lakes, unproductive forest land, peat- and wetlands and glaciers. Of the total land area 1.4 % is built-up.

The total agricultural area (operated by those who applied for agricultural production subsidies in 2009) covered 10,100 km^2.

The most important crops are grass production (grazing and fodder production), cereals and potato. Where local soil and climate conditions are good both fruit (apple, cherry, strawberry, raspberry, black and red currant) and vegetables (cabbage, salad, carrots, onions etc) can be grown. Certain fruits and vegetables can be grown up to the most northern parts of Norway. Long days combined with relatively low night temperatures results in crops containing lots of sugar (carrots, berries).

The area of meadows for mowing and pastureland covered 6,600 km^2 in 2009, and represented 65 % of the total agricultural area in use. The area used for cereals covered 30 % of the total agricultural area.

The total grain area amounted to 3,000 km^2 in 2009. Barley comprised 44 % of the total grain area, while wheat and oats covered 27 % and 26 % respectively. The average holding with grain and oil seeds grew 0,224 km^2 of the corresponding crops in 2009.

The number of dairy cows fell by 8,700 to 239,600 in 2009. During the last 10 years, the number of dairy cows has been reduced by 73,200, while the number of beef cows has increased by 29,700 to 66,300. In the same period, the number of other cattle decreased by 111,700 to a total of 571,000.

In 2009, organic farmland covered 415.5 km^2 of the agricultural area in use, or 4.1 % of the total area. A total of 28,600 cattle were approved for organic farming in 2009. About 8,100 of these were dairy cows and 3,800 beef cows. Table 4 shows the main agricultural crops in 1998 and 2009 (in hectares).

Table 4 Main agricultural crops in 1998 and 2009. Hectares (Statistics Norway)

Land use and crop	1998	2009
Agricultural area in use, total	1 017 979	1 011 284
Of which fully cultivated land	877 326	836 592
Open fields and gardens		
Grain	397 825	355 090
Wheat	322 423	304 807
Rye and triticale	67 277	81 763
Barley	7 058	7 119
Oats	161 205	135 188
Oil seeds	86 882	80 737
Potato	6 050	4 345
Roots for feed, crops for green fodder and silage	15 779	13 765
Vegetables, field grown	35 809	11 881
Other crops	5 610	7 257
Meadows for mowing and pastures	12 154	13 036
Fully cultivated	620 154	656 194
Permanent grassland and surface cultivated land	479 501	481 502
Surface-cultivated meadows	140 653	174 692
Other infield pasture-land	29 179	21 858

1.4.2. LAND USE AND AGRICULTURAL POLICY

The main pillars in the national agricultural policy are:

1. To have rural activities and habitation everywhere in the country. An active agriculture is very important in this respect. Focus is on rural development and many rural development programmes are developed. Developing local products and niche productions is an important element.
2. Norwegian agriculture should as much as possible be able to supply the national population with the most crucial needs for food in periods of a crisis (food security). In this respect protecting the best soils for soil sealing is a highly prioritised topic and instruments are developed or under development to realise this.
3. All produced food should be safe for consumption (food safety).

After the Second World War an intensification and mechanisation process in Norwegian agriculture started. At the same time it was decided to prioritise grain production in the areas where there are no climatic restrictions for that. Especially in SE Norway large scale land levelling was done to realise the change from dairy to grain production. Later on this change had as consequence an increased risk for soil erosion.

At the end of the 1980s a blue algae explosion caused lots of damage in Skagerrak and North Sea. All countries bordering these seas agreed on a strong reduction of pollution of water by N and P. Norway decided to reduce soil erosion in the exposed watersheds. An adequate soil

mapping program started and an Agro Environmental Scheme was established to reduce the risk on erosion. On this moment the reduction targets are more or less reached; however some watersheds still need considerable efforts to reach environmental sound standards (Water Frame Work Directive).

In the low lying agricultural areas and in the broad river valleys fields are easy to be worked and to be reached. In the mountainous areas agriculture is more marginal and there is often a long distance to the market. In these areas land abandonment is a problem. Abandoned land is slowly changing into forest land. A consequence of this process is the disappearance of old cultural landscapes. Measures are taken to try to reverse this process.

In the more densely populated areas sealing of our best agricultural land is seen as a problem. This item is already many years an important topic on the political agenda. Each year an area of ca 8 km^2 agricultural land is sealed. Target is to reduce the sealing of our best agricultural land by 50 % within 2010, to less than 5.7 km^2 each year. In the period 1999 – 2004, each year 11 km^2 – 14 km^2 agricultural land was lost. After 2005 the loss has been less, but the target is still not reached. It is now proposed to establish so-called soil protection areas, which means that these areas get the same level of protection as for example nature reserves. Data on soil quality will be valuable to delineate these areas.

Due to the difficult climate and terrain conditions Norwegian agriculture is not competing well on the global marked. To keep agricultural activity alive in the whole country national agricultural production is protected by high import barriers. In the WTO negotiations Norway tries in cooperation with some other countries (Japan, Switzerland) to get understanding for our position and role of agriculture.

Figure 8 Constructing the new E18 motorway through the municipality of Askim caused the sealing of very productive agricultural land (photo: Oskar Puschmann)

1.5. Classification of agricultural soils in Norway

Soil maps (1: 15 000 scale) are currently covering about half of the agricultural area in Norway (5,000 km^2). 80 % of this area is located in the eastern parts of Southern Norway. The Trondheimsfjord area in Central Norway and the Jæren area south of Stavanger are also partly covered by soil maps. A large part of the agricultural areas in the valleys of Southern Norway, along the coast and fjords of Western Norway and in Northern Norway, are so far unmapped.

The pie chart below shows the relative distribution of WRB-groups mapped in Norway. A brief description of the soils in some of the mapped areas follows.

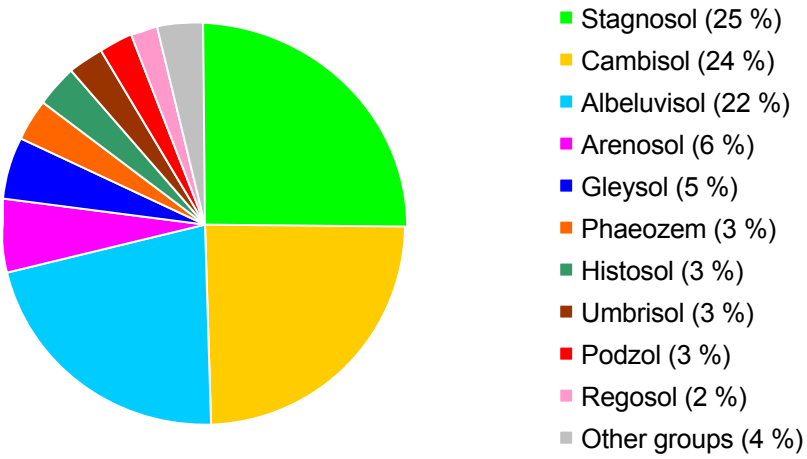


Figure 9 The relative distribution of WRB-groups mapped in Norway

The Oslofjord area

This area which includes the counties Østfold and Vestfold, and parts of Akershus and Buskerud, consists of lowlands with elevations below the marine limit. The dominating parent material is marine silt and clay. Several sandy end moraines run through the areal in an east-west direction.

Parent material, topography and age are important soil forming factors. The soils on the young plains along the fjord have stagnic and gleyic features but no diagnostic subsurface horizons. They are mapped as Stagnosols and Gleysols. On the north side of the major end moraine, called Raet, the landscape is older and more dissected. Argic horizons with albeluvic tonguing are more common and Albeluvisols and Stagnosols dominate. The end moraines in this area have been washed by waves and consist of sorted material with sandy or loamy textures. On the sandy parts we find Arenosols and Podzols, while the loamy parts are dominated by Cambisols.

From the soil maps of this area we can conclude that poorly drained soils with high silt content dominate. Stagnosols and Albeluvisols each cover about a third of the cultivated area, while Cambisols, Gleysols and Arenosols cover between five and ten per cent. Excursion sites 2 through 6 represent this area.

The Romerike area

This area is located north of Oslo, in Akershus County. The cultivated areas lie below the marine limit and marine silt and clay is the most common parent material. In the central and eastern parts, the clay is covered by a layer of glacial silt which was deposited during a catastrophic flood event that was caused by a break in the ice dam of a huge glacial lake in one of the valleys. In the northern parts of Romerike we find large glacio-fluvial deposits, and the largest one is home to Oslo International Airport, Gardermoen.

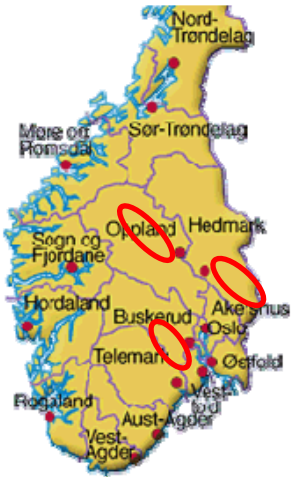
Soils formed in marine deposits are found in the western and southern parts of the area, as well as along the rivers in other parts. Stagnosols and Albeluvisols dominate, and a large part has been disturbed by bulldozing. Gullies and other steep areas were levelled to increase the area of the farm land, and more than 20 % of the cultivated areas in Romerike today are affected by this activity. Stagnosols are also mapped where the thin layer of glacial silt covers the marine clays. Cambisols take over where the silt layer is close to a meter or more thick. Podzols and Arenosols are most common in the glacio-fluvial areas.

Stagnosol is the largest WRB-group in Romerike, covering more than 40 % of the cultivated area. Albeluvisols and Cambisols are also common (25 % and 16 %) while Arenosols and Podzols are common in specific areas (both 5 %). Excursion site 1 represents this area.

The Lake Mjøsa Area

Lake Mjøsa, which is Norway's largest lake, is located north of Romerike. The east side of the lake belongs to Hedmark County and the west side to Oppland County. Both sides have a rolling agricultural landscape. The soils have high base saturation and a loamy texture with 10 % to 20 % clay. The parent material is glacial till, which contains materials from shales and limestones. Cambisols cover more than half of the cultivated area, and most of them are classified as Eutric. About half of the Cambisol area has stagnic colour pattern within one meter depth, and the impeded drainage is in many cases caused by a Fragic horizon at 70 to 100 cm depth. Phaeozems cover more than 20 % and are associated with the Cambisols throughout the area. They differ from the Cambisols because of darker and often thicker A-horizons. Other important WRB-groups include Stagnosols (10 %), Histosols (4 %) and Anthrosols (3 %), while Podzols, Umbrisols and Albeluvisols are almost absent. Excursion site 7 represents this area.

The valleys of Eastern Norway



Some of the valleys in Eastern Norway are unmapped, and some are only partially covered by soil maps. The valleys with the best coverage are described here. Glåmdalen in southern part of Hedmark County is a wide valley with low hills on both sides, Gudbrandsdalen in Oppland County is a narrow valley with steep sides and Numedal/Lågendalen in Buskerud County has a narrow northern part and a wide southern part. The valley floor of the wide valleys has meandering rivers and are dominated by alluvium. The soils are mainly Fluvic Cambisols, Arenosols and Stagnosols. Cambisols are also common in the upland areas where they are formed in marine sediments and glacial materials. Albeluvisols and Stagnosols are common where marine silt and clay borders the alluvial plains. In the narrow valleys, a large part of the valley floor is occupied by the river and the river bed. The alluvial parts of the valley floor are often subject to flooding, such as the alluvial plains in Gudbrandsdalen where we often find poorly drained Fluvisols instead of Cambisols. Most of the cultivated areas in Gudbrandsdalen are located on the valley sides. Glacial deposits and colluvium in different topographical and climatic settings have resulted in a mosaic of different soils. In the southern and more humid parts we find Cambisols, Stagnosols, Podzols and Umbrisols. In the northern and drier parts, Cambisols are associated with Phaeozems and Regosols. Excursion sites 8 and 9 are located in the dry northern part of Gudbrandsdalen.

The Jæren area

The Jæren area is located in the southwestern county of Rogaland. This area receives more precipitation than Eastern Norway, and the mild winters causes the highest mean annual temperatures in the country. The landscape is flat along the coastline but becomes rolling and eventually hilly further inland. Aeolian sand and marine beach sand are common along the coast, but the rest of the area consists mainly of glacial till. The till is generally granitic in composition, but in certain areas it has higher mica content.

Most soils in Jæren have an Umbric or Histic horizon. The exception is the coastal Arenosols and Gleysols which are low in organic matter. Umbrisols cover more than 30 % of the glacial till area. The rest is mainly divided between Umbric Podzols, Umbric Stagnosols, Umbric and Histic Gleysols and Histosols. The base saturation is normally low due to acid parent material and wet climate, but heavy use of animal manure has led to an increase in base saturation in some cultivated areas. The soils generally have low gravel content, but rocks and boulders are abundant in places, especially in the eastern pasture areas where rocks and boulders might cover up to 50 % of the soil surface.

The Trondheimsfjord area

The area is located in the counties of North and South Trøndelag. It contains many of the elements from the other areas: marine landscape along the fjord, broad valleys with alluvial plains, glacial landscapes with moraines, tills and glacio-fluvial deposits and areas with in-situ weathering. In many areas all these elements occur within short distances, resulting in complex soil maps with none of the soils dominating. In marine areas we find Stagnosols, Gleysols and Arenosols near the fjord and Albeluvisols closer to the upper marine limit. Some of the Gleysols and Stagnosols are calcaric due to shell fragments. The alluvial plains are dominated by Cambisols, Stagnosols and Arenosols, just like in the valleys of eastern Norway. The exception is Verdal where a large part of the valley floor is covered by clay from clayslides. These areas are mapped as Gleysols. Cambisols dominate the moraine and glacial till areas. The moraines and tills often contain material from limestone, shale, schists and other basic rocks, so Podzols are therefore rare. Soils developed in in-situ weathered bedrock are common locally where the bedrock consists of phyllite, mica schist or greenschist. Shallow Regosols are most common but Cambisols are often formed where the weathering is deep.

Using soil map data from the areas described above, the table below compares percent coverage of the eleven most common WRB-groups on agricultural land in Norway.

Table 5 Percent coverage of the eleven most common WRB-groups in the six different areas

	Oslofjord	**Romerike**	**Lake Mjøsa**	**Eastern valleys**	**Jæren**	**Trondheimsfjord**
Dominating (> 50 %)	-	-	Cambisol	Cambisol	-	-
Common (10 - 50 %)	Albeluvisol Stagnosol	Stagnosol Albeluvisol Cambisol	Phaeozem Stagnosol	Stagnosol	Umbrisol Podzol Gleysol Histosol Stagnosol	Stagnosol Cambisol
Less common (2 - 10 %)	Cambisol Gleysol Arenosol Umbrisol Podzol	Podzol Arenosol Gleysol	Histosol Regosol Gleysol	Arenosol Albeluvisol Fluvisol Podzol Histosol	Arenosol Regosol	Albeluvisol Arenosol Gleysol Histosol Regosol Umbrisol
Rare or absent (< 2 %)	Fluvisol Histosol Regosol Phaeozem	Histosol Fluvisol Regosol Umbrisol Phaeozem	Arenosol Podzol Fluvisol Albeluvisol Umbrisol	Phaeozem Gleysol Regosol Umbrisol	Cambisol Albeluvisol Fluvisol Phaeozem	Fluvisol Podzol Phaeozem

1.6. Soil survey

1.6.1. DETAILED MAPPING 1:15 000

The soil mapping program in Norway started in the early 1980s. The purpose was to provide detailed and standardized data on soil as a resource, to enable the optimal utilization of the cultivated land and to be able to evaluate the environmental costs of modern agriculture. In the years 1988-1989, an algae catastrophe in Norway contributed strongly to the focus on erosion and runoff from the cultivated land. This led to the North Sea agreement, in which Norway undertakes to reduce strongly the erosion and the runoff of nitrogen and phosphorous to watercourses. One of the measures was to introduce subsidies for not ploughing in the autumn on land with an erosion risk.

To be able to identify the most vulnerable areas, an intensive program for soil mapping of cultivated land with drainage to the North Sea and Skagerrak was initiated. A map showing the erosion risk was developed, using soil data and an adjusted version of the Universal Soil Loss Equation (USLE) as a basis. The Norwegian Forest and Landscape Institute is responsible for the soil mapping.

The basic mapping unit is soil type. The soil type is classified according to an adjusted version of the World Reference Base for Soil Resources (see 3.1 Using WRB as basis for soil mapping units in detailed soil mapping in Norway). Soil development, particle size distribution, soil depth and type of Quaternary deposit are characteristics used for distinguishing between the mapping units. These parameters strongly affect the soil's suitability for cultivation, and the risk of runoff and erosion. In each polygon three different soil types are allowed. In addition each polygon can contain up to 30 % of a different soil type without this being part of the signature of the polygon, existing as inclusions.

Furthermore, the signature of the polygons in the mapped area contains information on various surface features affecting their practical use, if present. These are: slope and the occurrence of stones, rocks and outcrops. The naturally occurring soil types in the landscape are determined and their boundaries directly digitized onto field tablets, and can thus be used in geographical information systems.

Most of the soil data are collected by using augers to take soil samples to a depth of one metre for in situ classification. If a new soil type is discovered, a complete soil profile is dug, which is described in detail and from which samples are taken and analyzed according to standard guidelines. This information forms the basis for defining the various soil types.

Efficient, user-friendly solutions for digital production, management and transfer of land resource data are established. These data are stored in structured databases and can be accessed via the Internet.

http://www.skogoglandskap.no/kilden/

1.6.2. GENERAL MAPPING 1: 50 000

Detailed soil mapping in the scale of 1: 15 000 on agricultural land in Norway has been going on since the beginning of the1980s. Approximately half of the cultivated area is now mapped. With the present funding it will take more than 80 years to complete the mapping in this way. The main objects of a more general mapping system on a smaller scale were to speed up the general progress of soil mapping especially in areas with less intensive agriculture, and make a system, less detailed, but still describing the most important soil factors. The system should also be suitable for mapping non-agricultural areas.

By skipping the detailed level of soil series and soil types and concentrating on the WRB-unit and WRB-group level, it is possible to map important soil qualities without loosing too much information.

With this system one aims to establish the connection between the soils in one area with already known secondary data in digital form, such as geology, topography (DEM) and land cover. Combinations of these secondary data are used to determine where to collect soil data in the field. At each point selected in the field, the soil is classified down to the WRB-unit level. All information is recorded on a field tablet. Soil data from the field is combined with secondary data in a model to predict soils in the whole project area. The accuracy of the predictions is largely dependent of the kind and quality of the secondary data, and how many different combinations of those data are covered with field soil data. The first predictions have to be controlled and validated in the field. In addition to areas where the predictions are assumed to be accurate, areas where the predictions are presumed to be uncertain and areas with combinations of secondary data lacking corresponding soil data are selected for validation. New soil data collected in this process is used to improve the model to make the predictions better.

At present this method has been tested in two areas with very different climate, topography and soils. One area is in the municipality of Dovre, which is a high-lying inland area with rather cool climate and low precipitation. The other area is Stranda municipality on the western coast with high precipitation and very steep topography from the fjord to high mountain areas.

Preliminary results from these two test areas show an overall accuracy of the predictions for the WRB-group level of 60 % for Dovre, and 57 % for Stranda. It also shows that individual soil factors as for instance drainage and depth to bedrock are predicted more accurate than the WRB-group as a whole.

Figure 10 Mountain valley in Stranda municipality: Haplic Podzol (Skeletic) (photo: Eivind Solbakken)

1.7. Land levelling

In the late 1950s, a process to increase the area suitable for cereal production started. Large steep and hilly areas were levelled during the 1960s and the 1970s, and thus making them suitable for heavy machinery which at that time was available. These were mainly marine deposits in the SE and Central Norway. The organic enriched top layer was often removed and placed in the bottom of the hills, in order to make hills less steep and having a more even slope. Due to the fact that soil unaffected by the soil forming processes often was placed on the top, this has led to a poor soil structure. In addition, these areas have a low amount of manure available, being situated in parts of the country with mainly production of cereal and therefore artificial fertilizers. Figure 13 and 14 show the distribution of levelled land in two areas of the country. The area in site 12 was levelled in the late 1970s.

Figure 11 shows the amount of area to which there was a subsidized land levelling in the years 1971 – 1992, for the country as a whole (Statistics Norway, www.ssb.no).

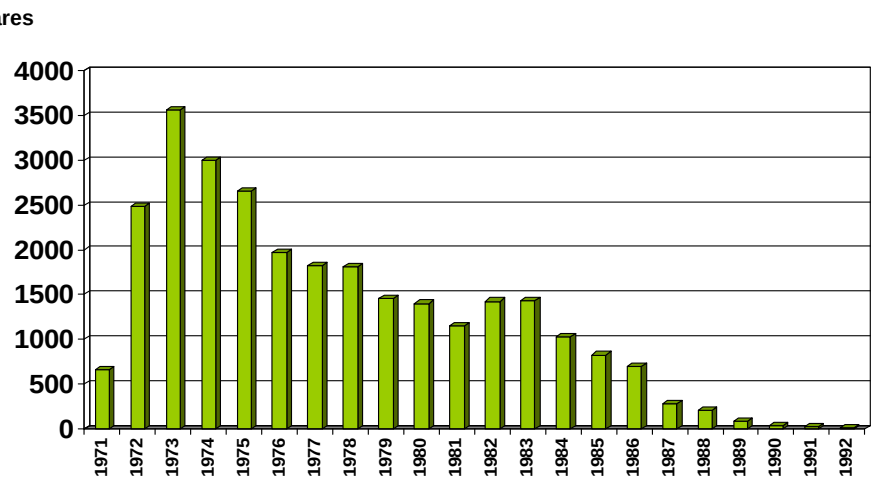


Figure 11 Area which received subsidies for land levelling in the years 1971 – 1992 (Statistics Norway, www.ssb.no).

Figure 12 Area in the municipality of Skaun. The steepest hills were left un-levelled and are now either used for grazing or being reforested (photo: Siri Svendgård-Stokke).

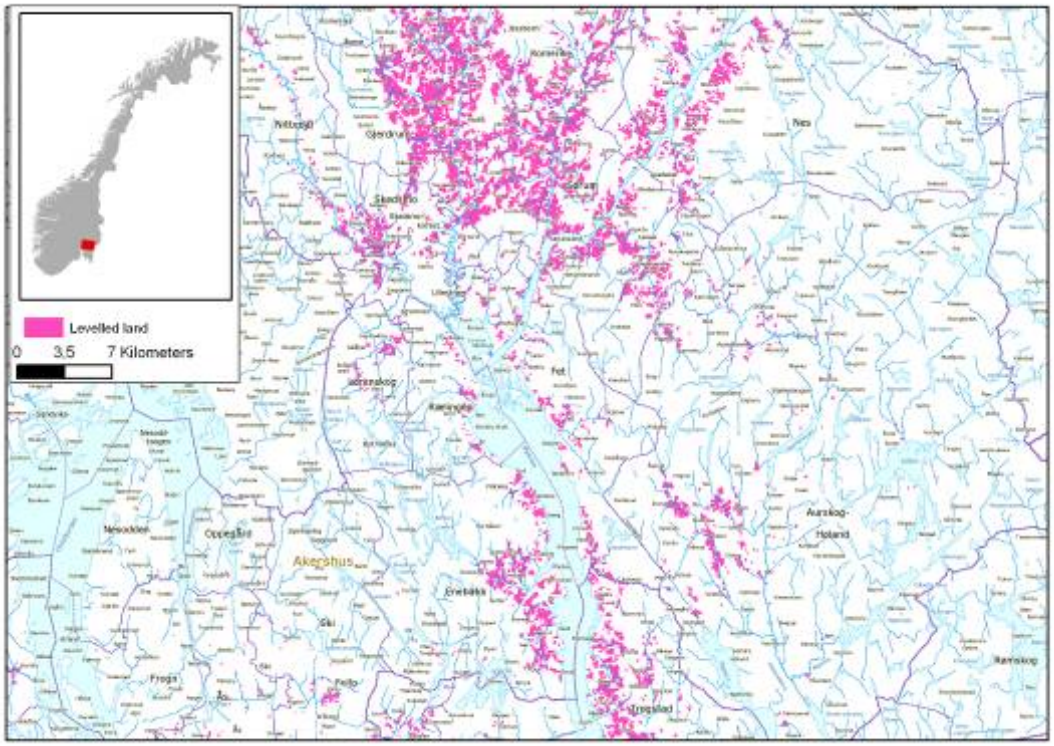


Figure 13 Levelled land in the region of Romerike

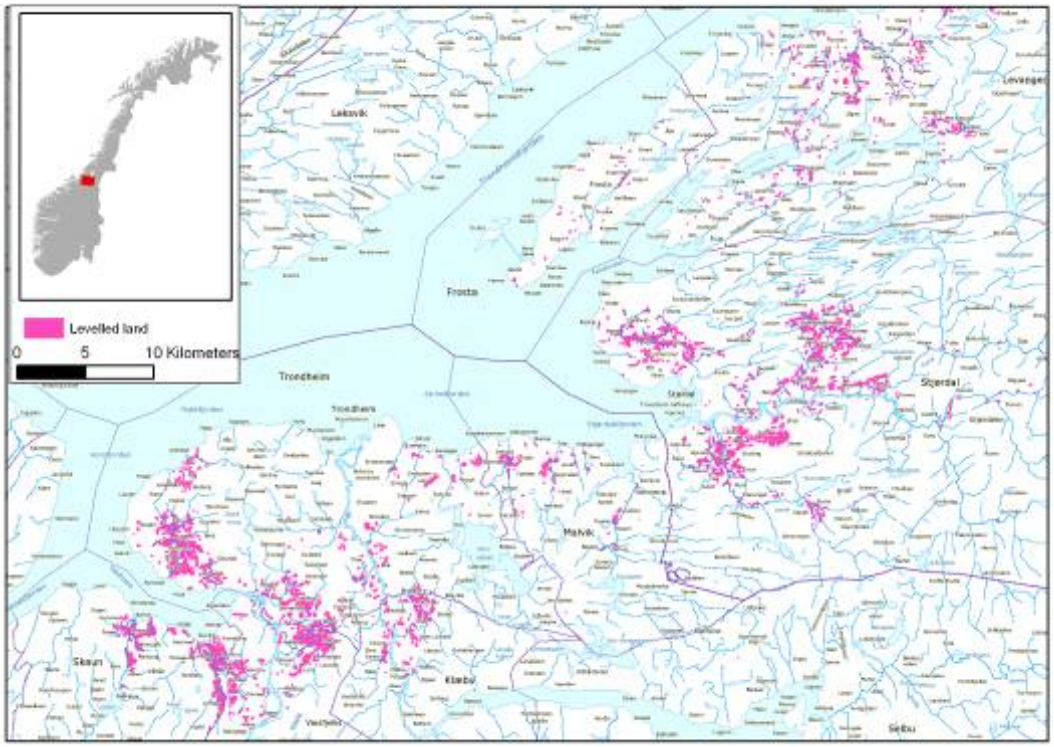
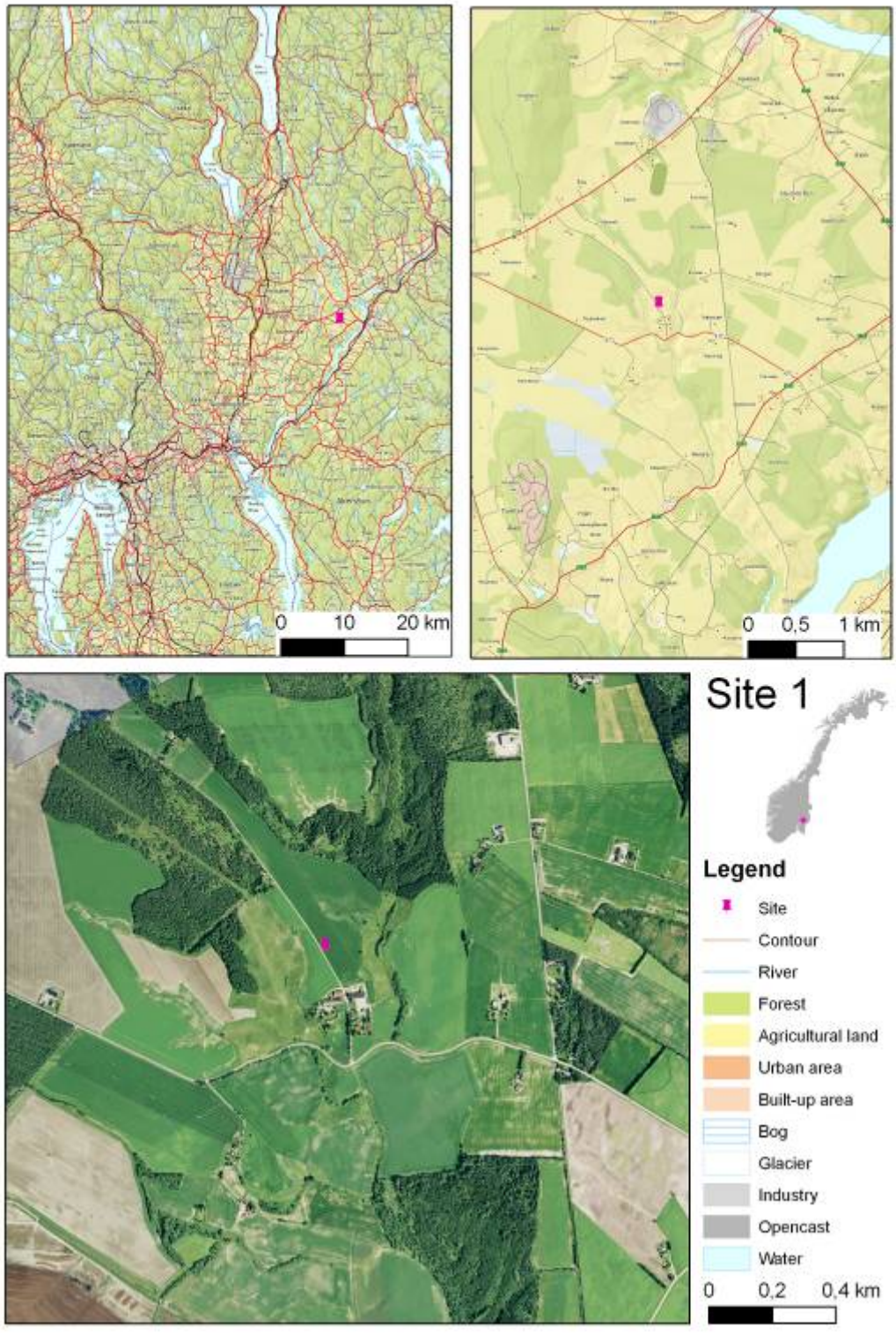


Figure 14 Levelled land in the Trondheimsfjord region

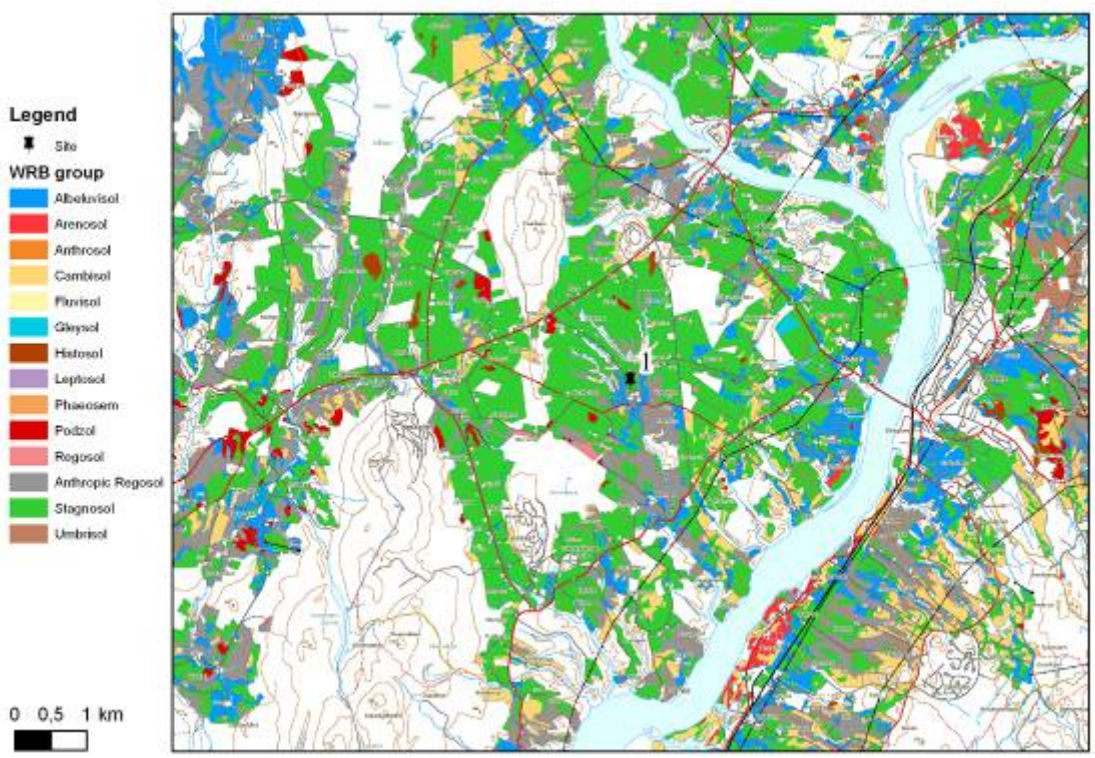
Figure 15 In the municipality of Skaun, county of Sør-Trøndelag, approximately 5 km^2 agricultural land was levelled during the 1950s and 1960s. This has led to large agricultural land having soils with a low content of soil organic matter in the plough layer, a poor soil structure and the areas are more susceptible for soil loss through erosion – but, the new topography of the agricultural land is easier to manage by large machinery (photos: Siri Svendgård-Stokke).

2. SITES

2.1. Site 1: Vandsemb, Nes



2.1.1. SOILS IN THE MUNICIPALITY OF NES



Most common WRB-units (one prefix) and most common qualifiers (prefix and suffix) as % of the agricultural area* in the municipality of Nes			
WRB-units	**%**	**Qualifiers**	**%**
Haplic Stagnosols	34.9	Siltic	84.7
Endostagnic Cambisols	15.5	Epistagnic	62.8
Epistagnic Albeluvisols	9.4	Eutric	39.5
Endostagnic Albeluvisols	8.7	Haplic	36.6
Umbric Stagnosols	3.6	Dystric	35.5
Endostagnic Podzols	2.1	Endostagnic	27.7
Fluvic Cambisols	1.0	Ruptic	24.1

*17.8 % of the agricultural area consists of soils disturbed by land levelling

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1: Site 1 (photo: Eivind Solbakken).

2: Ravines near site 1 (photo: Eivind Solbakken).

3: Main profile wall, site 1 (photo: Even Øverbø).

2.1.2. PROFILE DESCRIPTION SITE 1

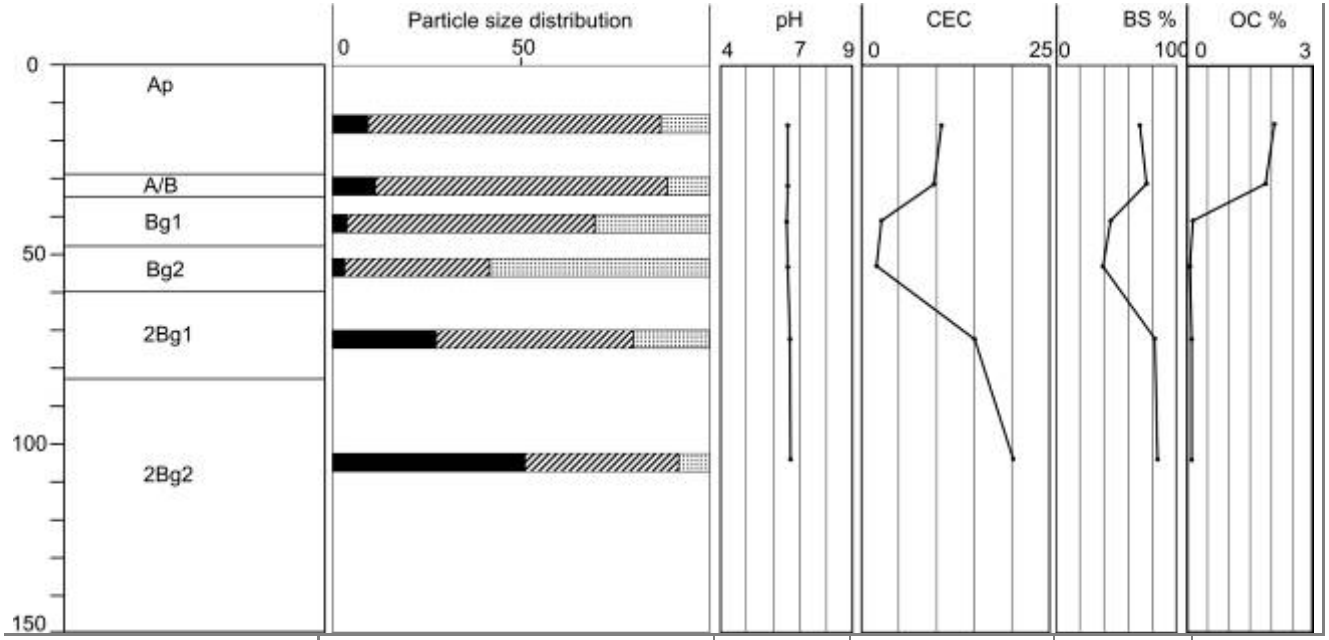
Location	***Vandsemb, municipality of Nes, county of Akershus***
Date of description	04.06.1998
Authors	Eivind Solbakken, Even Øverbø
Elevation	261m ASL
Coordinates	UTM 32 V: N: 6667947, E: 632981 EUREF 89 GEOGR.: N: 60°7. 36,6', E: 11°23. 37,1'

Soil formation factors	
Climate	**Present weather conditions:** Overcast **Former weather conditions:** Rainy without heavy rain the last 24 hours **Soil temperature:** Cryic
Landform and topography	**Major landform:** Level land: old seabed **Position:** Plain **Slope form:** Straight **Slope gradient and orientation:** Level 180° (N = 400)
Land use and vegetation	**Land use:** Annual field cropping **Crops:** Barley, wheat, oats **Human influence:** Artificial drainage and application of fertilizers
Parent material	Jøkullaup deposit covering marine clay
Age of the land surface	Holocene (ca 10 000 calendar years)

Information on the profile	
Surface characteristics	**Rock outcrops:** None **Coarse surface fragments:** None **Erosion:** No evidence of erosion
Profile depth	93 cm
Level of groundwater	Unknown
Max. root depth	48 cm

Site 1: Vandsemb, municipality of Nes, county of Akershus

Pedon boundary (cm), horizon	Boundary	Soil moisture	Soil textural classes	Rock fragments	Soil colour (matrix) moist	Soil colour (matrix) dry	Soil structure	Mottling	Additional information
0 – 29, Ap1	Abrupt, wavy	Moist	Silt loam	None	10 YR 4/2		Weak coarse angular blocky breaking into weak fine and medium subangular blocky		Common very fine and fine roots in pores and cracks. Few earthworms and excrements observed. Remnants of straw
29 – 35, Ap2	Abrupt, wavy	Moist	Silt loam	None	10 YR 4/2 in major part remnants of B-material with colour 10 YR 4/6 covering less than 10 %		Moderate thick and very thick platy breaking into moderate angular blocky of all sizes	Very few fine and medium, sharp nodules, 2.5 YR 3/4, randomly placed	Few medium and very few fine pores. Few very fine and fine roots in pores and cracks. Few earthworms and excrements observed.
35 – 48, Bg1	Clear, wavy	Moist	Silt loam	None	10 YR 4/6 and 2.5Y 6/3 covering 20 – 50 %		Weak very thick platy breaking into weak very coarse and coarse angular blocky	Abundant fine and medium, clear redox concentrations, 7.5 YR 5/8 in matrix and very few fine and medium, sharp nodules, 2.5 YR 3/4, randomly placed	Few medium and common very fine pores. Very few very fine roots in pores. Few earthworms and excrements observed. Earthworm channels and cracks filled with humus observed
48 – 60, Bg2	Abrupt, smooth	Moist	Sandy loam	None	2.5 Y 6/3		Weak thick and very thick platy braking into weak medium and coarse angular blocky	Common fine, medium and coarse, clear redox concentrations, 7.5 YR 5/8 as rounded mottles and vertical stripes and few, fine and medium, sharp nodules, 2.5 YR 3/4, in pores	Very few medium and few vey fine and fine pores. Earthworm excrements observed
60 – 83, 2Btg1	Clear, smooth	Moist	Silty clay loam	None	10 YR 4/3		Moderate medium to very thick platy breaking into moderate coarse and very coarse angular blocky	Many medium, clear redox depletions, 2.5 Y 5/1 and common fine, sharp nodules, 2.5 YR 2,5/1, in pores	Very few medium and few very fine pores. Earthworm channels filled with silt and earthworm excrements observed. Indication of clay coatings
83 +, 2Bg2		Moist	Silty clay	None	Not described		Not described		Bottom of profile pit covered with water due to one heavy rain shower during description

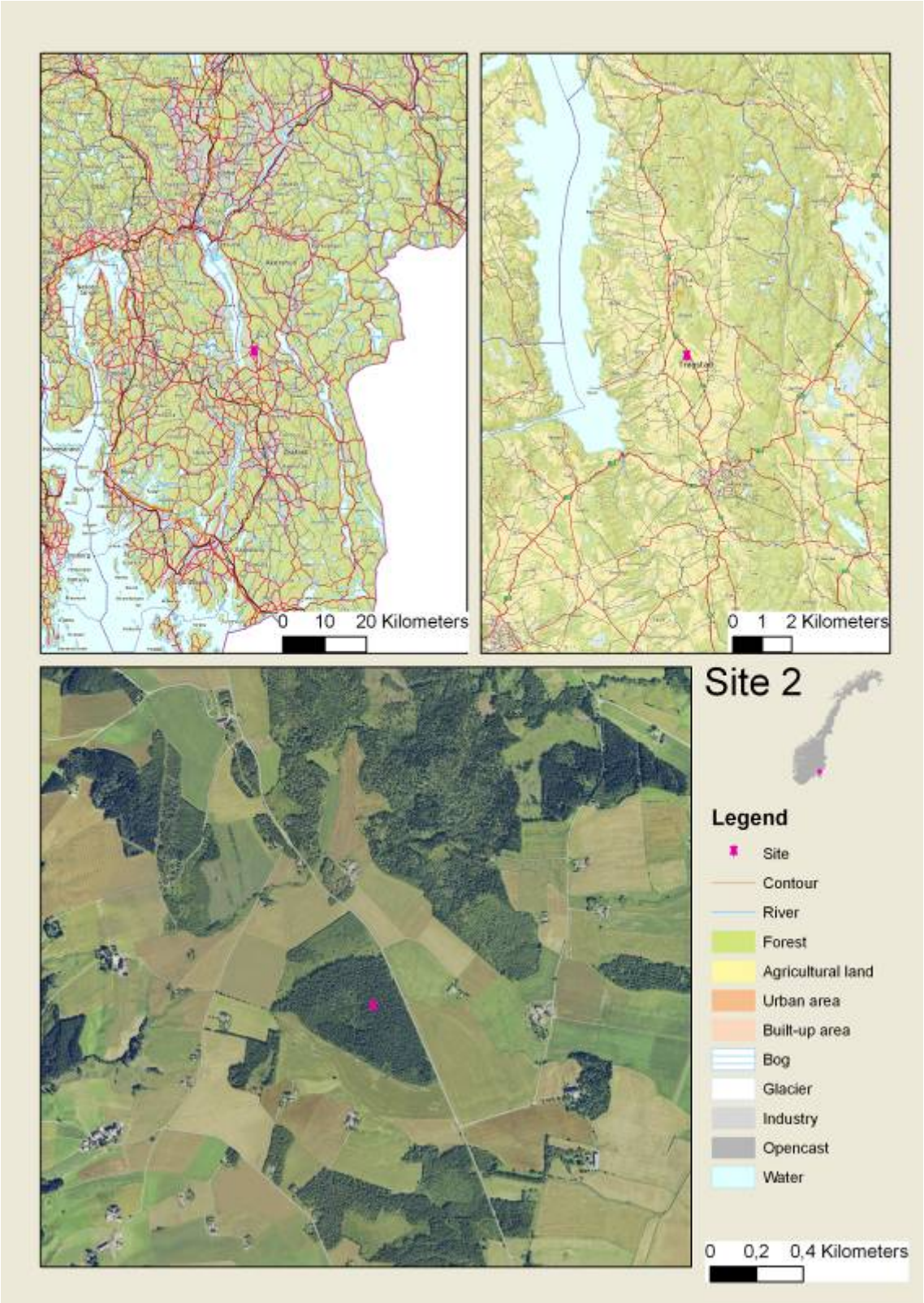


Vandsemb – Site 1	Particle size distribution						
Pedon boundary (cm), horizon	**Clay %**	**Silt %**	**Sand %**	**pH (H_2O)**	**CEC (mmolckg-1)**	**BS (%)**	**OC (%)**
0 - 29, Ap	9.5	77.2	13.4	6.5	10.37	70	2.1
29 - 35, A/B	11.4	77.1	11.2	6.6	9.75	74	1.8
35 - 48, Bg1	4	65.4	30.5	6.5	2.78	46	0.2
48 – 60, Bg2	3.3	38.5	58.2	6.6	2.12	39	0.1
60 – 83, 2Bg1	27.6	52	19.6	6.7	15.2	82	0.2
83 +, 2Bg2	51	40.5	9.1	6.7	20.57	84	0.2

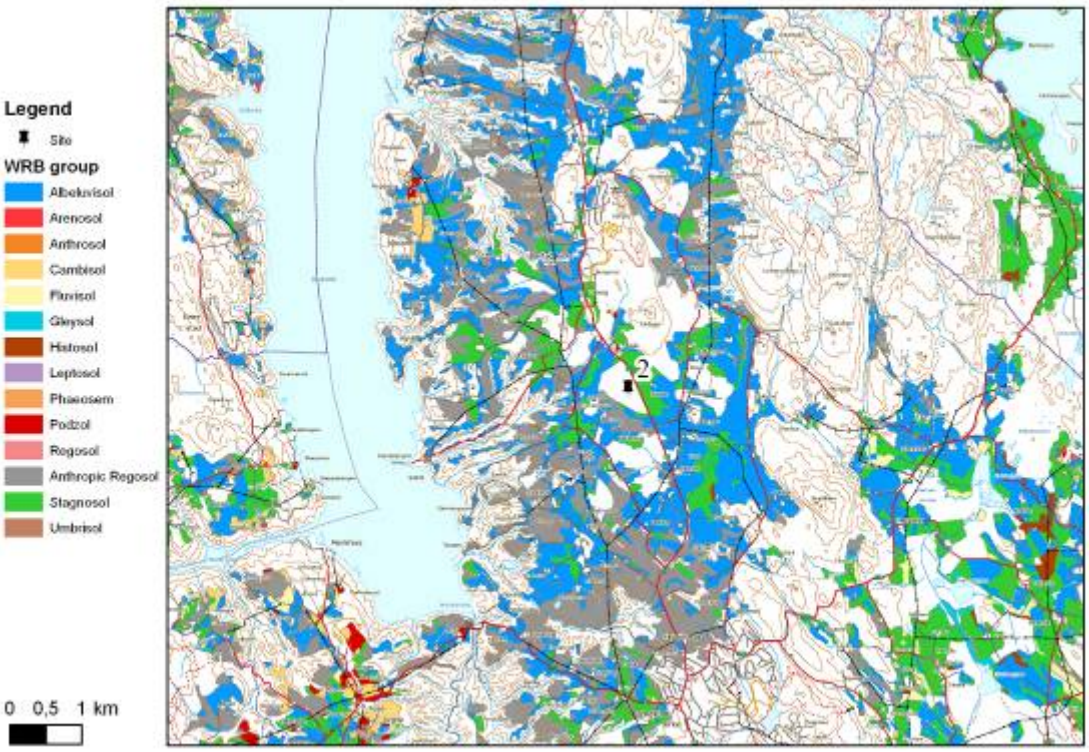
2.1.3. CLASSIFICATION PROBLEMS/ DISCUSSION

Site 1: Vandsemb, municipality of Nes, county of Akershus	
Diagnostic horizons	Cambic horizon, possible albic horizion
Diagnostic properties	Abrupt textural change, lithological discontinuity, stagnic colour pattern
Diagnostic material	
Classification	Haplic Planosol (Albic, Ruptic, Siltic)
Discussion	Planosol? Albic horizion (48-60 cm)?
Conclusion	

2.2. Site 2: Båstad, Trøgstad



2.2.1. SOILS IN THE MUNICIPALITY OF TRØGSTAD



Most common WRB-units (one prefix) and most common qualifiers (prefix and suffix) as % of the agricultural area* in the municipality of Trøgstad			
WRB-units	**%**	**Qualifiers**	**%**
Epistagnic Albeluvisols	39.3	Siltic	92.6
Haplic Stagnosols	21.3	Epistagnic	88.2
Endostagnic Albeluvisols	3.3	Eutric	87.7
Epigleyic Fluvisols	2.1	Glossalbic	42.6
Endostagnic Cambisols	2.0	Haplic	21.4
Sapric Histosols	0.6	Dystric	7.8

*28.5 % of the agricultural area consists of soils disturbed by land levelling

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1: Site 2 (photo: Åge Nyborg). 2: Main profile wall (photo: Daniela Sauer).

3: Horizontal section, 20 cm depth (photo: Daniela Sauer). 4: Horizontal section, 43 cm depth, site 2 (photo: Daniela Sauer).

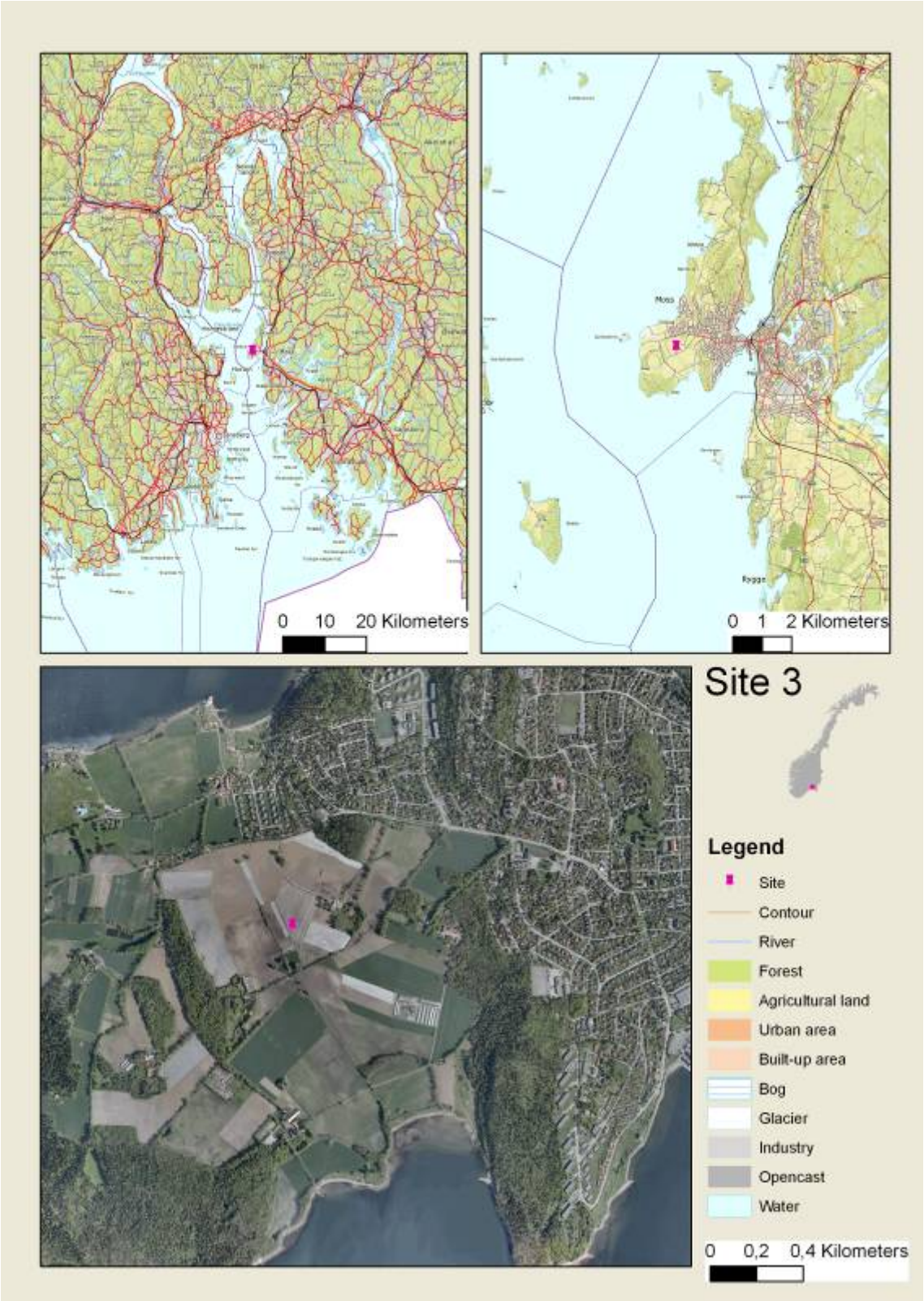
Clay landslide in Trøgstad in 1967. Four people were killed. This area is a few minutes drive on our way from site 2 to The Norwegian Forest and Landscape Institute. A monument is raised in the memory of the slide and the persons killed.

2.2.2. PROFILE DESCRIPTION SITE 2 (SEE MICRO PHOTOS IN APPENDIX 3.3 AND HANDOUTS: [1)] SAUER, D. ET AL, 2008, PROFILE ØF-11, AND [2)] SPERSTAD, R., UNPUBLISHED)

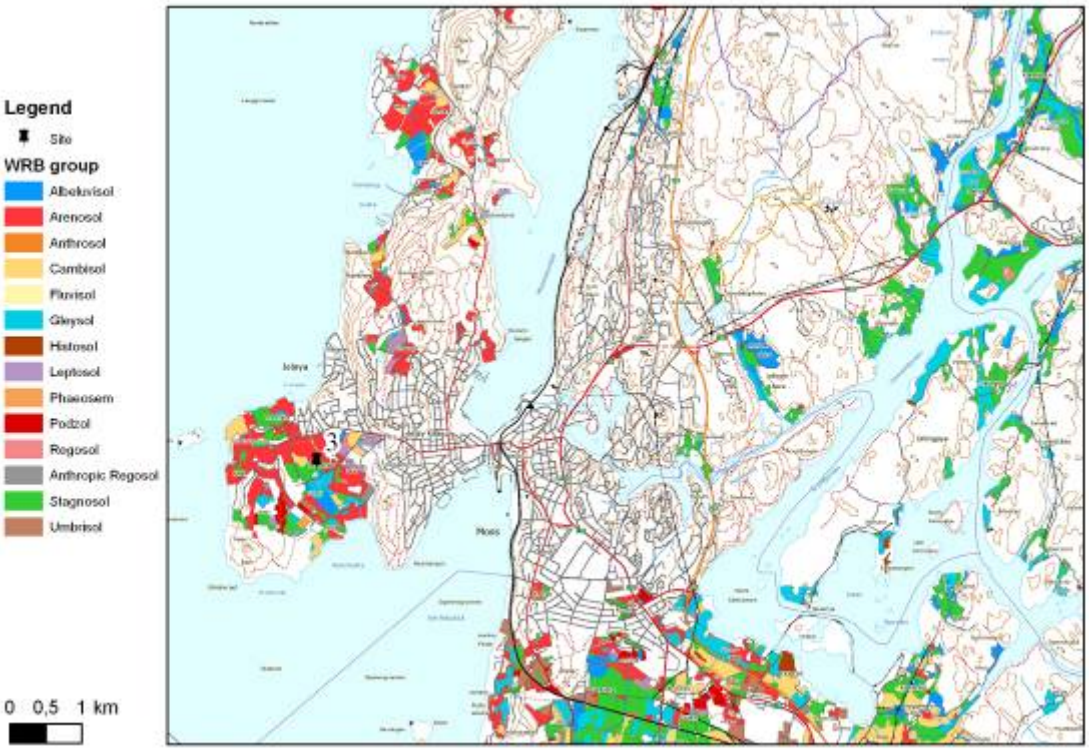
2.2.3. CLASSIFICATION PROBLEMS/ DISCUSSION

Site 2: Båstad, municipality of Trøgstad, county of Østfold	
Diagnostic horizons	
Diagnostic properties	
Diagnostic material	
Classification	Cutanic Epistagnic Albeluvisol (Endofluvic, Siltic, Protospodic) (Sauer, D. et al, 2008)
Discussion	
Conclusion	

2.3. Site 3: Jeløy, Moss



2.3.1. SOILS IN THE MUNICIPALITY OF MOSS



Most common WRB-units (one prefix) and most common qualifiers (prefix and suffix) as % of the agricultural area in the municipality of Moss

WRB-units	%	Qualifiers	%
Haplic Stagnosols	22.6	Dystric	52.4
Endogleyic Arenosols	20.1	Haplic	41.5
Haplic Arenosols	14.7	Epistagnic	38.4
Epistagnic Albeluvisols	10.7	Siltic	37.9
Mollic Gleysols	10.6	Eutric	35.4
Endostagnic Cambisols	7.3	Arenic	35.1

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1: Site 3. 2: Main profile wall. 3: Stagnic colour pattern, horizon 3. 4: Fe-concretion, horizon 5.

All photos: Siri Svendgård-Stokke

2.3.2. PROFILE DESCRIPTION SITE 3

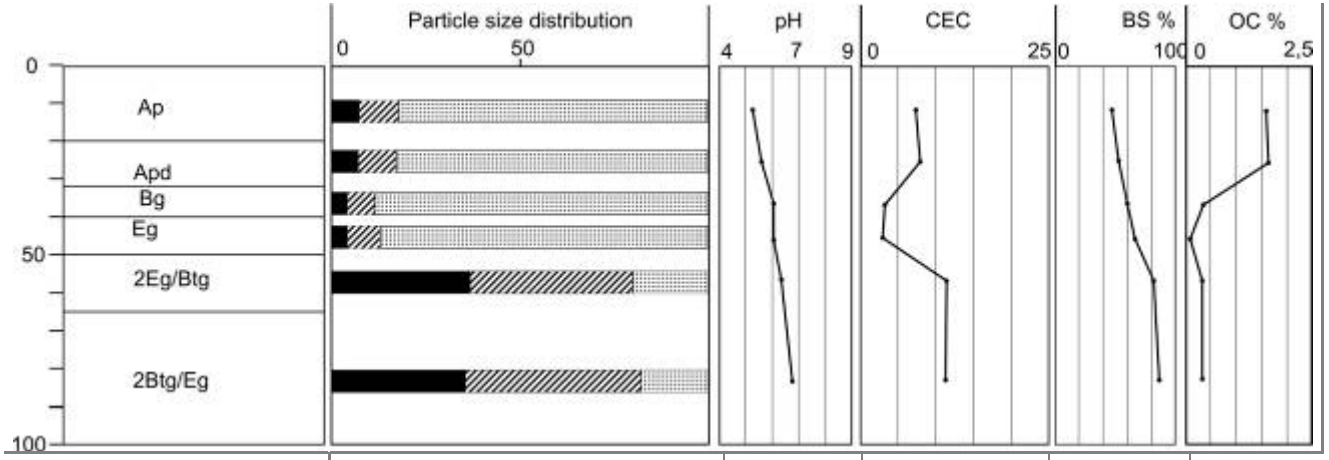
Location	***Jeløy, municipality of Moss, county of Østfold***
Date of description	23.10.2009
Authors	Eivind Solbakken, Frauke Hofmeister, Siri Svendgård-Stokke, Åge Nyborg
Elevation	12 m ASL
Coordinates	UTM 32 V: N: 6589256, E: 591357 EUREF 89 GEOGR.: N: 59°25. 55,0', E: 10°36. 37,6'

Soil formation factors	
Climate	**Present weather conditions:** Showers and overcast, 5.5° C at 10 am **Former weather conditions:** Rainy without heavy rain in the last 24 h **Soil temperature:** Frigid
Landform and topography	**Major landform:** Sloping land: medium-gradient hill **Position:** Lower slope **Slope form:** Straight **Slope gradient and orientation:** Gently sloping (4 %), 232 ° (N = 400)
Land use and vegetation	**Land use:** Annual field cropping **Crops:** Vegetables in shifting cultivation, onion (*Allium cepa*) in 2009 (harvested at time of description) **Human influence:** Sprinkler irrigation, artificial drainage and application of fertilizers
Parent material	Beach sediments covering marine silt and clay
Age of the land surface	Holocene: ca 3500 calendar years

Information on the profile	
Surface characteristics	**Rock outcrops:** None **Coarse surface fragments:** 2 % **Erosion:** No evidence of erosion
Profile depth	95 cm
Max. root depth	32 cm
Additional information	Water is stagnating in the profile, the profile being in a water receiving position. Water percolates through the sand (S1-S4) and stagnates on top of the clay (S5). In the clay, water movement is restricted along the aggregate surfaces. Biological activity is low (only one earthworm seen during digging and description).

Site 3: Jeløy, municipality of Moss, county of Østfold

Pedon boundary (cm), horizon	Boundary	Soil moisture	Soil textural classes	Rock fragments	Soil colour (matrix) moist	Soil colour (matrix) dry	Soil structure	Mottling	Additional information
0 – 20, Ap	Abrupt, smooth	Moist	Loamy coarse sand	Many	10 YR 3/2	2.5 Y 4.5/2	Weak, fine granular		Penetration resistance: 0.7 – 1.2 kg/cm^2
20 – 32, Apd	Abrupt, wavy	Moist	Loamy coarse sand	Many	10 YR 3.5/1	2.5 Y 4/2	Moderate fine, medium and very coarse angular blocky	Some (< 5 %) redox concentrations (7.5 YR 3/4) in parts of the horizon with coarser texture	Penetration resistance: 2.0 – 3.0 kg/cm^2
32 – 40, Bg	Abrupt, wavy	Moist	Coarse sand	Many	2.5 Y 3.5/2		Weak fine, medium and very coarse angular blocky	Some redox concentrations (7.5 YR 3/4) in parts of the horizon with coarser texture	
40 – 50, Eg	Abrupt, irregular	Moist	Medium sand	Many	2.5 Y 5/2		Single grain	Some redox concentrations (7.5 YR 3/4) in parts of the horizon with coarser texture	Infilled eartworm channel (4-5 cm diameter) seen at 50 cm depth (material from H1 and H3)
50 – 65, 2Eg/Btg	Abrupt, irregular	Moist	Silty clay loam	Few	5 Y 3/1 and 2.5 Y 5/1 (colour of tongues)		Weak, medium prismatic breaking to moderate medium and coarse lenticular	Some redox concentrations (7.5 YR 3/4) along the tongues	Pores mainly in the cracks/ tongues (diameter 2 – 5 mm and > 5 mm), 7- 8 per dm^2. Indication of some faint clay coatings in some pores. Stagnic colour pattern: reduced on pedfaces.
65 +, 2Btg/Eg		Wet in cracks, along aggregate surfaces, moist inside aggregates	Silty clay loam	Common	N 4/0		Moderate fine and medium angular blocky	Tongues cover < 10 % of the horizon Some Fe-enrichment (7.5 YR 3/4) along the tongues	Pores as in H5, but fewer. Indication of some faint, clay coatings in some pores. Stagnic colour pattern: reduced on pedfaces.

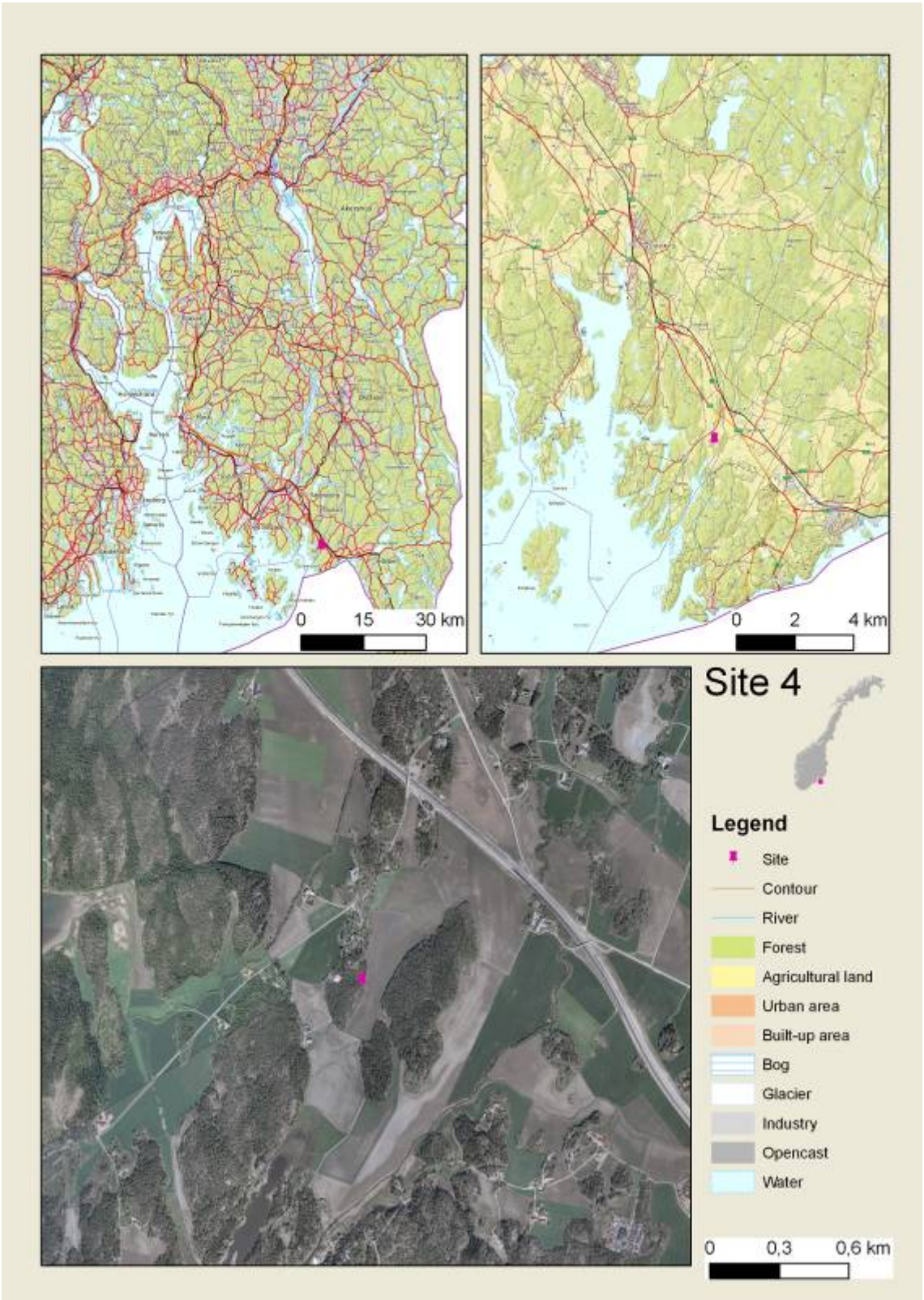


Jeløy – Site 3	Particle size distribution						
Pedon boundary (cm), horizon	**Clay** %	**Silt** %	**Sand** %	**pH (H_2O)**	**CEC (mmolckg-1)**	**BS (%)**	**OC (%)**
0 – 20, Ap	7.4	11.1	81.6	5.28	7.44	46	1.61
20 – 32, Apd	7.2	10.4	82.4	5.58	7.82	54	1.59
32 – 40, Bg	4.3	7.6	88.1	6.03	3.71	60	0.3
40 – 50, Eg	4.2	9.1	86.6	6.05	2.76	64	0.11
50 – 65, 2Eg/Btg	36.6	43.6	19.8	6.38	11.38	81	0.29
65 +, 2Btg/Eg	35.4	47.1	17.5	6.75	11.2	84	0.28

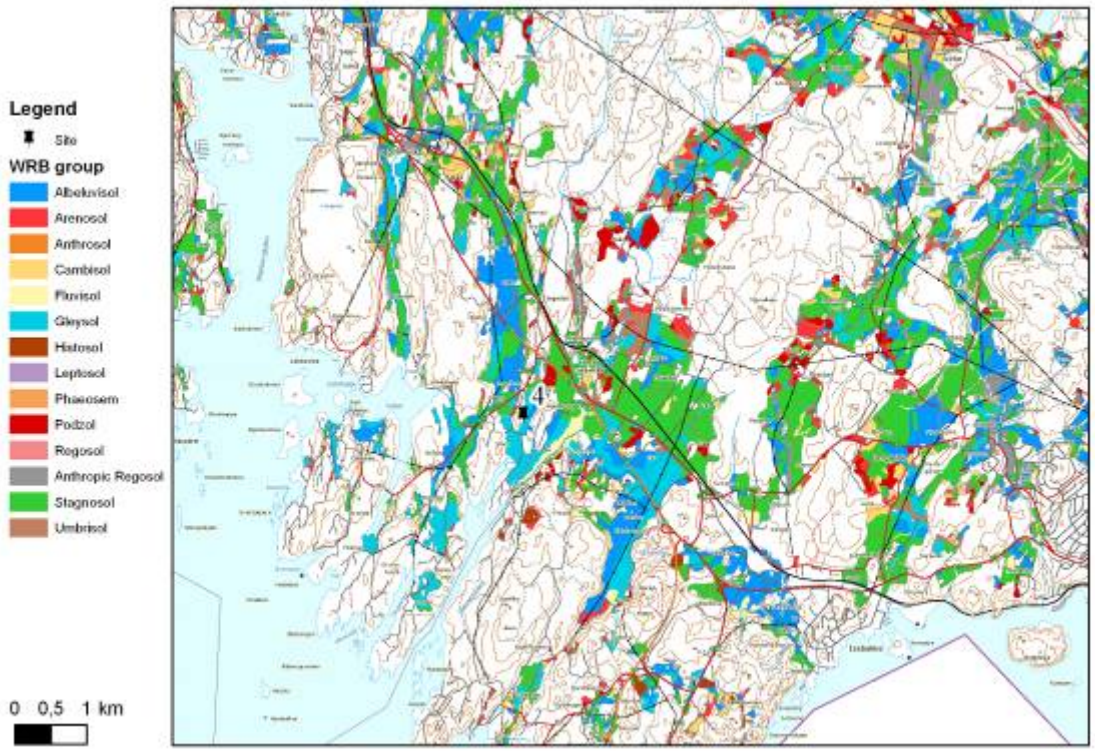
2.3.3. CLASSIFICATION/DISCUSSION

Site 3: Jeløy, municipality of Moss, county of Østfold	
Diagnostic horizons	Albic horizon, anthric horizon
Diagnostic properties	Abrupt textural change, lithological discontinuity, stagnic colour pattern
Diagnostic material	
Classification	Haplic Planosol (Albic, Ruptic, Hypereutric, Epiarenic, Endosiltic)
Discussion	Are diagnostic criterias for **albeluvic tonguing** fulfilled? → diagnostic criterias for **argic horizon** must also be fulfilled → Albeluvisol Use of the *densic* qualifier?
Conclusion	

2.4. Site 4: Løkkevika, Sarpsborg



2.4.1. SOILS IN THE MUNICIPALITY OF SARPSBORG



Most common WRB-units (one prefix) and most common qualifiers (prefix and suffix) as % of the agricultural area* in the municipality of Sarpsborg			
WRB-units	**%**	**Qualifiers**	**%**
Haplic Stagnosols	40.7	Epistagnic	70.6
Epistagnic Albeluvisols	23.2	Eutric	68.1
Mollic Gleysols	8.5	Siltic	67.7
Endostagnic Cambisols	6.3	Haplic	43.2
Endogleyic Arenosols	3.1	Glossalbic	25.9
Umbric Stagnosols	2.7	Dystric	16.0

*3.2 % of the agricultural area consists of soils disturbed by land levelling

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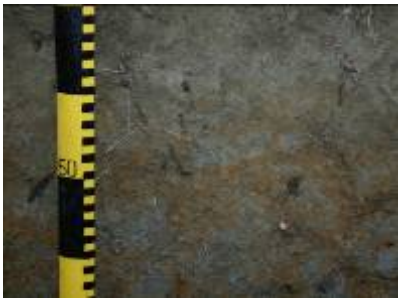

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1: Site 4 (photo: Åge Nyborg).

2: Main profile wall (photo: Daniela Sauer).

3: Agricultural land, near site 4 (photo: Åge Nyborg).

4: Stagnic colour pattern (photo: Åge Nyborg).

5: Pores surrounded by iron-oxide, 100 cm depth (photo: Daniela Sauer).

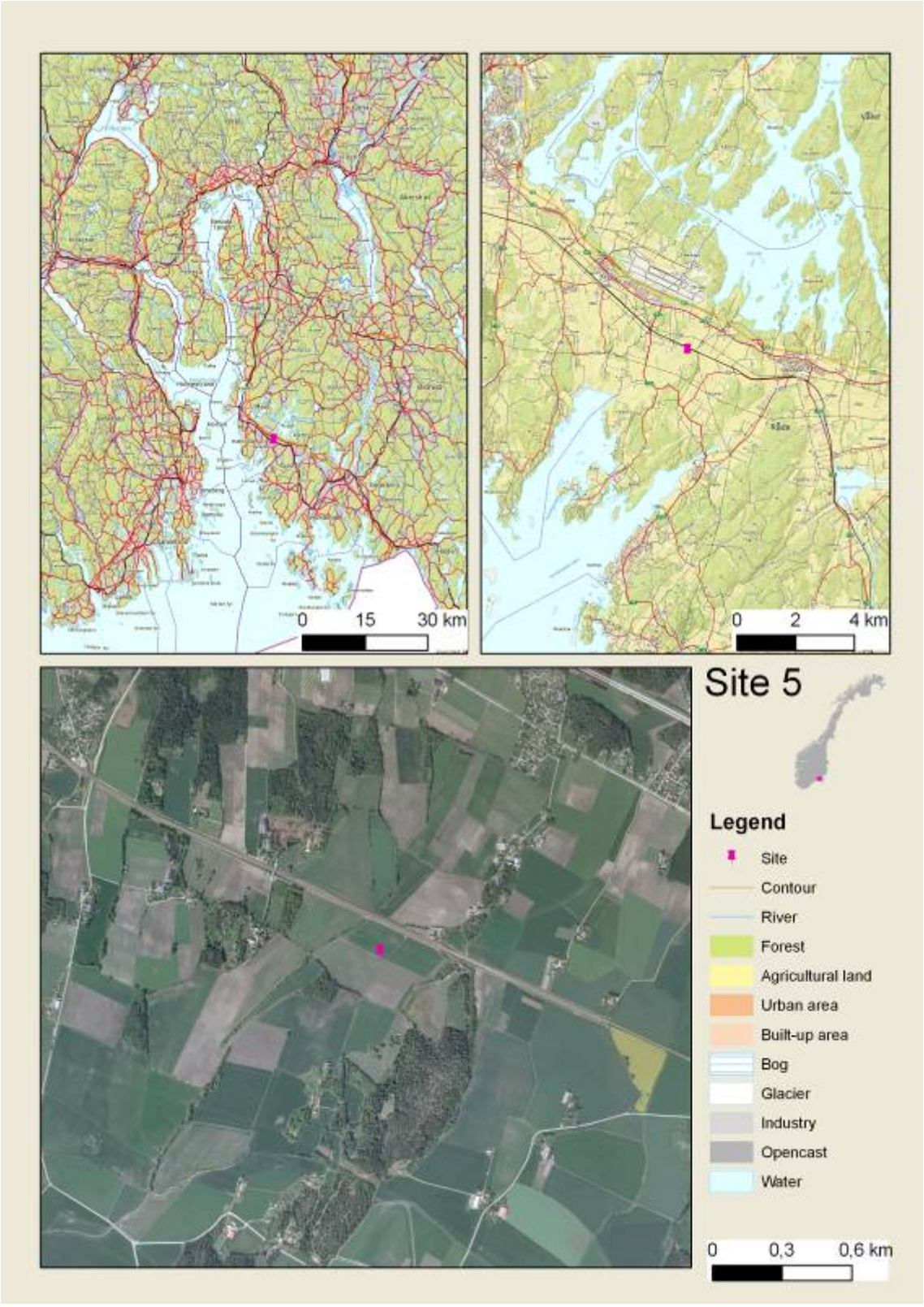
2.4.2. PROFILE DESCRIPTION SITE 2 (SEE MICRO PHOTOS IN APPENDIX 3.3 AND HANDOUTS: [1)] SAUER, D. ET AL, 2008, PROFILE ØF-3, AND [2)] SPERSTAD, R., UNPUBLISHED)

2.4.3. CLASSIFICATION PROBLEMS/ DISCUSSION

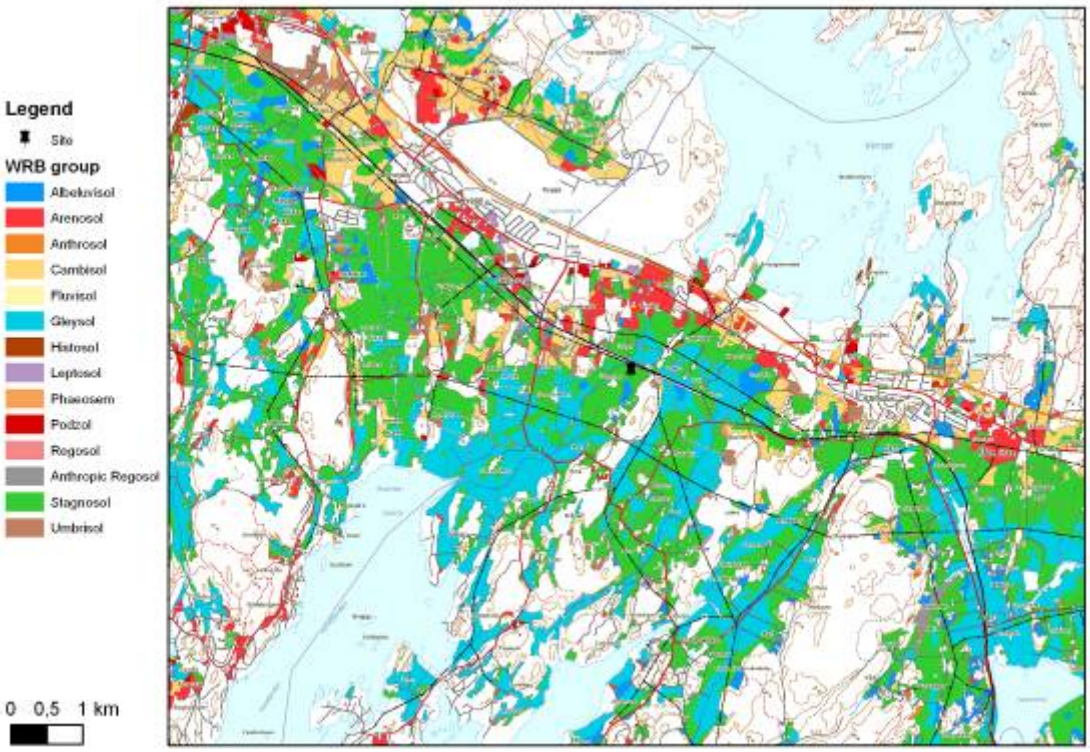
Site 4: Løkkevika, municipality of Sarpsborg, county of Østfold

Diagnostic horizons	
Diagnostic properties	
Diagnostic material	
Classification	Endogleyic Alic Stagnosol (Hyperdystric, Siltic) (Sauer, D. et al, 2008)
Discussion	
Conclusion	

2.5. Site 5: Heiabekken, Råde



2.5.1. SOILS IN THE MUNICIPALITY OF RÅDE



Most common WRB-units (one prefix) and most common qualifiers (prefix and suffix) as % of the agricultural area in the municipality of Råde			
WRB-units	**%**	**Qualifiers**	**%**
Haplic Stagnosols	41.5	Eutric	69.7
Mollic Gleysols	29.4	Siltic	67.3
Endostagnic Cambisols	6.4	Epistagnic	53.7
Epistagnic Albeluvisols	5.5	Haplic	42.6
Endogleyic Arenosols	5.3	Mollic	34.2
Mollic Stagnosols	4.7	Epigleyic	30.6

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1: Site 5 (photo: Åge Nyborg).

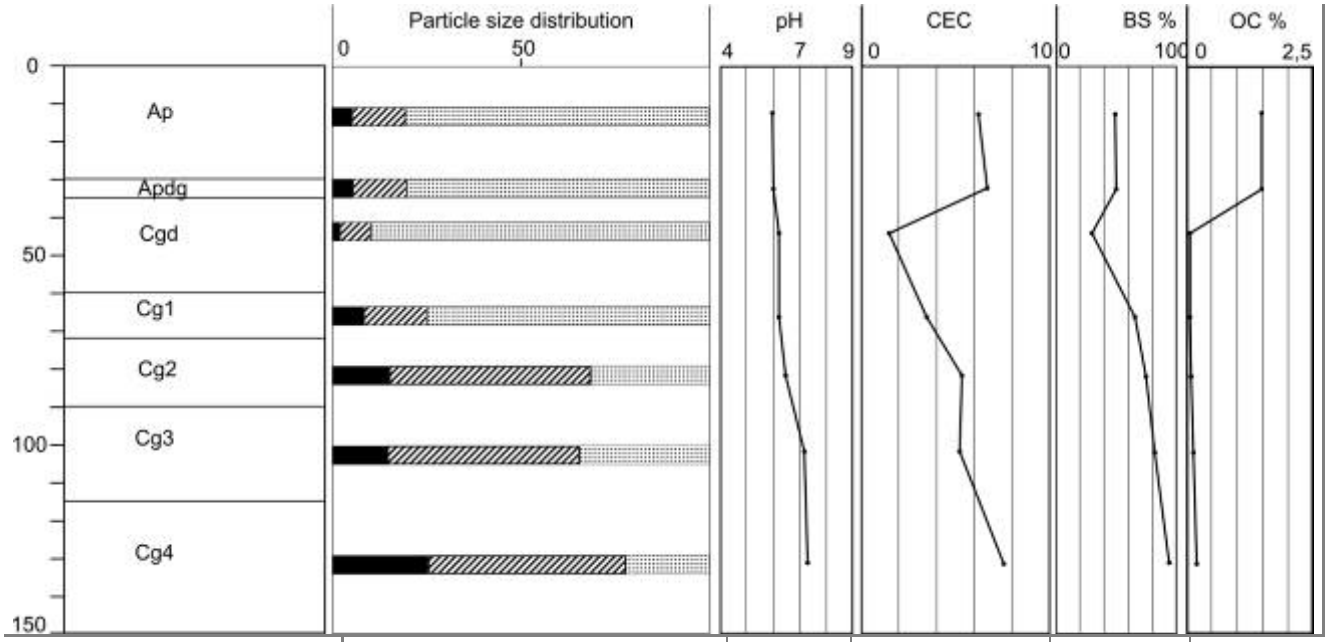
2: Main profile wall, site 5 (photo: Åge Nyborg). 3 – 5: Horizontal sections, profile site 5 (photo: Siri Svendgård-Stokke).

2.5.2. PROFILE DESCRIPTION SITE 5

Location	***Heiabekken, municipality of Råde, county of Østfold***
Date of description	14.10.2009
Authors	Eivind Solbakken, Siri Svendgård-Stokke, Åge Nyborg
Elevation	16 m ASL
Coordinates	UTM 32 V: N: 6581137, E: 602251 EUREF 89 GEOGR.: 59°21. 23,6', E: 10°47. 54,7'
Soil formation factors	
Climate	**Present weather conditions:** Sunny/clear, 1.8° C at 10 am (frost during the previous night) **Former weather conditions:** No rain in the last 24 h **Soil temperature:** Frigid
Landform and topography	**Major landform:** Level land: plain **Position:** Plain (slightly water shedding) **Slope form:** Straight **Slope gradient and orientation:** Nearly level (1 %), 116 ° (N = 400)
Land use and vegetation	**Land use:** Annual field cropping (animal husbandry to 1972-73) **Crops:** Barley/ wheat and potatoes in shifting cultivation (ploughed at time of description) **Human influence:** Sprinkler irrigation, artificial drainage, application of fertilizers and surface compaction
Parent material	Beach sediments covering marine silt and clay
Age of the land surface	Holocene: ca 3500 calendar years
Information on the profile	
Surface characteristics	**Rock outcrops:** None **Coarse surface fragments:** None **Erosion:** No evidence of erosion
Profile depth	130 cm
Level of groundwater	121 cm
Max. root depth	30 cm
Additional information	Biological activity is low (no earthworm is seen during digging nor description).

Site 5: Heiabekken, municipality of Råde, county of Østfold

Pedon boundary (cm), horizon	Boundary	Soil moisture	Soil textural classes	Rock fragments	Soil colour (matrix) moist	Soil colour (matrix) dry	Soil structure	Mottling	Additional information
0 – 30, Ap	Abrupt, smooth	Moist	Loamy fine sand	Very few	10 YR 2.5/2	2.5 Y 4.5/2	Weak, all sizes subangular blocky		Penetration resistance: 0.5 kg/cm^2
30 – 35, Apdg	Abrupt, wavy	Moist	Loamy fine sand	Very few	10 YR 2/2	2.5 Y 4.5/2	Moderate, thick and very thick platy	Some redox concentrations along a few pores	Penetration resistance: 2.8 kg/cm^2 Traces after old ploughing?
35 – 60, Cgd	Clear, wavy	Moist	Fine sand	Very few	2.5 Y 5/1.5		Massive	Some redox concentrations mostly in a zone in the upper centimetres of the horizon: colour: 5 YR 3/4. Horizontal section at 39 cm: reduced round zones (2 – 10 mm), oxidized zones surrounding them. Horizontal section at 58 cm: reduced zones have larger diameter.	Penetration resistance: 3.4 kg/cm^2
60 – 72, Cg1	Clear, wavy	Moist	Loamy fine sand	Very few	Zones of enrichment: 10 YR 3/4, 7.5 YR 4/6 Zones of displacement: 5 Y 4.5/1		Massive	Horizontal section at 61 cm: reduced zones, round (20 – 30 mm), oxidized zones surrounding the reduced zones.	Penetration resistance: 1.7 kg/cm^2
72 – 90, Cg2	Gradual, wavy	Very moist	Silt loam	Very few	Zones of enrichment: 2.5 YR 3/4 Zones of displacement: 5 Y 4.5/1		Massive	Some redox concretions. Horizontal section at 79 cm: pattern is almost the same as at 61 cm depth.	Penetration resistance: 0.5 kg/cm^2
90 – 115, Cg3	Clear, wavy	Wet	Silt loam	Very few	10 Y 4/1		Massive	Some oxidized pores, but also some pores still reduced.	
115 + , Cg4		Under water water	Silt loam	Very few	10 Y 4/1		Massive	Oxidized pores with colour: 7.5 YR 5/6	



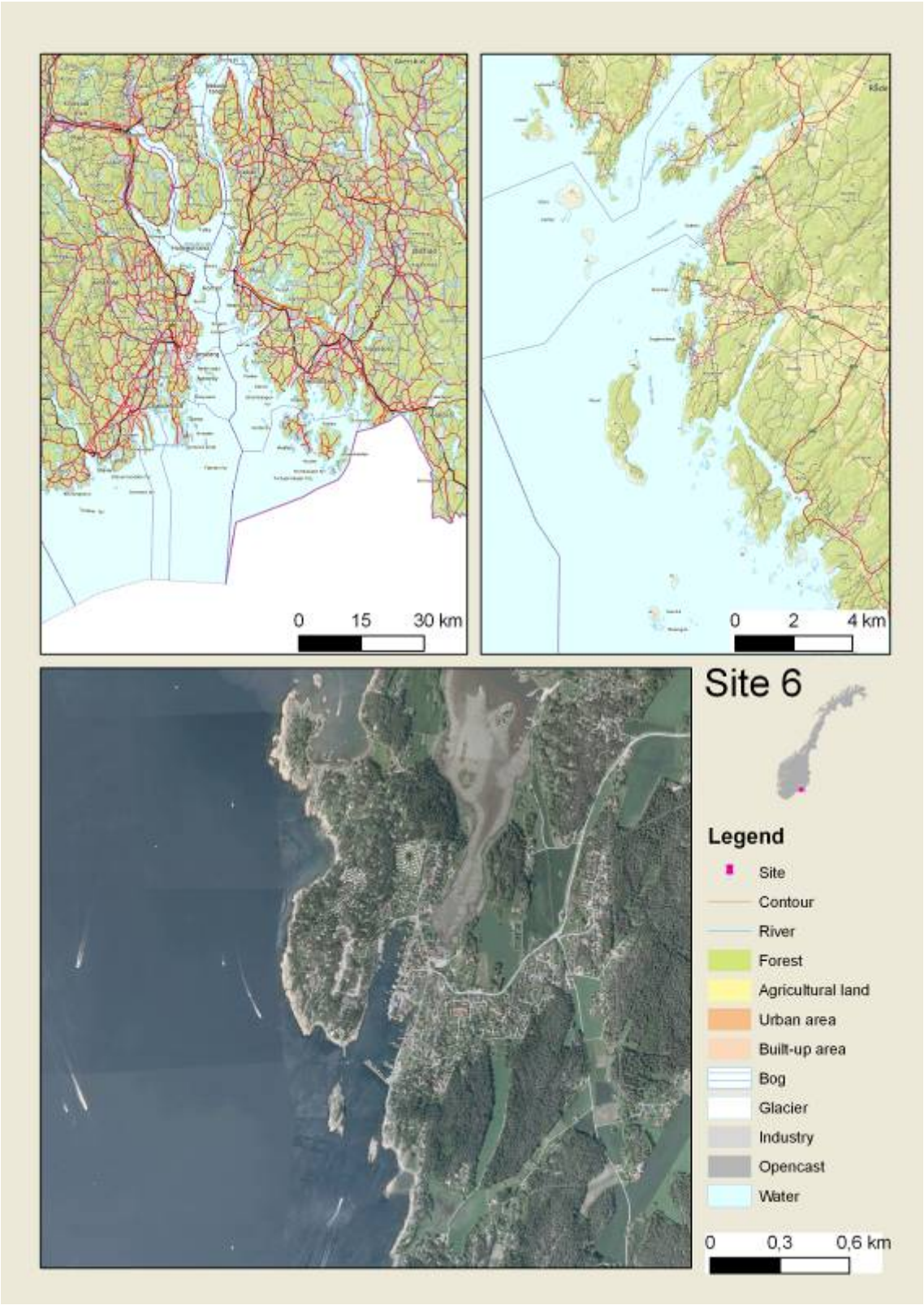
Heiabekken – Site 5	Particle size distribution						
Pedon boundary (cm), horizon	**Clay %**	**Silt %**	**Sand %**	**pH (H_2O)**	**CEC (mmolckg-1)**	**BS (%)**	**OC (%)**
0 – 30, Ap	5.4	14.6	80	6	6.15	48	1.51
30 – 35, Apdg	5.5	14.7	79.7	6.06	6.58	50	1.51
35 – 60, Cgd	2	8	90	6.17	1.73	31	0.05
60 – 72, Cg1	8.2	16.6	75.2	6.16	3.47	63	0.08
72 – 90, Cg2	14.9	53.2	31.8	6.57	5.32	76	0.08
90 – 115, Cg3	14.7	50.7	34.6	7.18	5.19	81	0.11
115 + , Cg4	25.1	52.2	22.6	7.23	7.53	87	0.2

2.5.3. CLASSIFICATION PROBLEMS/ DISCUSSION

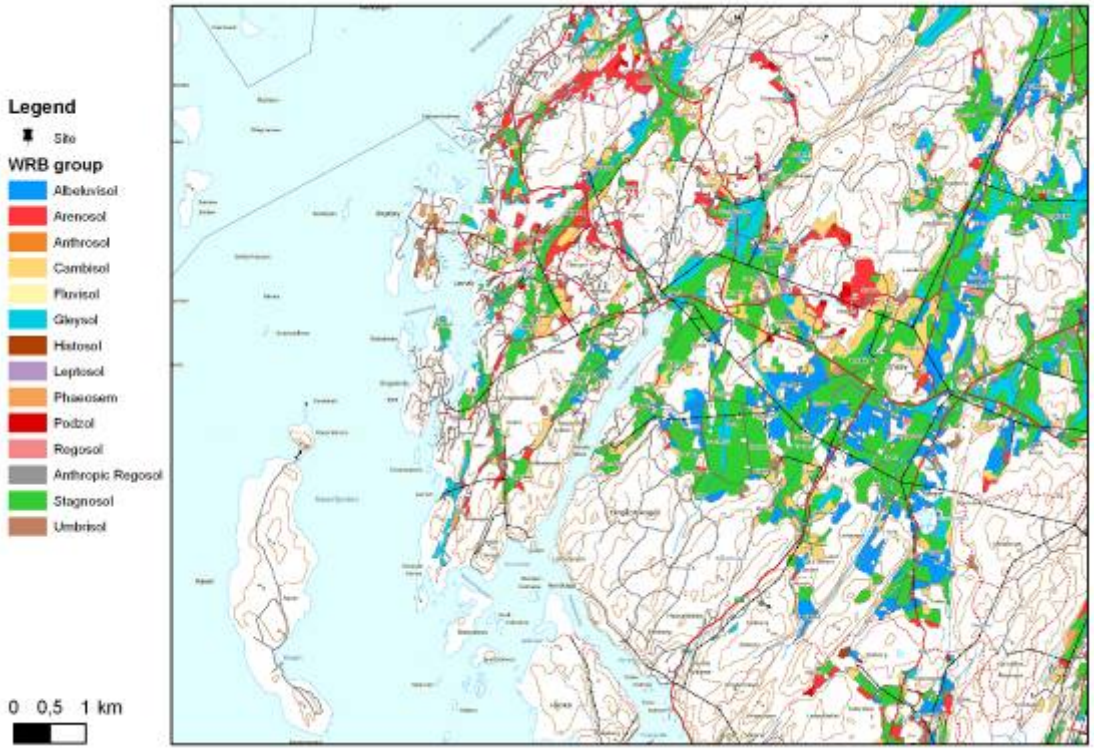
Site 5: Heiabekken, municipality of Råde, county of Østfold	
Diagnostic horizons	Anthric horizon, umbric horizon
Diagnostic properties	Gleyic colour pattern, stagnic colour pattern
Diagnostic material	
Classification	Umbric Endogleyic Stagnosol (Epiarenic)
Discussion	Use of the *densic* qualifier?

Conclusion

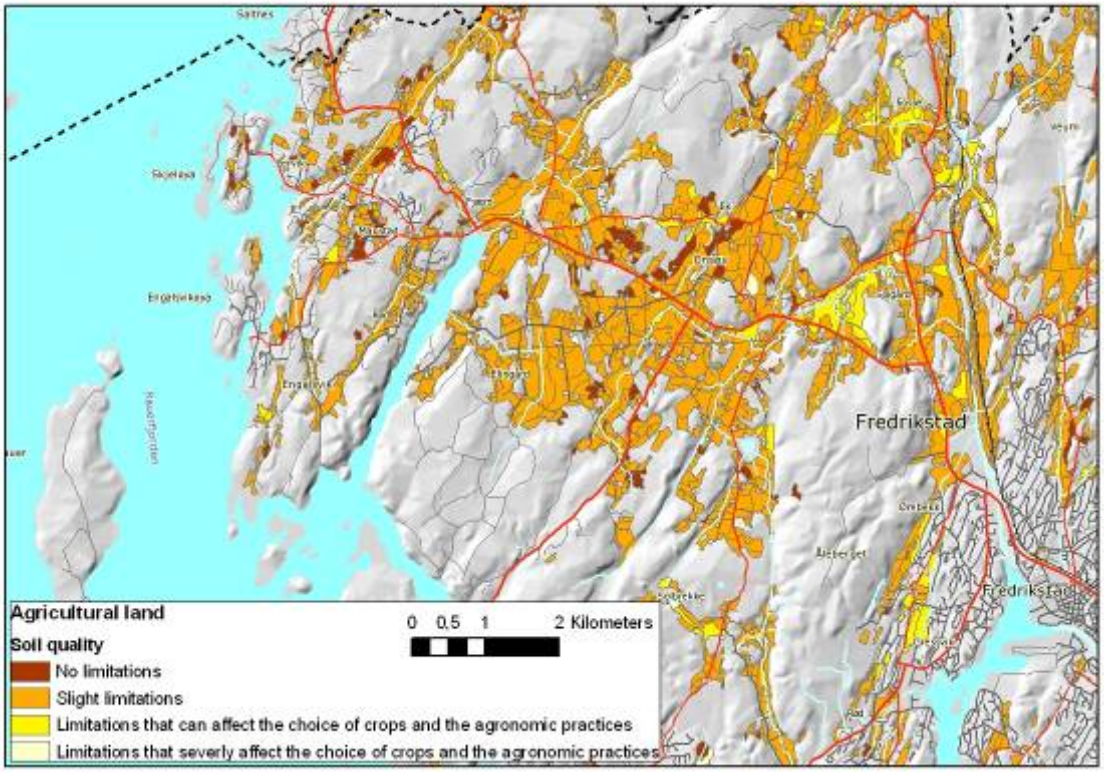
2.6. Site 6: Engelsviken, Fredrikstad: Use of WRB in soil survey 1: 15 000 (SEE: 1.6.1)



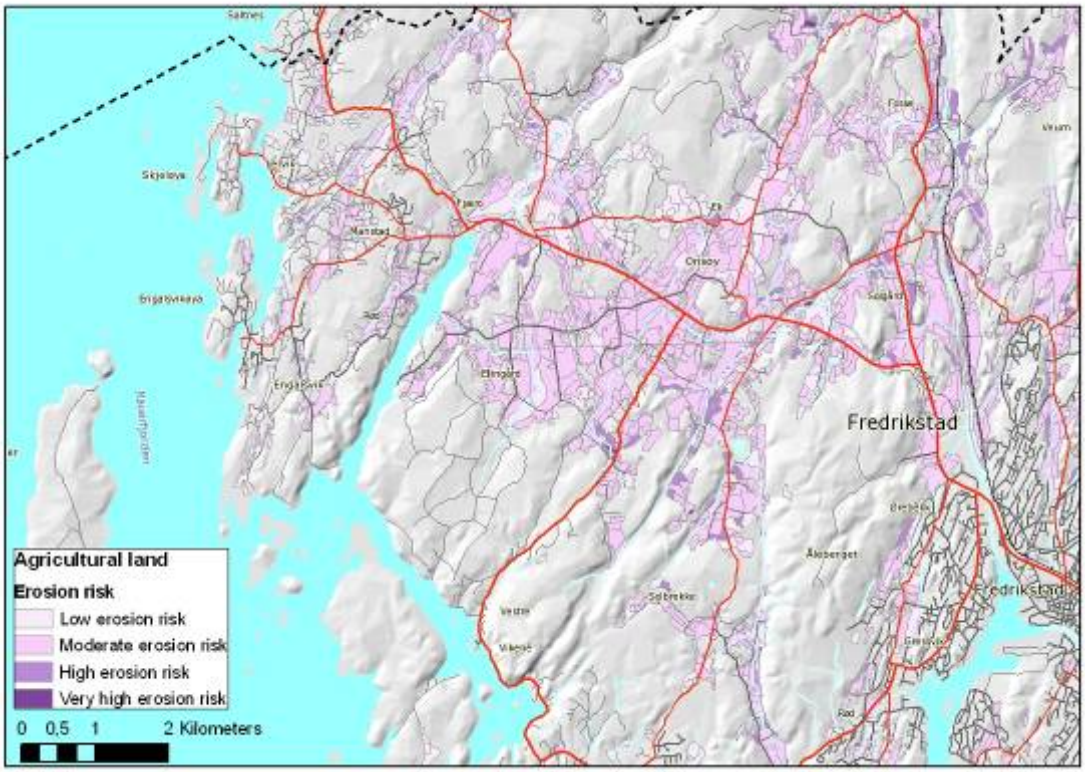
2.6.1. SOILS IN THE MUNICIPALITY OF FREDRIKSTAD



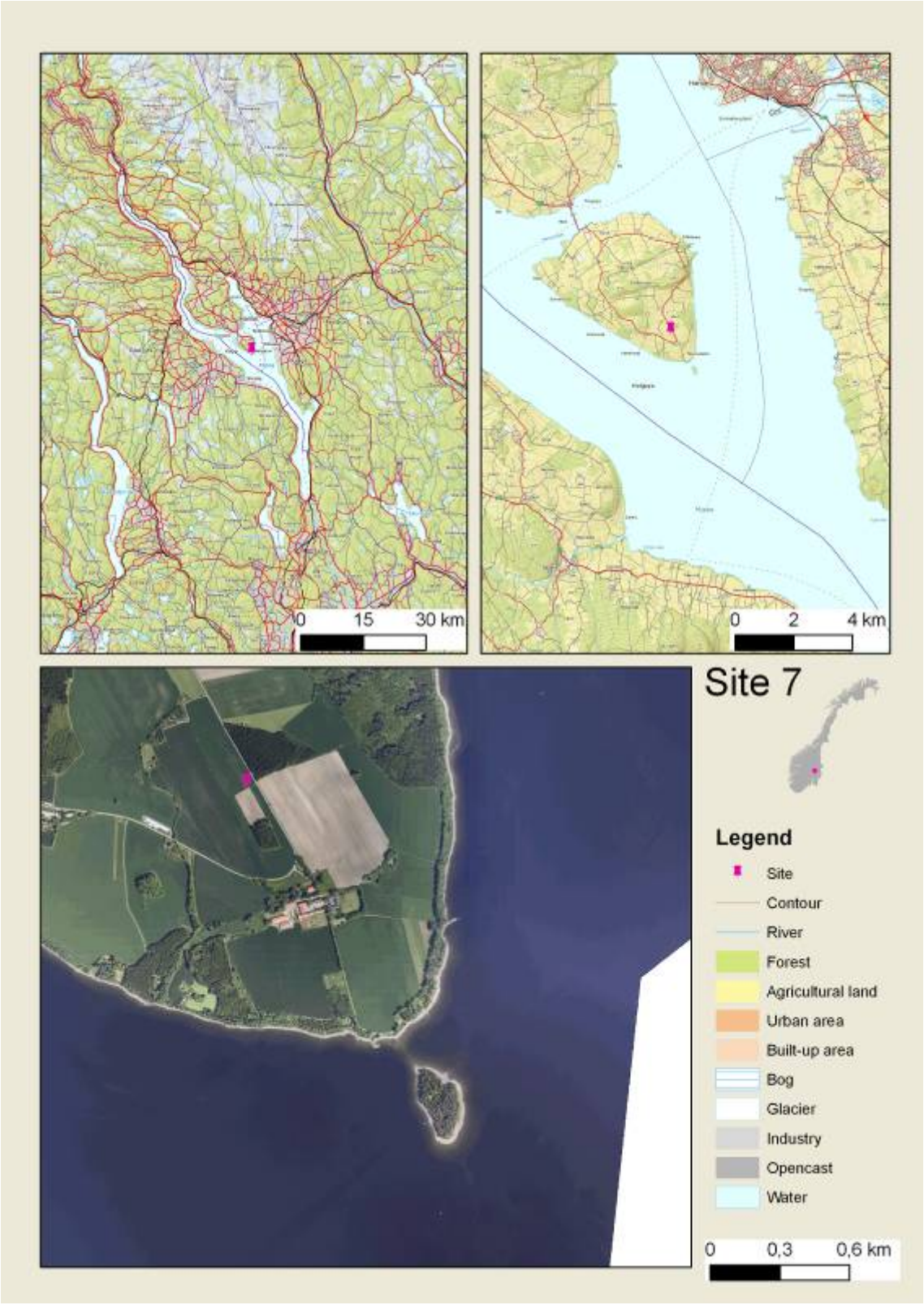
Most common WRB-units (one prefix) and most common qualifiers (prefix and suffix) as % of the agricultural area in the municipality of Fredrikstad			
WRB-units	**%**	**Qualifiers**	**%**
Haplic Stagnosols	56.9	Eutric	72.8
Mollic Gleysols	12.7	Epistagnic	71.6
Epistagnic Albeluvisols	11.0	Siltic	65.7
Endostagnic Cambisols	7.5	Haplic	58.3
Endogleyic Arenosols	2.9	Dystric	15.2
Umbric Stagnosols	1.5	Mollic	14.1



The map above shows different soil qualities based on type and degree of limiting soil factors for agricultural use. The soil quality classes are derived by a soil index model that uses WRB qualifiers as input. Each qualifier or combinations of qualifiers are rated according to what degree they affect the choice of crops, farming practices and other agronomical concerns. The map below shows the risk of erosion from agricultural land (when autumn ploughed). Both maps are from an area in the municipality of Fredrikstad



2.7. Site 7: Helgøya, Ringsaker



2.7.1. SOILS IN THE MUNICIPALITY OF RINGSAKER

Most common WRB-units (one prefix) and most common qualifiers (prefix and suffix) as % of the agricultural area in the municipality of Ringsaker			
WRB-units	**%**	**Qualifiers**	**%**
Endostagnic Cambisols	21.5	Eutric	88.7
Fragic Cambisols	14.5	Endostagnic	49.2
Endostagnic Phaeozems	14.4	Mollic	29.0
Endoleptic Cambisols	13.0	Endoleptic	18.1
Haplic Stagnosols	6.4	Haplic	16.1
Haplic Cambisols	5.3	Fragic	14.5

Site 7 a

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1: Site 7 (photo: Siri Svendgård-Stokke).

2: Main profile wall (photo: Ove Klakegg).

3: Stagnic colour pattern, 70 - 80 cm depth (photo: Åge Nyborg).

4: Tonguing (photo: Åge Nyborg).

Site 7 b

Main profile wall (photo: Åge Nyborg)

2.7.2. PROFILE DESCRIPTION SITE 7

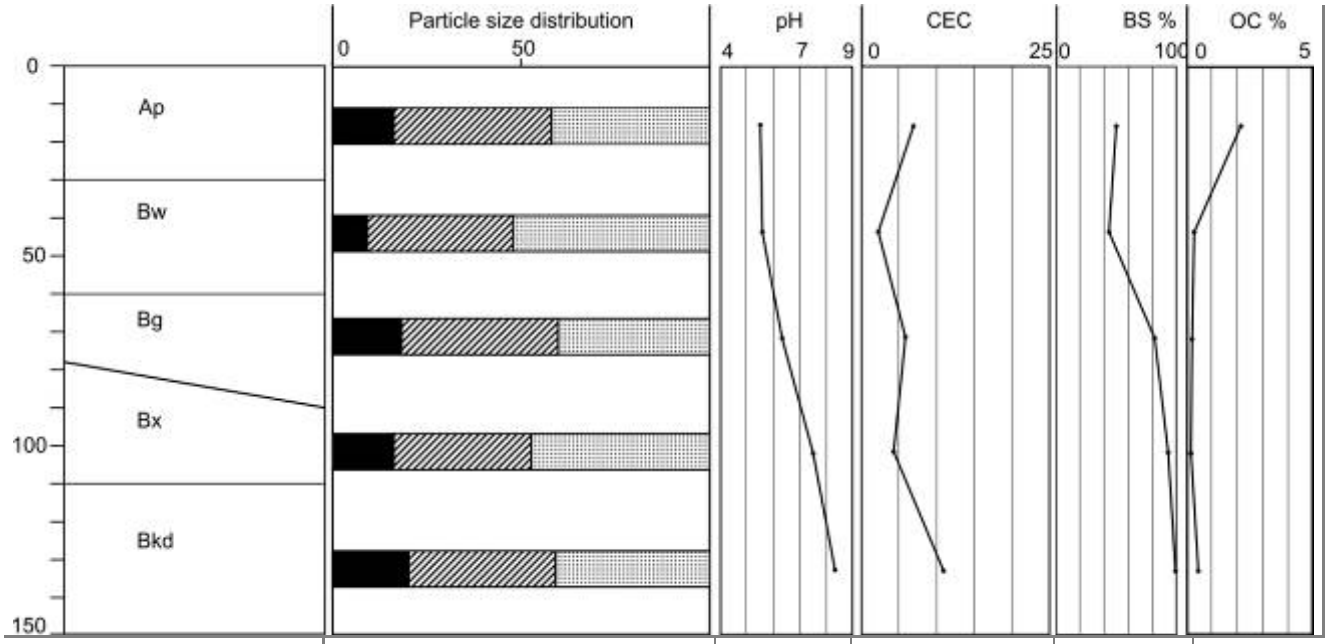
Location	***Helgøya, municipality of Ringsaker, county of Hedmark***
Date of description	18.04.2007
Authors	Arnold Arnoldussen, Eivind Solbakken, Elling Mjaavatten, Johnny Hofsten, Ove Klakegg, Ragnhild Sperstad, Siri Svendgård-Stokke, Åge Nyborg
Elevation	205 m ASL
Coordinates	UTM 32 V: N: 6733639, E: 609212 EUREF 89 GEOGR.: 60°43. 24,1', E: 11°0. 7,4'0

Soil formation factors	
Climate	**Present weather conditions:** overcast **Former weather conditions:** rain without heavy rain in the last 24 hours **Soil temperature:** Cryic
Landform and topography	**Major landform:** Sloping land, medium-gradient hill **Position:** Middle slope **Slope form:** Convex **Slope gradient and orientation:** Sloping, South
Land use and vegetation	**Land use:** Arable land (7a), plantation forestry (7b) **Crops:** Grain, potatoes (7a), **Human influence:** Sprinkler irrigation (7a) **Vegetation:** Coniferous forest (7b)
Parent material	Lodgement till with rock fragments of sandstones, limestones and shales
Age of the land surface	Holocene, 10000 calendar years

Information on the profiles	
Surface characteristics	**Rock outcrops: None** **Coarse surface fragments:** 1 % (7a), 2 % (7b) **Erosion:** None
Profile depth	130 cm
Bedrock	Ordovisian shales and limestone
Level of groundwater	> 140cm
Max. root depth	70 cm

Site7a: Helgøya, municipality of Ringsaker, county of Hedmark

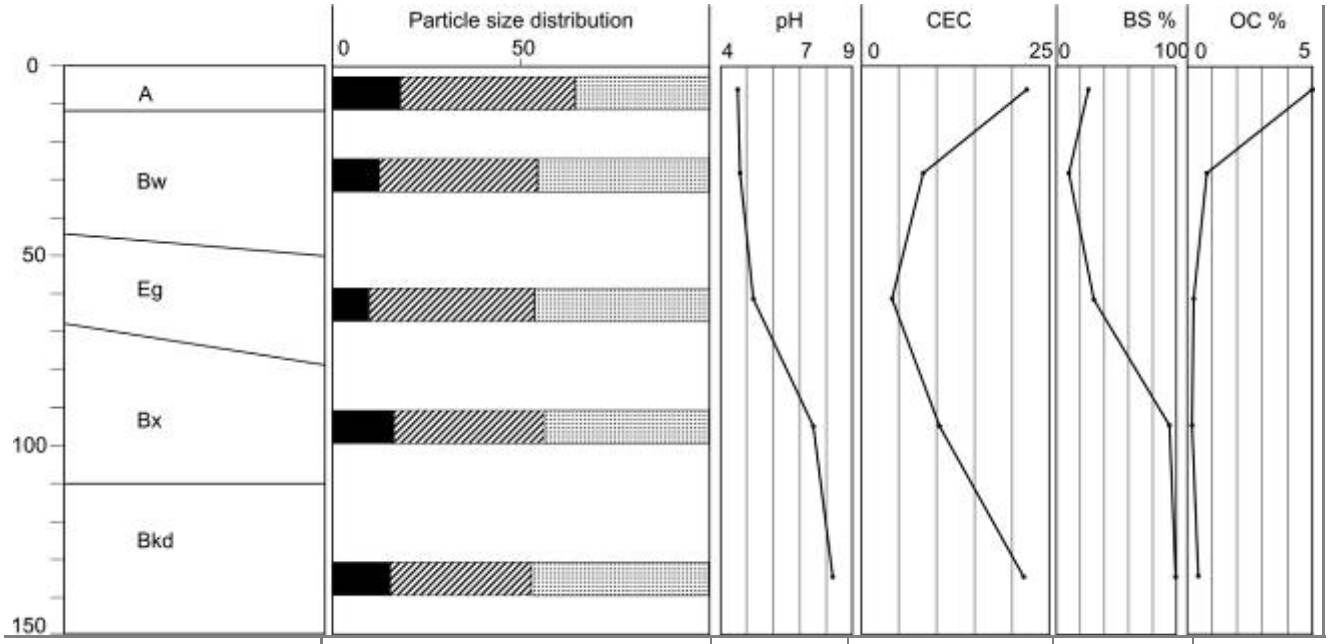
Pedon boundary (cm), horizon	Boundary	Soil moisture	Soil textural classes	Rock fragments	Soil colour (matrix) moist	Soil colour (matrix) dry	Soil structure	Mottling	Additional information
0 – 30, Ap	Abrupt, smooth	Slightly moist	Loam	None	10 YR 4/2		Fine and medium subangular blocky		
30 – 60, Bw	Clear, wavy	Slightly moist	Sandy loam	Common Coarse gravel	2.5Y 4.5/3		Fine and medium subangular blocky		Vertical cracks
60 – 78(90), Bg	Clear, wavy	Slightly moist	Loam	Few Coarse gravel	10 YR 4.5/3		Massive	Zones of enrichment: 7.5 YR 4/4 Zones of displacement: 2.5 Y 5.5/1	Lodgement till
78(90) – 110, Bx	Gradual, wavy	Slightly moist	Loam	Common Gravel and stones	2.5Y 4.5/3		Platy	Zones of enrichment: 10 YR 4/4 Zones of displacement: 2.5 Y 6/2	Compact lodgement till, brittle consistance, vertical cracks
110 – ,Bkd		Slightly moist	Loam	Common Gravel and stones	10YR 4/3		Platy, sedimentary structure?	Zones of enrichment: 2.5 YR 3/4 Zones of displacement: 5 Y 4.5/1	Compact lodgement till, reaction with HCl and H_2O_2



Helgøya – Site 7a	Particle size distribution						
Pedon boundary (cm), horizon	**Clay %**	**Silt %**	**Sand %**	**pH (H_2O)**	**CEC (mmolckg-1)**	**BS (%)**	**OC (%)**
0 – 30, Ap	16.6	41.5	41.8	5.5	13.69	51	2.18
30 – 60, Bw	9.1	38.5	52.4	5.6	4.9	45	0.31
60 - 78/90, Bg	18.2	41.3	40.5	6.3	11.29	82	0.18
78/90 – 110, Bx	16.1	36.3	47.6	7.5	8.82	94	0.13
110 - , Bkd	20.1	38.7	41.2	8.3	22.12	100	0.47

Site7b: Helgøya, municipality of Ringsaker, county of Hedmark

Pedon boundary (cm), horizon	Boundary	Soil moisture	Soil textural classes	Rock fragments	Soil colour (matrix) moist	Soil colour (matrix) dry	Soil structure	Mottling	Additional information
0 – 12, A	Clear, wavy	Slightly moist	Loam	Few	7.5 YR 3/2		Fine and medium granular,		1.5cm LHF on top
12 – 50, Bw	Clear, wavy	Slightly moist	Loam	Common Coarse gravel	10YR 4.5/4		Fine and medium subangular blocky,		Bioturbation
50 – 68, Eg	Clear, wavy	Slightly moist	Loam	Common	2.5Y 5/2		Massive, (weak platy)		Lodgement till Roots down to 68 cm
68 – 110, Bx	Gradual, wavy	Slightly moist	Loam	Many	10YR 3.5/2		Platy, Sedimentary structure?	Zones of enrichment: 10 YR 4/4 Zones of displacement: 2.5 Y 6/2	Compact lodgement till, brittle consistance H_2O_2-reaction at 80cm
110 + , Bkd		Slightly moist	Loam	Many	10YR 4/3		Platy, Sedimentary structure?	Zones of enrichment: 2.5 YR 3/4 Zones of displacement: 5 Y 4.5/1	Compact lodgement till, HCl reaction

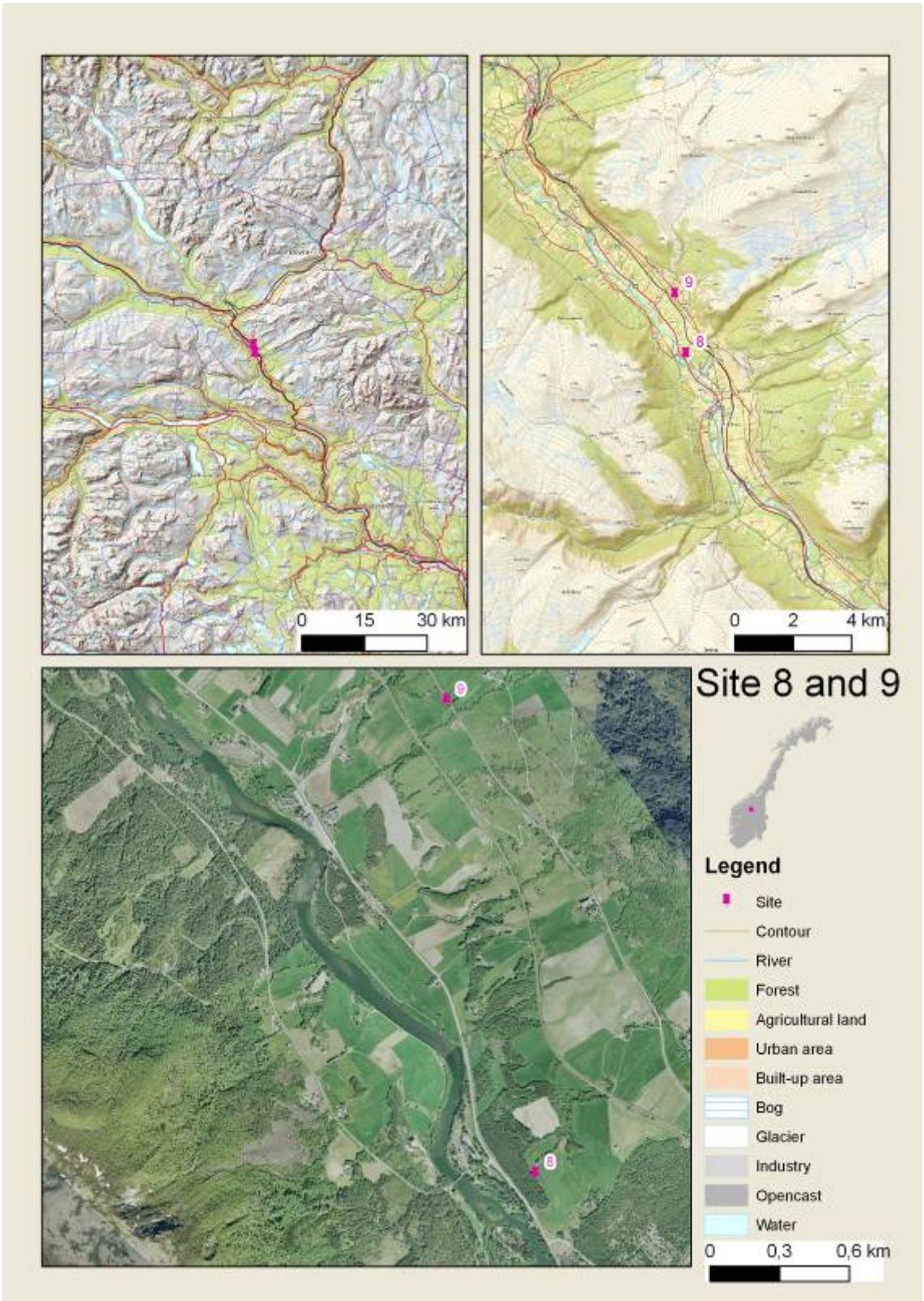


Helgøya – Site 7b	Particle size distribution						
Pedon boundary (cm), horizon	**Clay %**	**Silt %**	**Sand %**	**pH (H_2O)**	**CEC (mmolckg-1)**	**BS (%)**	**OC (%)**
0 – 12, A	18	46.1	36	4.7	21.8	27	5.02
12 - 45/50, Bw	12.3	41.9	45.9	4.8	7.82	10	0.86
45/50 – 68/78, Eg	9.5	43.6	46.9	5.2	4.22	31	0.23
68/78 - 110, Bx	16.2	39.6	44.2	7.5	10.33	94	0.16
110 + , Bkd	15.3	37.4	47.3	8.2	21.61	100	0.45

2.7.3. CLASSIFICATION PROBLEMS/ DISCUSSION

Site 7: Helgøya, municipality of Ringsaker, county of Hedmark	
Diagnostic horizons	7a: Cambic, fragic, 7b: Cambic, fragic, albic
Diagnostic properties	Endostagnic, eutric (7a)
Diagnostic material	Bathicalcaric
Classification	7a: Endostagnic Fragic Cambisol (Bathicalcaric) 7b: Endostagnic Fragic Cambisol (Bathicalcaric, Dystric)
Discussion	
Conclusion	

2.8. Site 8: Toftemo, Dovre



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1: Site 8. 2: Main profile wall. 3: Detail from the top 30 cm.

4: Detail from the 3 cm thick layer with slightly higher clay content (depth 80 – 83 cm).

5: Root horizontally on the layer with slightly higher clay content, finding its way further down in a crack.

All photos: Åge Nyborg

2.8.1. PROFILE DESCRIPTION

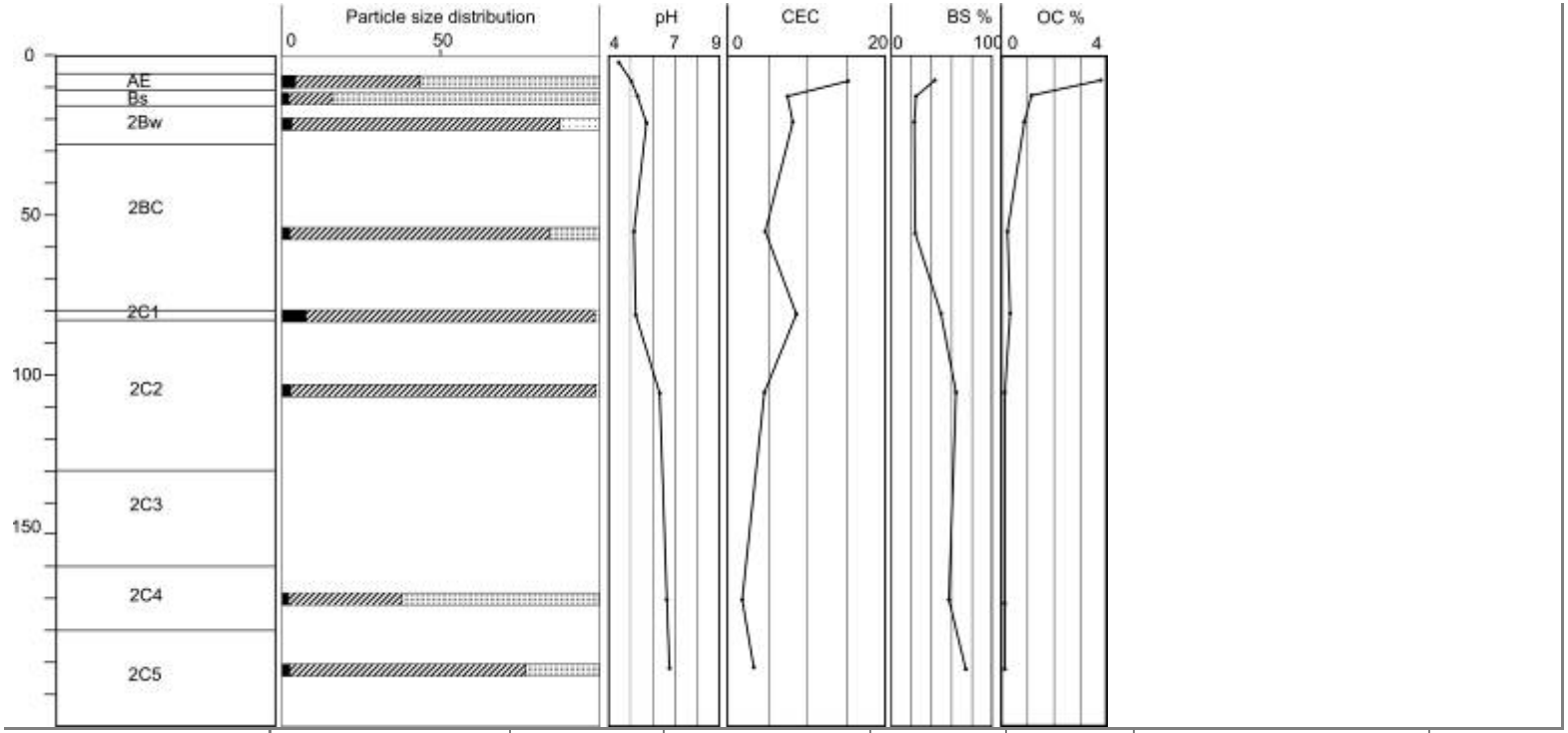
Location	***Toftemo, municipality of Dovre, county of Oppland***
Date of description	22.09.2009
Authors	Eivind Solbakken, Åge Nyborg
Elevation	482 m ASL
Coordinates	UTM 32 V: N: 6874044, E: 511862 EUREF 89 GEOGR.: 61°59. 54,9', E: 9°13 35,3'

Soil formation factors	
Climate	**Present weather conditions:** Partly cloudy with light rain showers **Former weather conditions:** No rain last week **Soil temperature:** Cryic
Landform and topography	**Major landform:** Level land:: valley floor **Position:** Upper slope on dissected terrace **Slope form:** Convex **Slope gradient and orientation:** Moderately steep (20 %), 370° (N=400)
Land use and vegetation	**Land use:** Woodland on the edge of cultivated field **Human influence:** The soil is exposed to 3 m depth due to excavations along the cultivated field **Vegetation:** Semi-deciduous (birch and pine)
Parent material	Glacio-lacustrine silt covered by a thin layer of sand and gravel (colluvial?)
Age of the land surface	Holocene (ca. 10 000 calendar years)

Information on the profile	
Surface characteristics	**Rock outcrops:** None **Coarse surface fragments:** None **Erosion:** No evidence of surface erosion
Profile depth	210 cm
Level of groundwater	More than 300 cm
Max. root depth	More than 200 cm (pine roots), restricted to cracks

Site 8: Toftemo, municipality of Dovre, county of Oppland

Pedon boundary (cm), horizon	Boundary	Soil moisture	Soil textural classes	Rock fragments	Soil colour (matrix) moist	Soil colour (matrix) dry	Soil structure	Mottling	Additional information
0 – 6, Oi	Clear, wavy	Slightly moist	-	None	-	-	-		
6 - 11, AE	Clear, wavy	Slightly moist	Sandy loam	Few fine gravel	10YR 4/2 (upper part 7.5YR 3/2)	10YR 5/2	Single grain and fine granular		Upper part dominated by very fine and fine roots. Decreasing OM content with depth.
11 – 16, Bs	Clear, wavy	Slightly moist	Loamy coarse sand	Abundant fine gravel	7.5YR 4/3		Single grain		Very fine and fine roots
16 – 28, 2Bw1	Clear, smooth	Slightly moist	Silt	None	2.5Y 4/4		Weak, very fine and fine subangular blocky		Patches of very fine roots between peds
28 – 80, 2Bw2	Clear, smooth	Slightly moist	Silt	None	5Y 4/3		Weak, fine and medium angular blocky		Fine and medium roots stop at horizon boundary
80 – 83, 2C1	Abrupt, smooth	Slightly moist	Silt	None	5Y 4/2		Massive		Roots only sporadically in cracks
83 - 130, 2C2	Abrupt, smooth	Slightly moist	Silt	None	5Y 4/2		Massive		Some thin fine sandy loam strata
130 - 160, 2C3	Abrupt, smooth	Slightly moist	Silt / fine sandy loam	None	5Y 4/2		Layered		Stratified
160 - 180, 2C4	Abrupt, smooth	Slightly moist	Fine sandy loam	None	5Y 4/2		Massive		Some thin silt strata
180 - 210+, 2C5		Slightly moist	Silt loam / fine sandy loam	None	5Y 4/2		Layered		Stratified

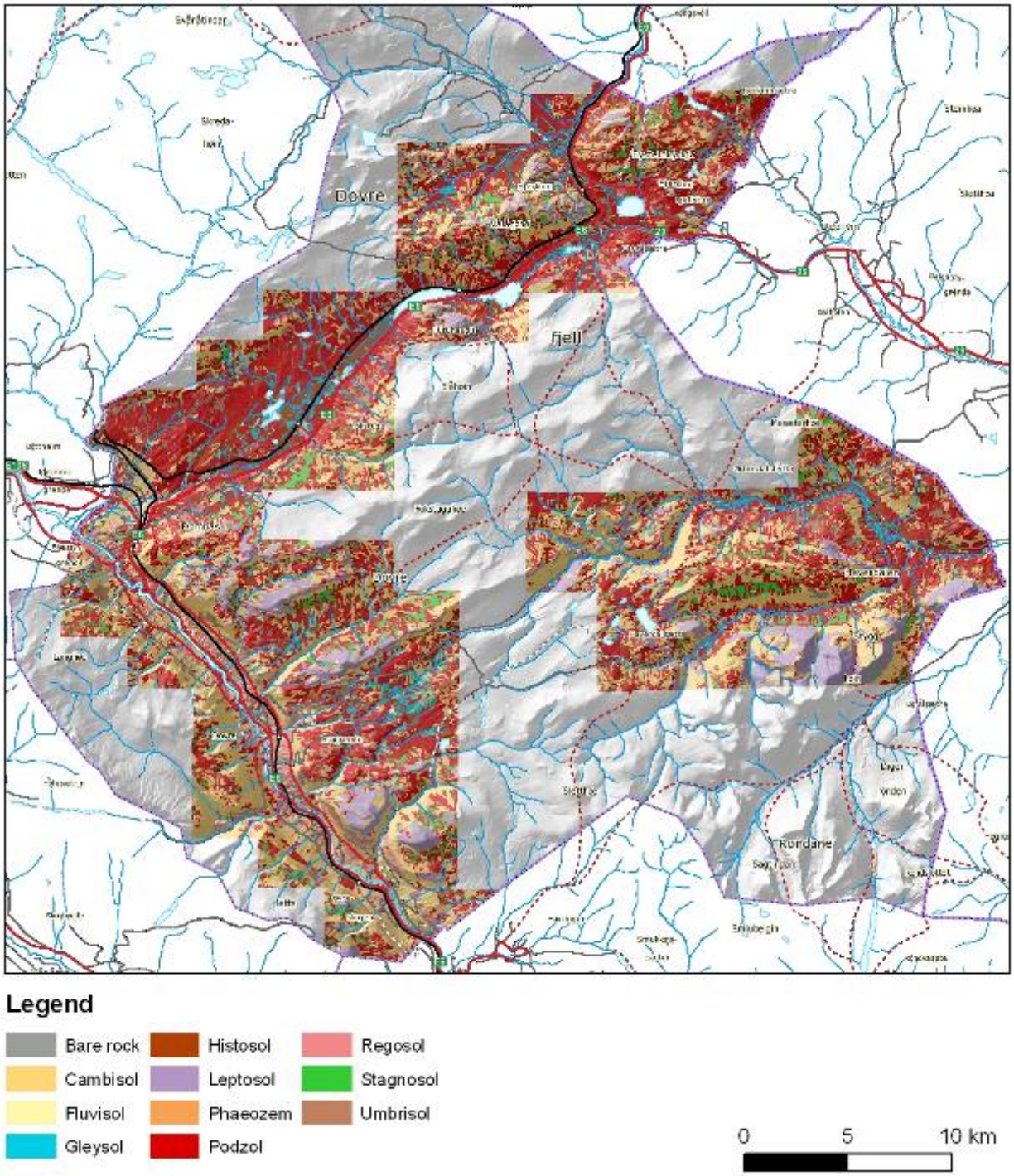


Toftemo – Site 8	Particle size distribution										
Pedon boundary (cm), horizon	Clay %	Silt %	Sand %	pH (H_2O)	CEC (mmolckg-1)	BS (%)	OC (%)	Ox Fe	Ox Al	Ox Al + 1/2 Fe	ODOE
0 – 6, Oi	-	-	-	4.58	-	-	23				
6 – 11, AE	4.2	39.3	56.6	5.05	15.33	43	3.82	0.28	0.09	0.23	0.432
11 – 16, Bs	2.2	13.9	83.9	5.37	7.39	24	1.15	0.94	0.3	0.77	0.416
16 – 28, 2Bw	3.2	84.5	12.3	5.74	7.87	22	0.95	0.54	0.42	0.69	0.349
28 – 80,2 BC	2.6	81.8	15.5	5.13	4.89	26	0.23				
80 – 83, 2C1	7.5	90.5	2	5.23	8.13	52	0.32				
83 – 130, 2C2	2.7	95.8	1.5	6.35	4.53	65	0.09				
130 – 160, 2C3											
160 – 180, 2C4	2	35.5	62.5	6.57	1.9	58	0.04				
180 – 210+, 2C5	2.6	74.1	23.3	6.73	3.71	73	0.07				

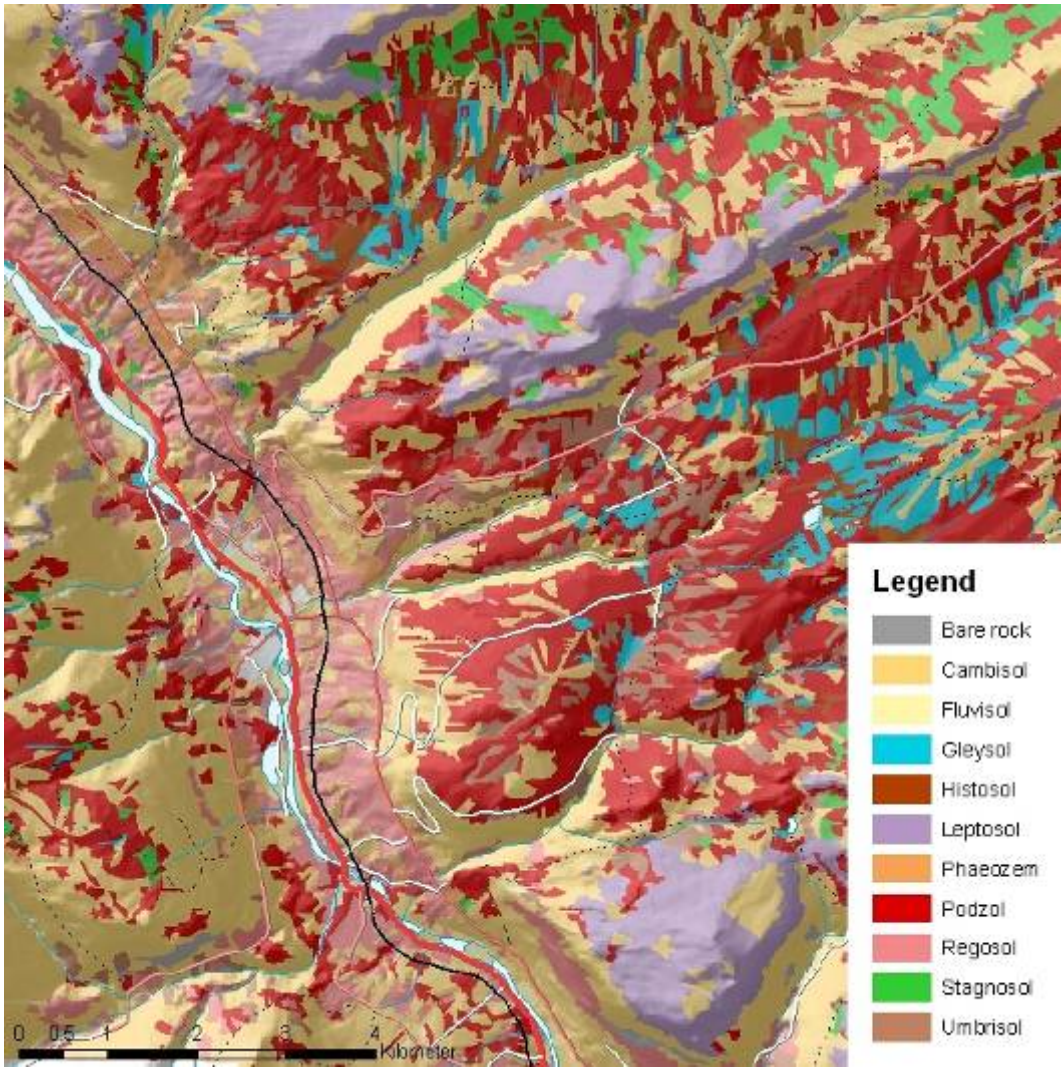
2.8.2. CLASSIFICATION PROBLEMS/ DISCUSSION

Site 8: Toftemo, municipality of Dovre, county of Oppland	
Diagnostic horizons	Albic, cambic, spodic
Diagnostic properties	Lithological discontinuity
Diagnostic material	
Classification	Albic Podzol (Ruptic)
Discussion	Siltic? Eutric? Podzols are abundant in Norway, in particular in coniferous forests. There is also podzol morphology on agricultural land, but the E horizon and part of the Bs horizon have been mixed in the Ap horizon due to ploughing. Without the albic horizon present, there is a need to meet the diagnostic criterias for amount of oxalate extracted Fe and Al, or the ODOE value (all the other requirements being fulfilled). Often, these requirements fail. In soil survey it's impossible to determine whether these diagnostic criterias are fulfilled or not.
Conclusion	

2.9. Site 9: Budsjord, Dovre: Use of WRB in soil survey 1: 50 000 (see 1.6.2)



The map above shows the area in the municipality of Dovre for which a soil map has been produced, based upon the general soil survey 1 : 50 000.

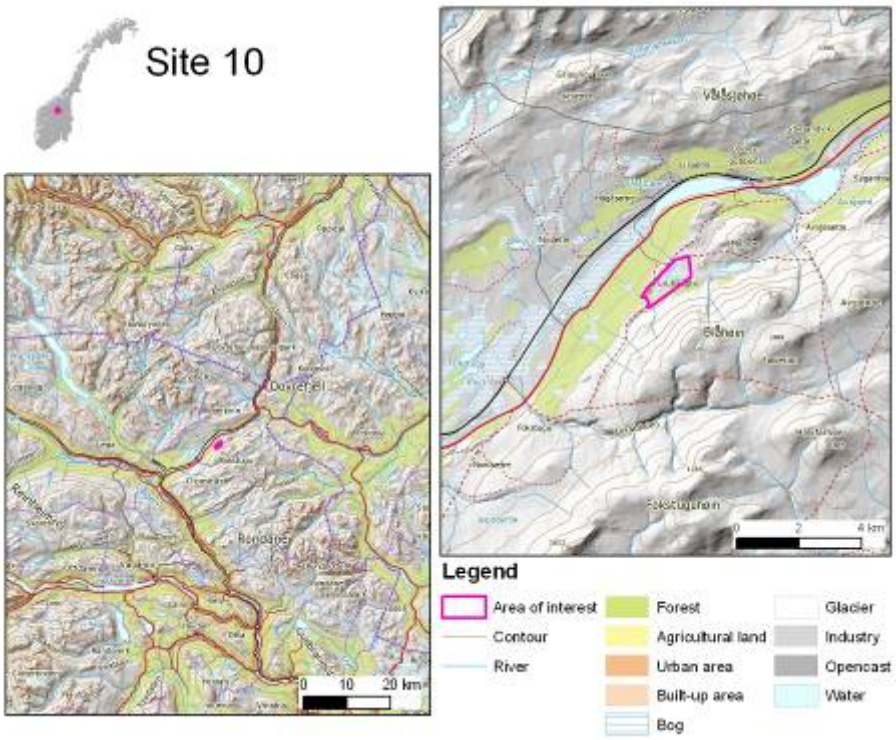


WRB-groups	Area [%]
Podzol	38,9 %
Cambisol	35,1 %
Leptosol	7,0 %
Stagnosol	4,0 %
Umbrisol	3,7 %
Histosol	3,4 %
Regosol	3,1 %
Gleysol	2,9 %
Fluvisol	0,6 %
Phaeozem	0,4 %
Bare rock	0,9 %

The map above is a soil map in an area in the municipality of Dovre, based upon the general survey 1: 50 000. All land within the area is surveyed (not only agricultural land).

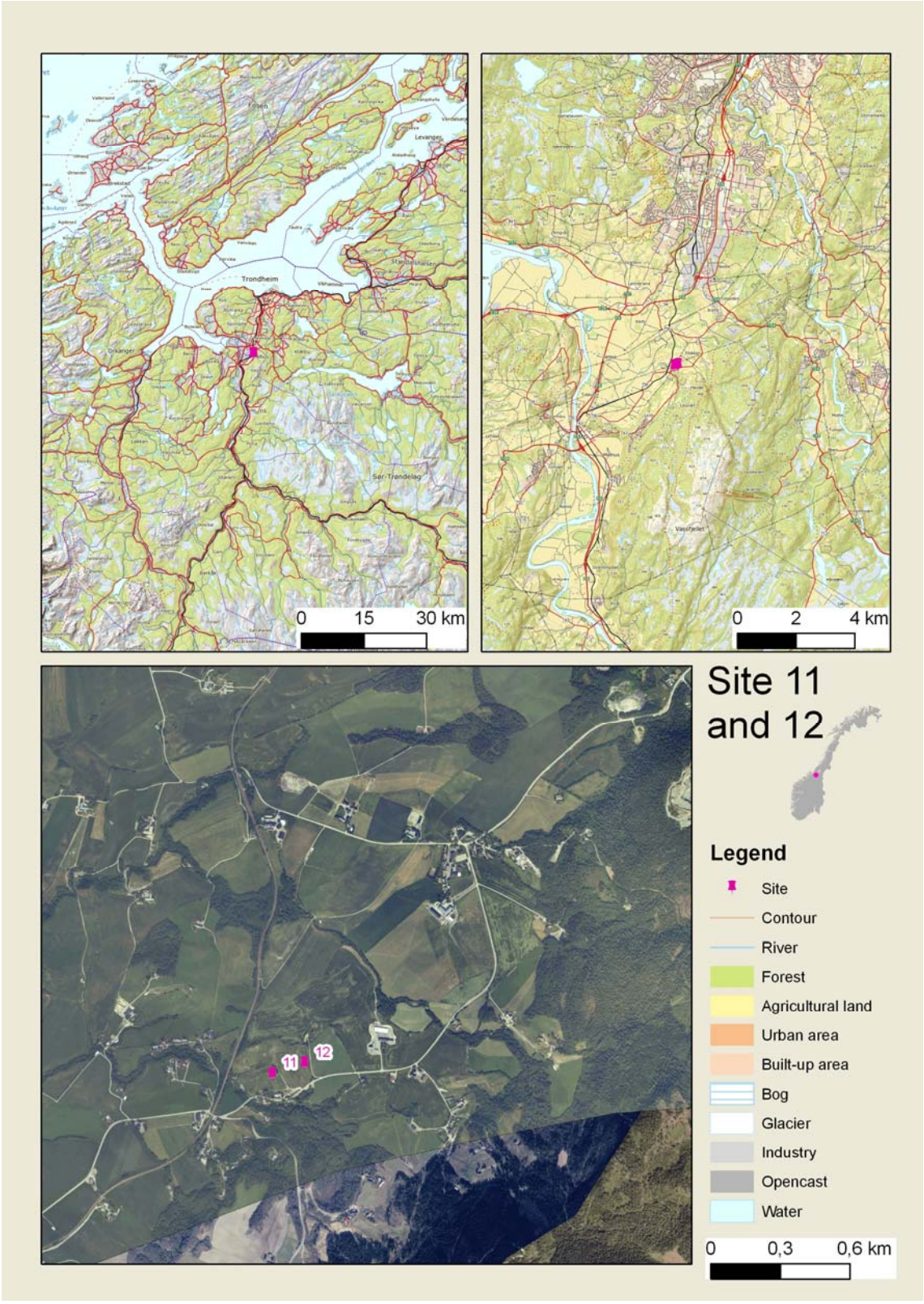
The table to the left shows the percentage area of the WRB groups present within the area which has been mapped in the municipality of Dovre.

2.10. Site 10: Haukskardmyrin, Dovrefjell

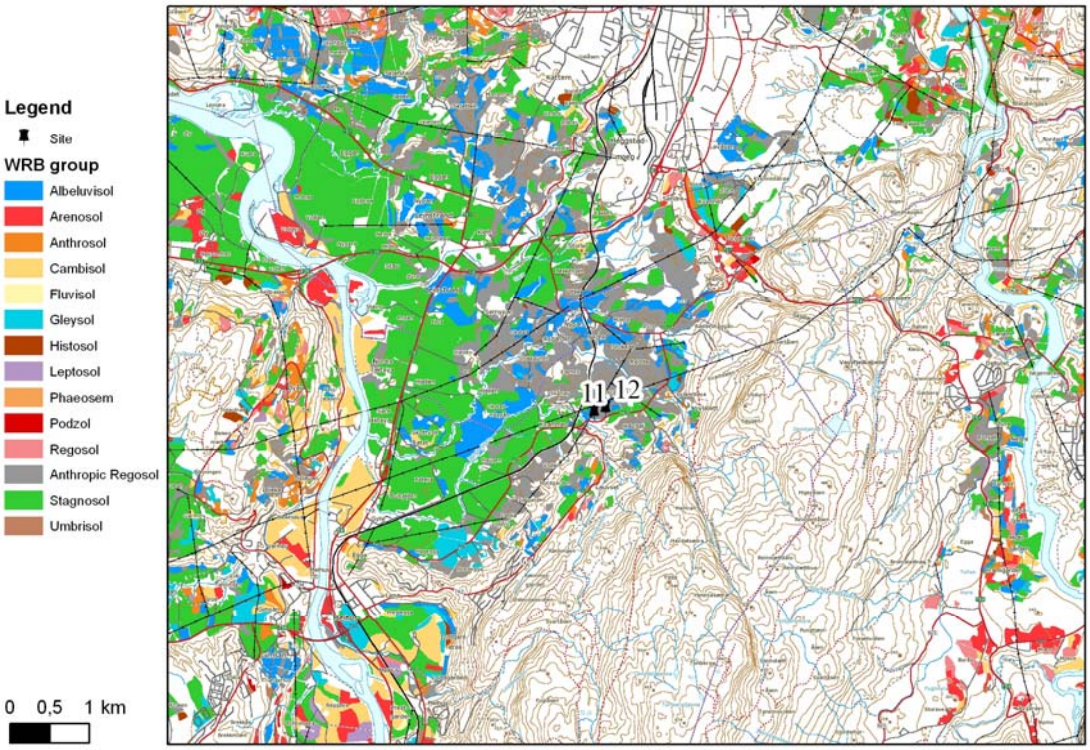


Palsa in Haukskardmyrin, Dovre (photo: Annika Hofgaard, NINA, , 8th of August 2005)

2.11. Site 11: Havdøl, Melhus



2.11.1. SOILS IN THE MUNICIPALITY OF MELHUS



Most common WRB-units (one prefix) and most common qualifiers (prefix and suffix) as % of the agricultural area* in the municipality of Melhus

WRB-units	%	Qualifiers	%
Haplic Stagnosols	23.9	Dystric	54.8
Endostagnic Cambisols	10.1	Epistagnic	46.8
Fluvic Cambisols	9.9	Siltic	43.0
Haplic Arenosols	4.9	Eutric	41.4
Epistagnic Albeluvisols	4.8	Haplic	38.2
Haplic Regosols	4.5	Endostagnic	19.7

*11.1 % of the agricultural area consists of soils disturbed by land levelling.

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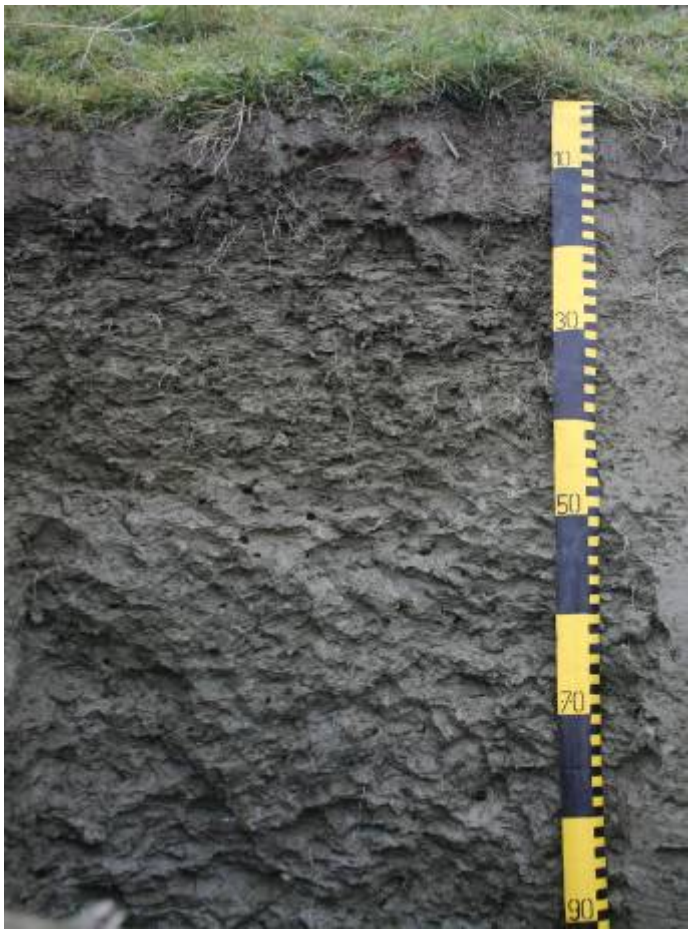

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1: Site 11

2: Main profile wall.

3: Lenticular structure, horizon 2.

4: Platy structure, horizon 4.

5: Coatings, horizon 5.

All photos: Siri Svendgård-Stokke

2.11.2. PROFILE DESCRIPTION SITE 11

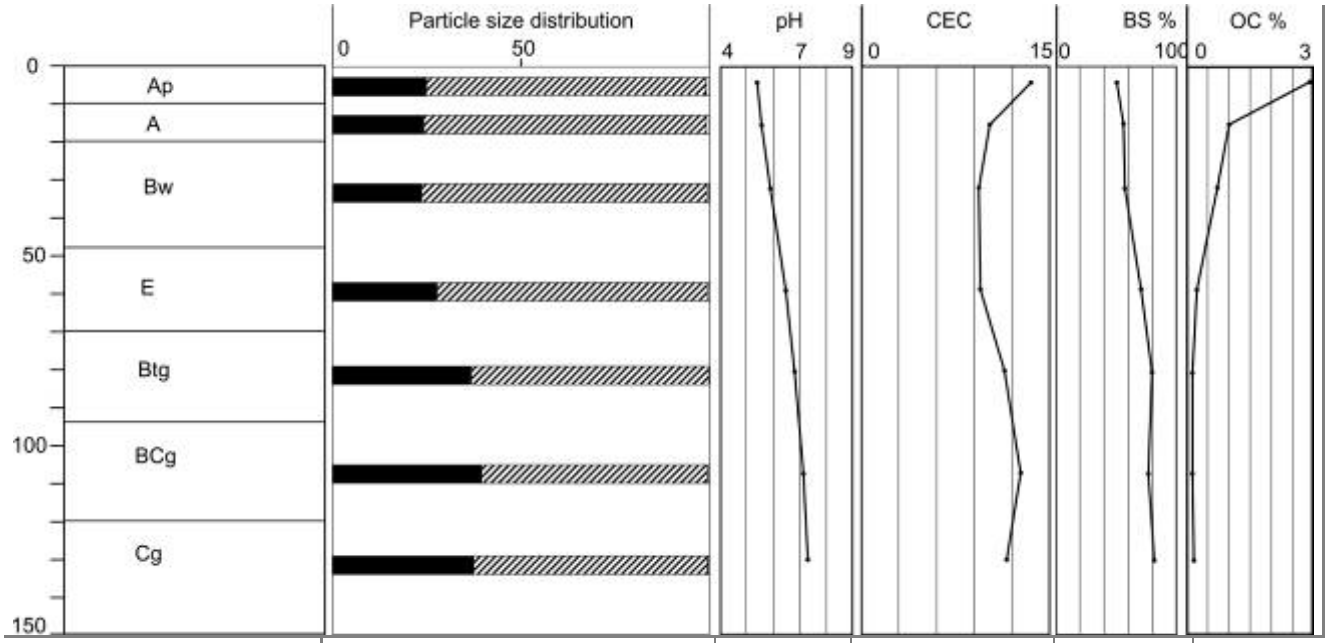
Location	***Havdøl, municipality of Melhus, county of Sør-Trøndelag***
Date of description	15.10.2009
Authors	Eivind Solbakken, Siri Svendgård-Stokke
Elevation	74 m ASL
Coordinates	UTM 32 V: N: 7020355, E: 567110 EUREF 89 GEOGR.: 63˚18. 20,7', E: 10˚20. 20,4'

Soil formation factors	
Climate	**Present weather conditions:** Overcast **Former weather conditions:** Heavier rain for some days **Soil temperature:** Cryic
Landform and topography	**Major landform:** Sloping land: dissected old sea bed **Position:** Upper slope **Slope form:** Convex **Slope gradient and orientation:** Steep (40 %), 180° (N=400)
Land use and vegetation	**Land use:** Animal husbandry, intensive grazing **Crops:** Grasses **Human influence:** Cultivation and grazing. Indication of human disturbance in the A-horizons due to the building of a power line nearby the profile site
Parent material	Marine clay and silt
Age of the land surface	Holocene (8000-10 000 calendar years)

Information on the profile	
Surface characteristics	**Rock outcrops:** None **Coarse surface fragments:** None **Erosion**: No evidence of erosion
Profile depth	110 cm
Level of groundwater	Unknown
Max. root depth	100 cm

Site 11: Havdøl, municipality of Melhus, county of Sør-Trøndelag

Pedon boundary (cm), horizon	Boundary	Soil moisture	Soil textural classes	Rock fragments	Soil colour (matrix) moist	Soil colour (matrix) dry	Soil structure	Mottling	Additional information
0 – 10, Ap	Abrupt, smooth	Slightly moist	Silt loam	None	10 YR 4/2		Mix of moderate fine granular and moderate fine subangular blocky		Many very fine and fine roots. Earthworms observed
10 – 20, A	Abrupt, smooth	Slightly moist	Silt loam	None	2.5 Y 4/2		Mix of moderate fine lenticular and moderate fine angular blocky		Many very fine and fine roots. Earthworms and earthworm excrements observed
20 – 48, Bw	Abrupt, wavy	Slightly moist	Silt loam	None	2.5Y 4.5/2		Moderate to strong fine and medium lenticular breaking into moderate to strong very fine and fine subangular blocky		Few fine, common medium and few coarse pores, mostly as channels within peds. Many roots mostly in pores. Earthworms and excrements observed
48 – 70, E	Gradual, wavy	Slightly moist	Silt loam	None	5 Y 5.5/2		Moderate to strong very thick platy		Few fine, few medium and common coarse pores, mostly as channels within peds. Many roots in pores and along ped faces. Earthworms and excrements observed
70 – 94, Btg	Clear, wavy	Moist	Silty clay loam	None	5 Y 4.5/2		Moderate to strong very thick platy breaking into moderate to strong coarse and very coarse angular blocky,	Common redox concentrations, 10 YR 4/6, within peds and redox depletions inside pores	Few fine, few medium and common coarse pores, mostly as channels within peds. Water moving inside coarse pores and on horizontal ped faces. Distinct coatings of clay and silt inside smaller pores. Few roots in pores and on ped faces. Earthworms and excrements observed
94 – 120, BCg		Slightly moist	Silty clay	None	5 Y 4.5/2		Weak very coarse angular blocky	Common redox concentrations, 10 YR 4/6, within peds and redox depletions inside pores	Very few fine, few medium and few coarse pores, mostly as channels within peds. Pores mostly dry inside. Water stagnates on top of the horizon. Very few roots in pores
120 + Cg		Slightly moist	Silty clay loam	None	5 Y 4.5/1		Massive	Common redox concentrations, 10 YR 4/4	

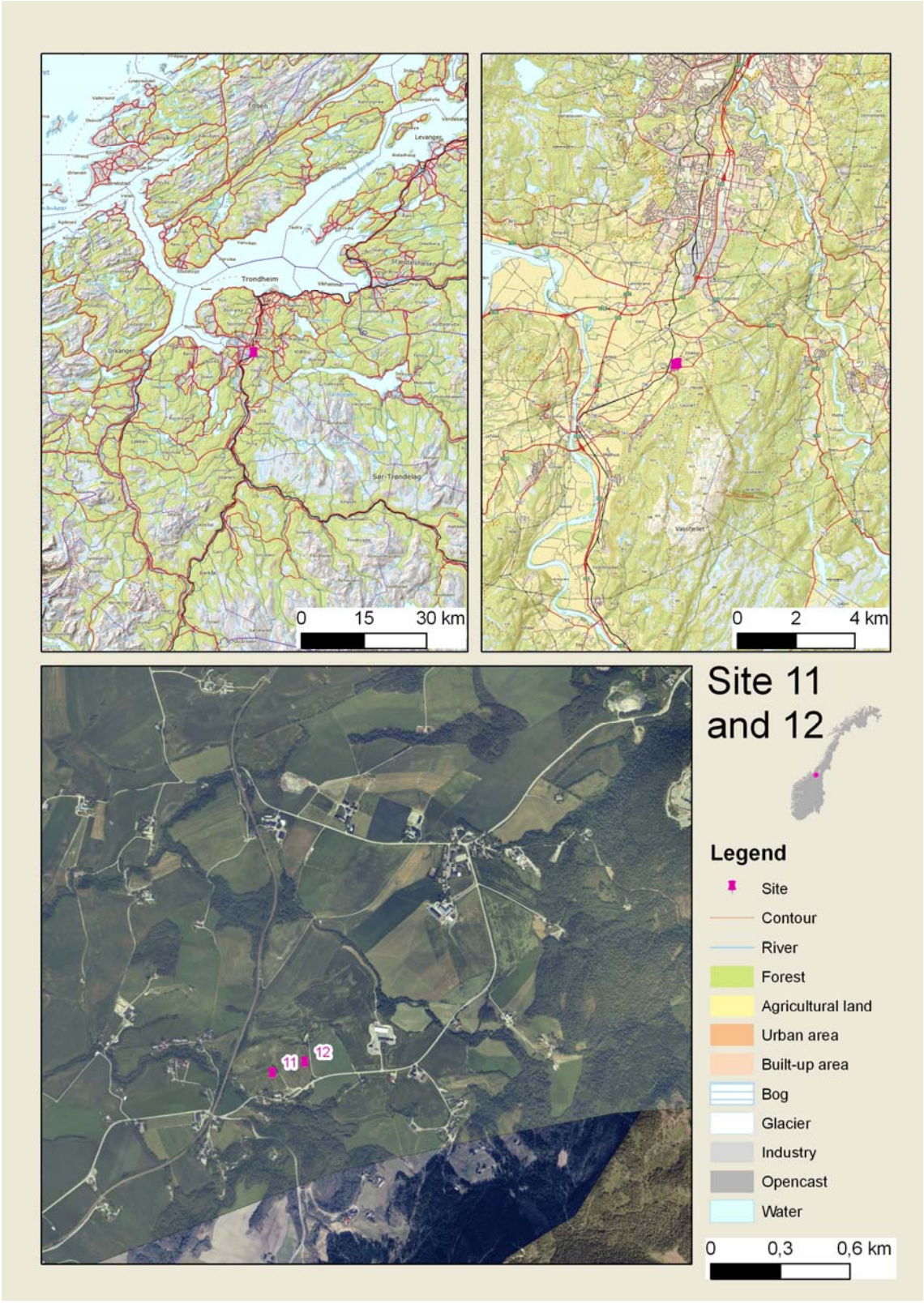


Havdøl – Site 11	Particle size distribution						
Pedon boundary (cm), horizon	**Clay %**	**Silt %**	**Sand %**	**pH (H_2O)**	**CEC (mmolckg-1)**	**BS (%)**	**OC (%)**
0 – 10, Ap	24.8	73.9	1.3	5.4	13.66	50	2.94
10 – 20, A	24	74.9	1.2	5.66	10.34	56	1.03
20 – 48, Bw	23.3	75.6	1.2	5.96	9.46	57	0.75
48 – 70, E	27.6	71.5	1	6.44	9.55	70	0.24
70 – 94, Btg	36.6	62.8	0.7	6.85	11.33	80	0.16
94 – 120, BCg	39.4	59.8	0.8	7.09	12.82	77	0.17
120+, Cg	37.3	61.9	0.8	7.3	11.84	81	0.19

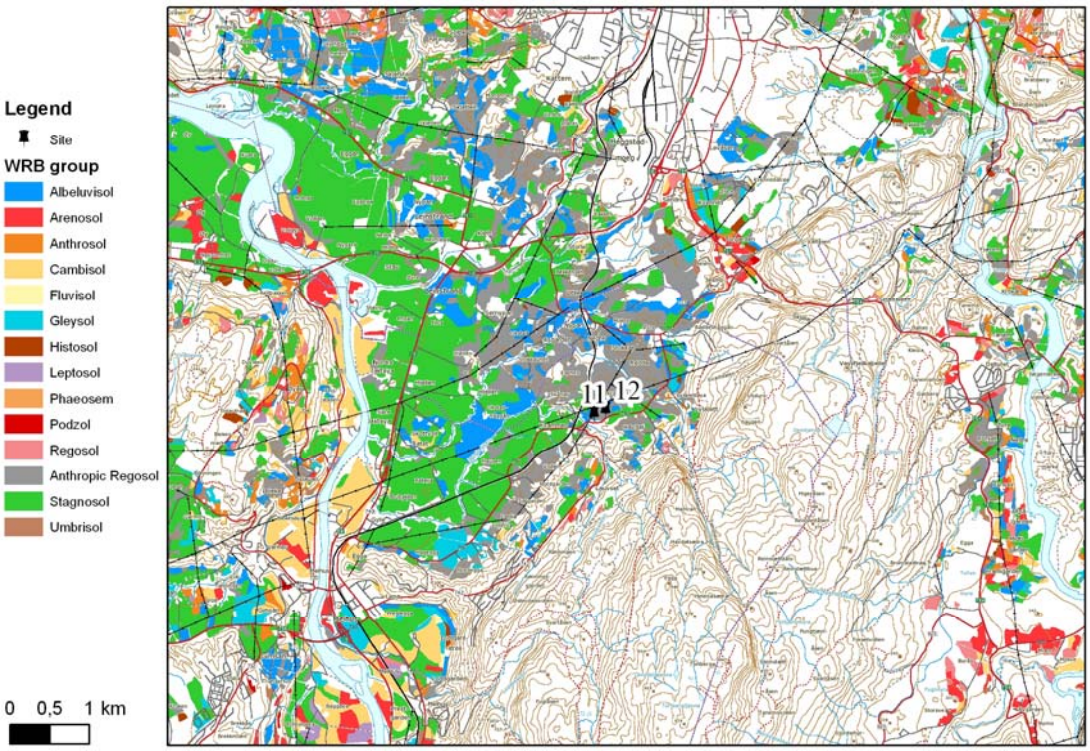
2.11.3. CLASSIFICATION PROBLEMS/ DISCUSSION

Site 11: Havdøl, municipality of Melhus, county of Sør-Trøndelag	
Diagnostic horizons	Cambic horizon, albic horizion, argic horizon
Diagnostic properties	Stagnic colour pattern
Diagnostic material	
Classification	Endostagnic Albic Cutanic Luvisol (Hypereutric, Siltic)
Discussion	
Conclusion	

2.12. Site 12: Havdøl, Melhus



2.12.1. SOILS IN THE MUNICIPALITY OF MELHUS



Most common WRB-units (one prefix) and most common qualifiers (prefix and suffix) as % of the agricultural area* in the municipality of Melhus

WRB-units	%	Qualifiers	%
Haplic Stagnosols	23.9	Dystric	54.8
Endostagnic Cambisols	10.1	Epistagnic	46.8
Fluvic Cambisols	9.9	Siltic	43.0
Haplic Arenosols	4.9	Eutric	41.4
Epistagnic Albeluvisols	4.8	Haplic	38.2
Haplic Regosols	4.5	Endostagnic	19.7

*11.1 % of the agricultural area consists of soils disturbed by land levelling.

1

2

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4

5

1: Site 12. 2: Main profile wall.

3: Colour pattern in horizon 2, along layers of the sediment.

4: Percolating water, horizon 3

5: Layered silty clay loam, horizon 3.

All photos: Siri Svendgård-Stokke

2.12.2. PROFILE DESCRIPTION SITE 12

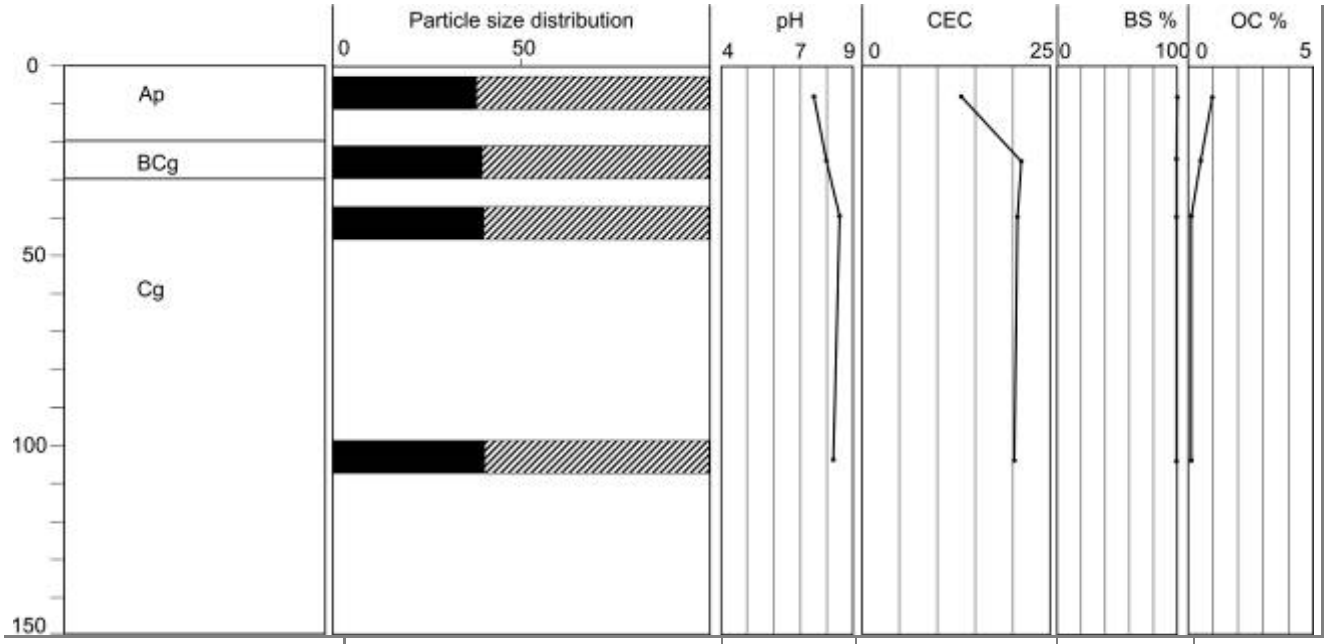
Location	**Havdøl, municipality of Melhus, county of Sør-Trøndelag**
Date of description	16.10.2009
Authors	Eivind Solbakken, Siri Svendgård-Stokke
Elevation	72 m ASL
Coordinates	UTM 32 V: N: 7020407, E: 567241 EUREF 89 GEOGR.: 63°18. 22,3', E: 10°20. 29,9'

Soil formation factors	
Climate	**Present weather conditions:** Rain **Former weather conditions:** Heavier rain for some days **Soil temperature:** Cryic
Landform and topography	**Major landform:** Sloping land: dissected plain **Position:** Middle slope **Slope form:** Convex **Slope gradient and orientation:** Moderately steep (18 %), 250° (N = 400)
Land use and vegetation	**Land use:** Perennial field cropping in shifting cultivation with barley every 4 years. The farm was certified as an organic farm in 1990. **Crops:** Grasses with some clover **Human influence:** Levelling was done in 1978/79. Artificial drainage was done decades before the levelling, and the system has only partly been upgraded after the levelling. Application of artificial fertilizers has not been done since 1986, only manure.
Parent material	Marine clay and silt
Age of the land surface	Young (10 – 100 years) anthropogeomorphic

Information on the profile	
Surface characteristics	**Rock outcrops:** None **Coarse surface fragments:** None **Erosion:** No evidence of erosion
Profile depth	62 cm
Max. root depth	62 cm (roots in macro pores and cracks)
Additional information	Water percolates from pores and cracks/layers while digging the profile. The profile was emptied for water several times during description. The main water movement is on the surface of H3. Biological activity is higher than expected for these soils. This is due to the organic farming system.

Site 12: Havdøl, municipality of Melhus, county of Sør-Trøndelag

Pedon boundary (cm), horizon	Boundary	Soil moisture	Soil textural classes	Rock fragments	Soil colour (matrix) moist	Soil colour (matrix) dry	Soil structure	Mottling	Additional information
0 – 20, Ap	Abrupt, wavy	Moist	Silty clay loam	None	5 Y 4/1	-	Weak, very fine, fine and medium sized angular and subangular blocky		Many roots and earthworms present
20 – 30, BCg	Clear, wavy	Moist	Silty clay loam	None	10 Y 4.5/	-	Moderate, thin lenticular breaking to moderate very fine and fine angular blocky	Some redox concentrations (colour: 2.5 Y, 4/4) along the horizon boundary H1-H2	Many roots and earthworms present. Few pores (> 10 mm).
30 +, Cg		Very moist	Silty clay loam	None	10 Y 4/	-	Layered		Earthworms present, but in a smaller amount than in H1 and H2. Fewer roots than in H1 and H2. These are "unhappy" roots: being horizontally orientated on the sedimentary structure and as a consequence flat, finding their way down in cracks and pores (> 10 mm) where these are present (very few).



Havdøl – Site 12	Particle size distribution						
Pedon boundary (cm), horizon	**Clay %**	**Silt %**	**Sand %**	**pH (H_2O)**	**CEC (mmolckg-1)**	**BS (%)**	**OC (%)**
0 – 20, Ap	38	61.5	0.5	7.51	13.25	100	1.01
20 – 30, BCg	39.4	60	0.6	7.97	21.19	100	0.52
30 +, Cg (sample depth: 35 – 43 cm)	39.7	60.1	0.2	8.43	20.27	100	0.18
30 + ,Cg (sample depth: 95 – 112 cm)	40	59.8	0.2	8.26	20.19	100	0.21

2.12.3. CLASSIFICATION PROBLEMS/ DISCUSSION

Site 12: Havdøl, municipality of Melhus, county of Sør-Trøndelag	
Diagnostic horizons	
Diagnostic properties	
Diagnostic material	
Classification	Haplic Regosol (Othoeutric, Siltic)
Discussion	stagnic colour pattern: difficult to verify according to the diagnostic criterias → If criterias for stagnic colour pattern are fulfilled → Stagnosol Haplic Stagnosol (Orthoeutric, Siltic) It would be useful to have a qualifier describing this kind of soils: mineral soil material which has been removed by human activity, leaving a mineral soil material at the surface, unaffected by soil formation factors = young soil.
Conclusion	

3. APPENDIXES

3.1. Using WRB as basis for soil mapping units in detailed soil mapping in Norway

A suitable national soil classification system has been lacking in Norway, especially for the purpose of differentiating soils in detailed soil mapping. When soil survey of agricultural land started in the early 1980-ies, soil characteristics such as soil texture, drainage class and parent material formed the basis for differentiating soil mapping units, and the Canadian System of Soil Classification was used to describe the pedogenesis. Other existing soil classification systems were also tried in search of a system that could differentiate Norwegian soils satisfactory and at the same time be easy to use in the field. After more than ten years of soil mapping, WRB evolved as the best candidate.

WRB was tested on the Norwegian soil profile data base already after the first draft was released during the 15th International Soil Science Congress in Mexico, 1994. When the World Reference Base for Soil Resources was published in 1998, the development of a Norwegian soil map legend based on WRB started. A test version of a soil mapping unit field guide was tried out during the 2002 field season, and the first official version was in use during spring 2003. A revision of the soil map legend and field guide was done when the new WRB version arrived in 2006.

During the development of the WRB based soil map legend, we encountered situations where some WRB definitions were impractical or did not suit our soil conditions well. Some adjustments were done for practical purposes and in other cases, some criteria was changed or dropped to make definitions more suitable. In other situations we supplied the list of qualifiers at WRB unit level in one group with qualifiers from other groups. Some of the changes we made were also proposed to the WRB working groups and included in the later versions.

The current field guide consists of a soil classification system with four levels:

- Level 1: WRB-group. 13 WRB groups have been mapped.
- Level 2: WRB-unit. 290 units are defined in the 2010 field guide.
- Level 3: Soil Series. About 800 soil series are defined on the basis of differences in texture, organic matter content, parent material, etc.
- Level 4: Soil Type. A subdivision of Soil Series based on top soil texture. Soil Type is also mapping unit in detailed soil surveys.

Following is an example from the field guide where we follow the path from the top of the WRB-group key down to the KBy-soil series and its soil types.

CAMBISOLS

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-

2. Other Cambisols with continuous hard rock within 50 to 100 cm depth:

ENDOLEPTIC CAMBISOLS

2.A. Endoleptic Cambisols with stagnic colour pattern:

ENDOSTAGNIC ENDOLEPTIC CAMBISOLS

2 soil series

2.B. Other Endoleptic Cambisols with calcaric materials within 50 cm depth:

ENDOLEPTIC CAMBISOL (CALCARIC)

1 soil series

2.C. Other Endoleptic Cambisols with low base saturation due to acid parent material:

ENDOLEPTIC CAMBISOL (DYSTRIC)

6 soil series

2.D. Other Endoleptic Cambisols:

ENDOLEPTIC CAMBISOL (EUTRIC)

4 soil series

-

-

-

ENDOLEPTIC CAMBISOL (DYSTRIC)

Soil Series	**Parent material**	**Top soil OM content**	**Dominating texture**
KKu	weathered phyllite or greenschist	3 - 6 %	sandy loam
KBy	**weathered mica schist**	**3 - 6 %**	**sandy loam**
KGp	weathered shale	3 - 6 %	gravelly sandy loam or loam
KQl	glacial till	3 - 6 %	gravelly medium or coarse sandy loam
KQv	glacial till	3 - 6 %	gravelly fine sandy loam
KLv	marine beach deposit	3 - 6 %	fine sandy loam

Soil Series definition:

Soil Series code: **KBy**

Soil Series name: Bymarka

WRB-unit: Endoleptic Cambisol (Dystric)

Parent material: Weathered mica schist

Defined: Skogn, Levanger, N -Trøndelag County, 1990

Description

10 cm		**Ap: 20-30 cm**
	Ap	**dark greyish brown (10YR 4/2) sandy loam, loam, silt loam (15-30% gravels), 3 - 6 % OM**
20		
30		
	Bw	**Bw: brown or dark yellowish brown (10YR 4/3, 4/4) sandy loam with mica fragments. Increasing gravel content with depth**
40		
50		
	Cr	
60		
70		
80		**R: continuous hard mica schist**
90		
	R	
100		

The KBy series has its main distribution in middle and northern Norway where it occurs in small and scattered areas. It is associated with the following series which are developed in similar parent materials: KRr (Haplic Cambisol (Dystric)), KKu (Endoleptic Cambisol (Dystric)), REx (Endoleptic Regosol (Dystric)) and RAp (Epileptic Regosol (Dystric)).

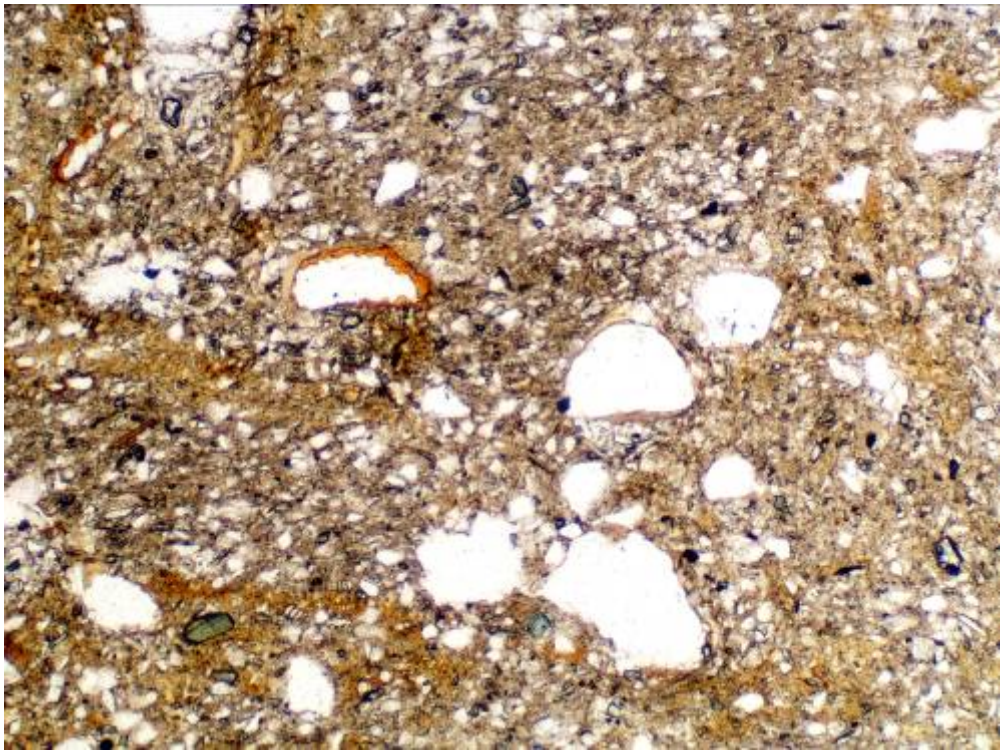
Soil types

Code	top soil texture	Mapped area (km^2)
KBy3	medium or coarse sandy loam	2.03
KBy4	fine sandy loam	3.92
KBy5	silt loam (< 12 % clay)	0.46
KBy6	silt loam (> 12 % clay)	0.13
KBy7	loam	0.06

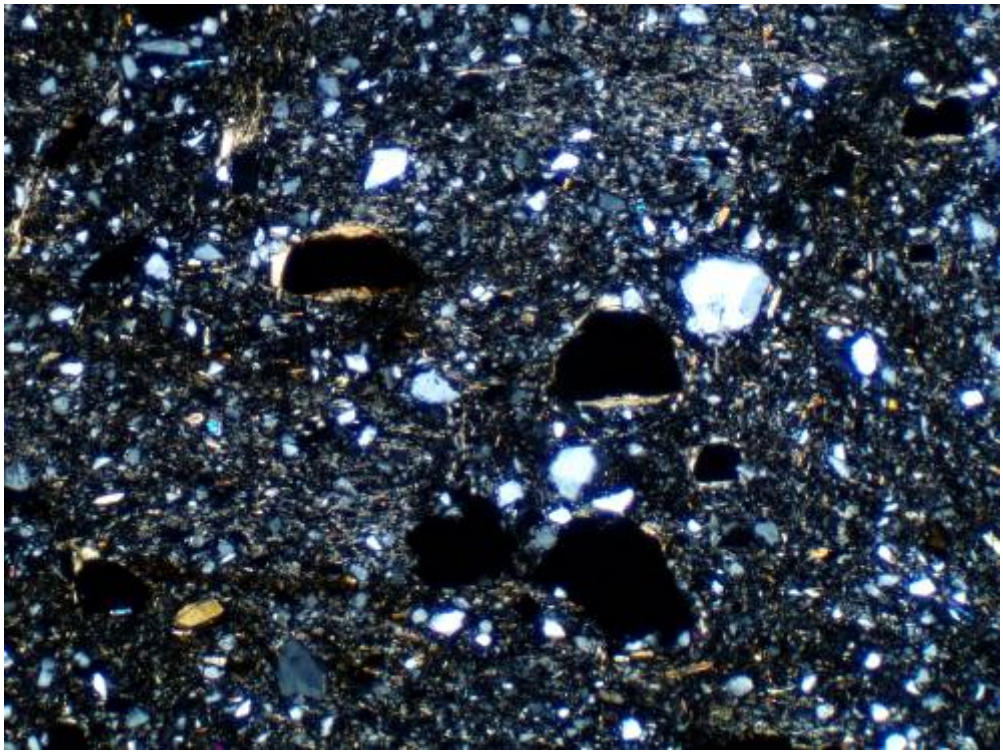
3.2. Methods of soil analysis with references

Method title	References
Total acidity in ammoniumacetat extract	Ogner, G., Wickstrøm, T., Remedios, G., Gjelsvik, S., Hensel, G. R., Jacobsen, J. E., Olsen, M., Skretting, E., Sørlie, B., 2000. The Chemical Analysis Program of the Norwegian Forest Research Institute, 2000. Norwegian Forest Research Institute, Ås, Norway.
Exchangeable cations (pH 7)	Ogner, G., Opem, M., Remedios, G., Sjøtveit, G., Sørlie, B., 1991. The Chemical Analysis Program of the Norwegian Forest Research Institute, 1991. Norwegian Forest Research Institute, Ås, Norway.
Acid extractable Potassium (K-HNO_3)	Krogstad, T. 1992. Metoder for jordanalyser. Rapport nr. 6/92. Institutt for jordfag Ås-NLH, ISSN 0803 – 1304.
Oxalate extraction	Burt, R. 2004. Soil Survey Laboratory Methods Manual, Soil Survey Investigations Report No. 42, Version 4.0 November 2004. U.S. Dept. Agric., Washington, D.C.
Dry matter of dried soil	Ogner, G., Wickstrøm, T., Remedios, G., Gjelsvik, S., Hensel, G. R., Jacobsen, J. E., Olsen, M., Skretting, E., Sørlie, B., 2000. The Chemical Analysis Program of the Norwegian Forest Research Institute, 2000. Norwegian Forest Research Institute, Ås, Norway. NS 4764 Tørrstoff og gløderest i vann, slam og sedimenter
pH of dried soil in H_2O	Ogner, G., Wickstrøm, T., Remedios, G., Gjelsvik, S., Hensel, G. R., Jacobsen, J. E., Olsen, M., Skretting, E., Sørlie, B., 2000. The Chemical Analysis Program of the Norwegian Forest Research Institute, 2000. Norwegian Forest Research Institute, Ås, Norway. ISO 10390 Soil quality – determination of pH*(modified to solid-liquid ratio 1:2,5)*
Particle size distribution	Manual for kornfordelingsanalyse etter pipettemetoden, ISSN 0803-1304(1991)(Krogstad, et.al) and ISO 11277
Carbon and Nitrogen analyses	ISO 10694(1995) and ISO 13878 modified to fit with the instrument(Elementar Vario EL CHN analyser)

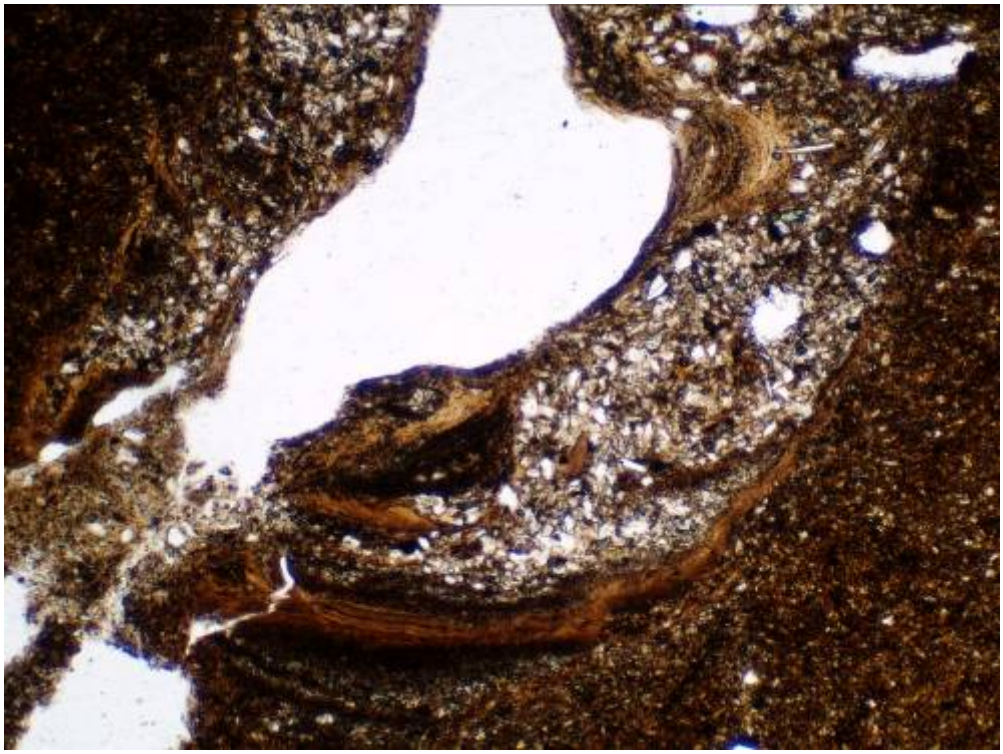
3.3. Micro photos showing Albeluvisol development in southern Norway



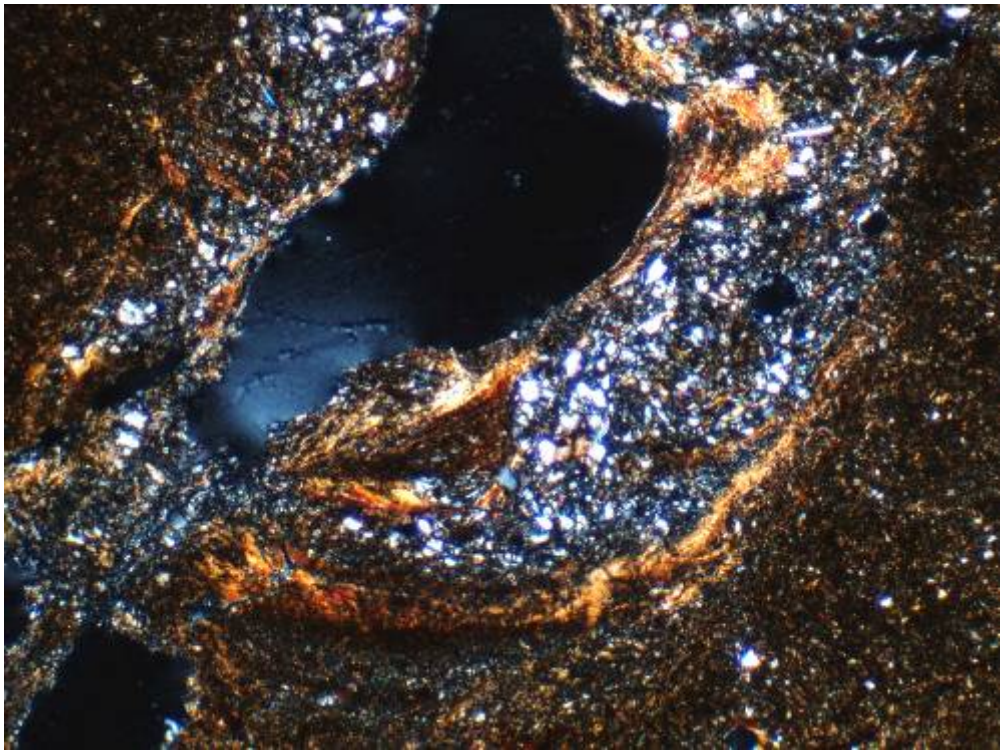
Site 4: Løkkevika (ØF3: age 3000 +/- 250 years): Bg horizon: The soil is silty with greyish fine material and some reddish brown mottles. Most pores have no clay coatings, a few pores have some thin clay coatings. Width of photograph: 2.15 mm, plane polarised light (photo and text: Daniela Sauer).



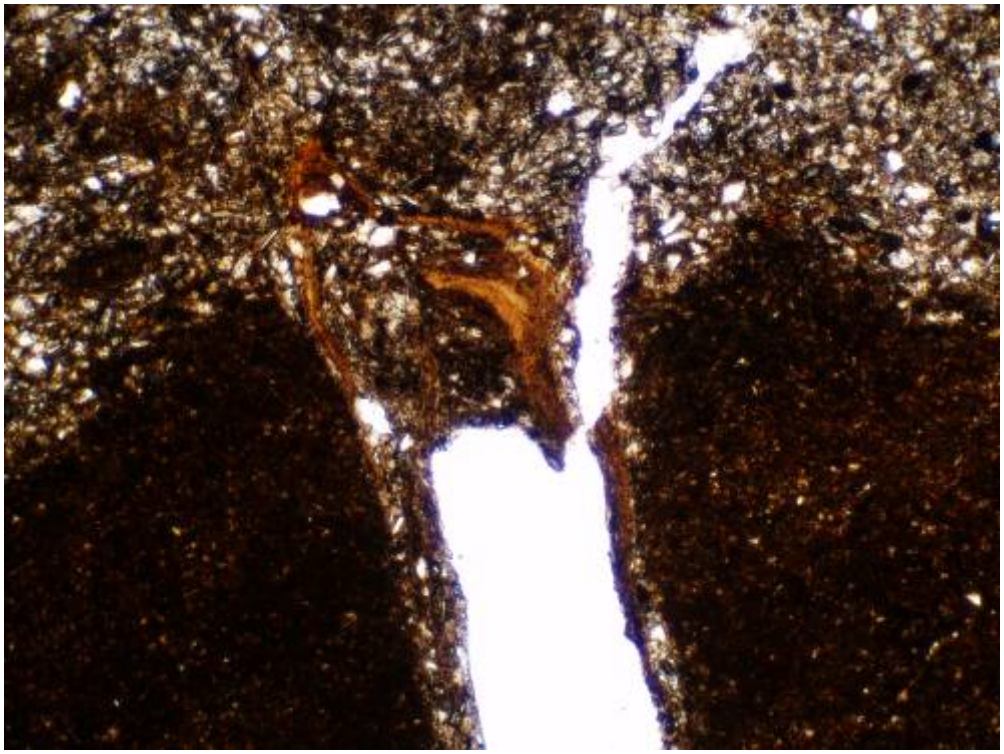
Site 4: Løkkevika (ØF3: age 3000 +/- 250 years): Bg horizon: The soil is silty with greyish fine material and some reddish brown mottles. Most pores have no clay coatings, a few pores have some thin clay coatings. Width of photograph: 2.15 mm, crossed polarisers (photo and text: Daniela Sauer).



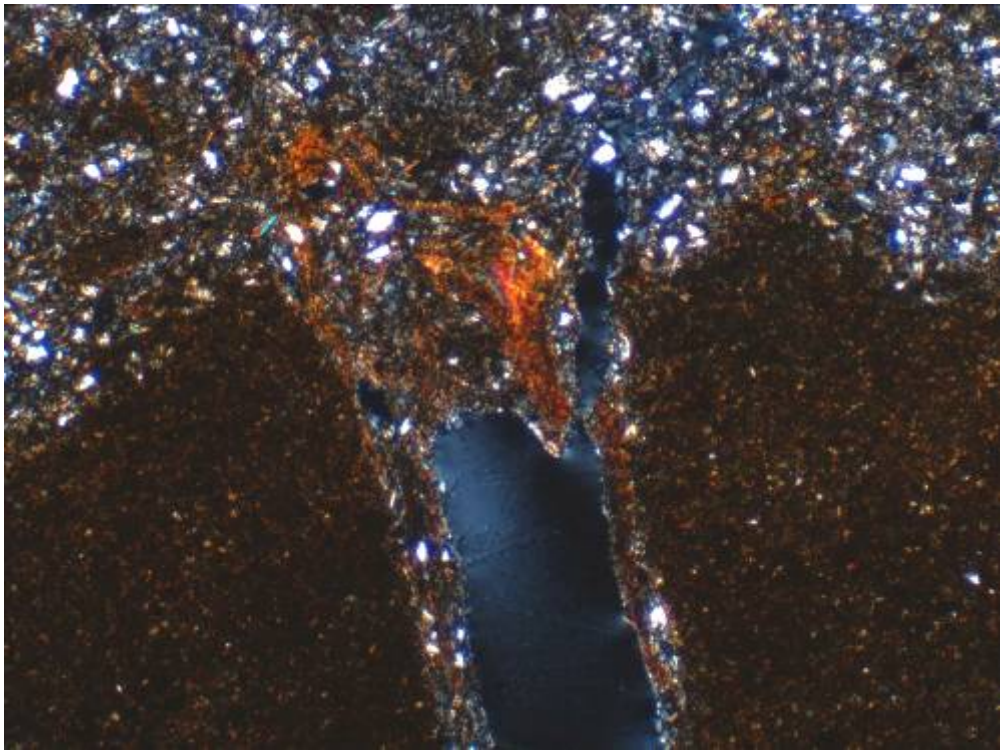
Os kirke (ØF8: age 9750 +/- 150 years): E/Btg horizon: White silt and illuvial clay in a crack in the Btg material. Width of photograph: 2.15 mm, plane polarised light (photo and text: Daniela Sauer).



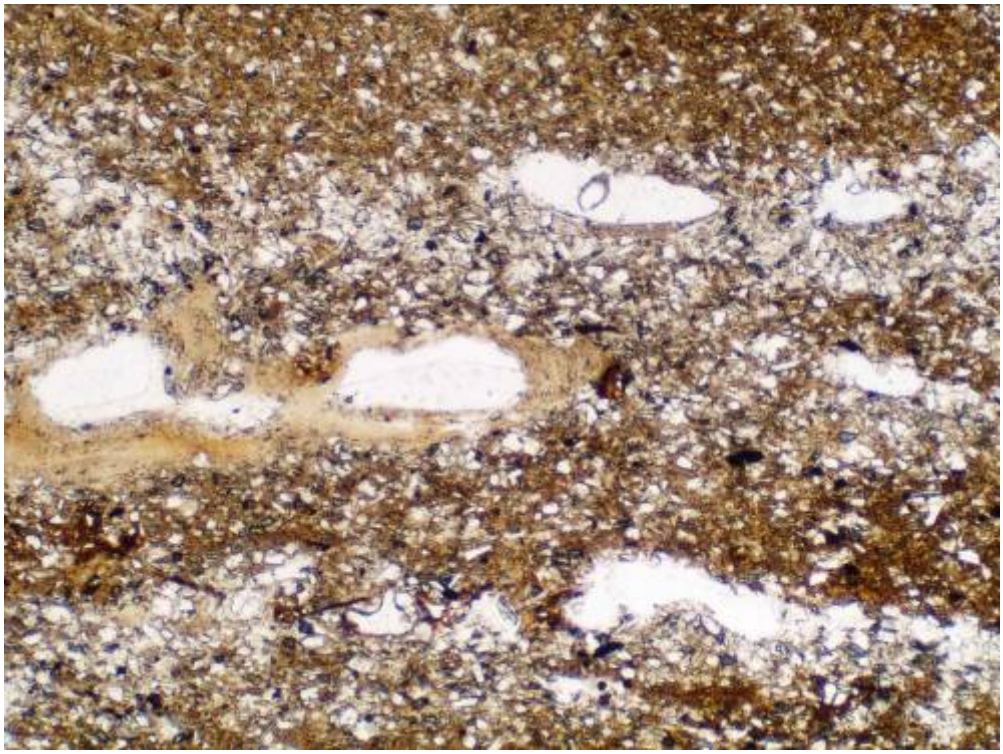
Os kirke (ØF8: age 9750 +/- 150 years): E/Btg horizon: White silt and illuvial clay in a crack in the Btg material. Width of photograph: 2.15 mm, crossed polarisers (photo and text: Daniela Sauer).



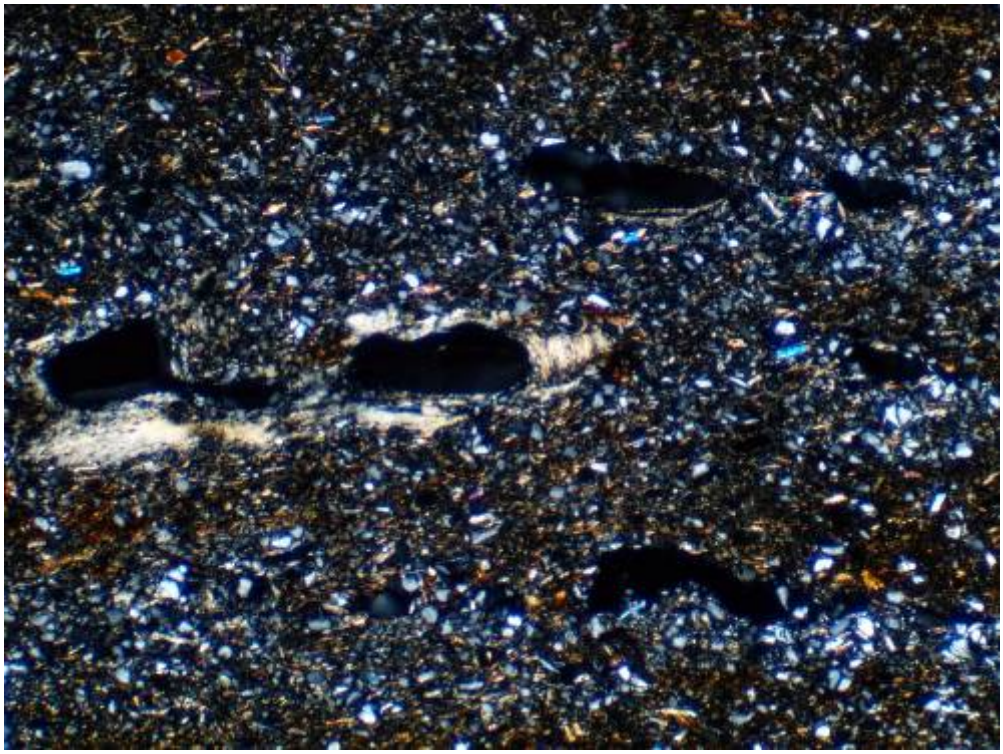
Os kirke (ØF8: age 9750 +/- 150 years): E/Btg horizon: White silt and layers of illuvial clay dropping into crack in Btg material. Width of photograph: 2.15 mm, plane polarised light (photo and text: Daniela Sauer).



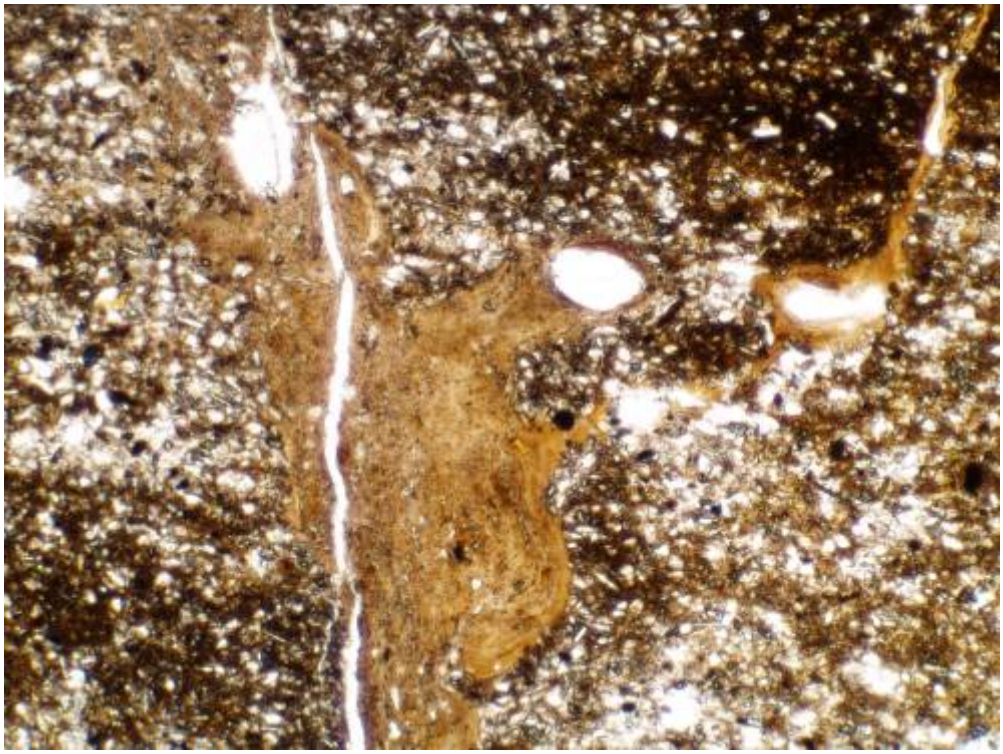
Os kirke (ØF8: age 9750 +/- 150 years): E/Btg horizon: White silt and layers of illuvial clay dropping into crack in Btg material. Width of photograph: 2.15 mm, crossed polarisers (photo and text: Daniela Sauer).



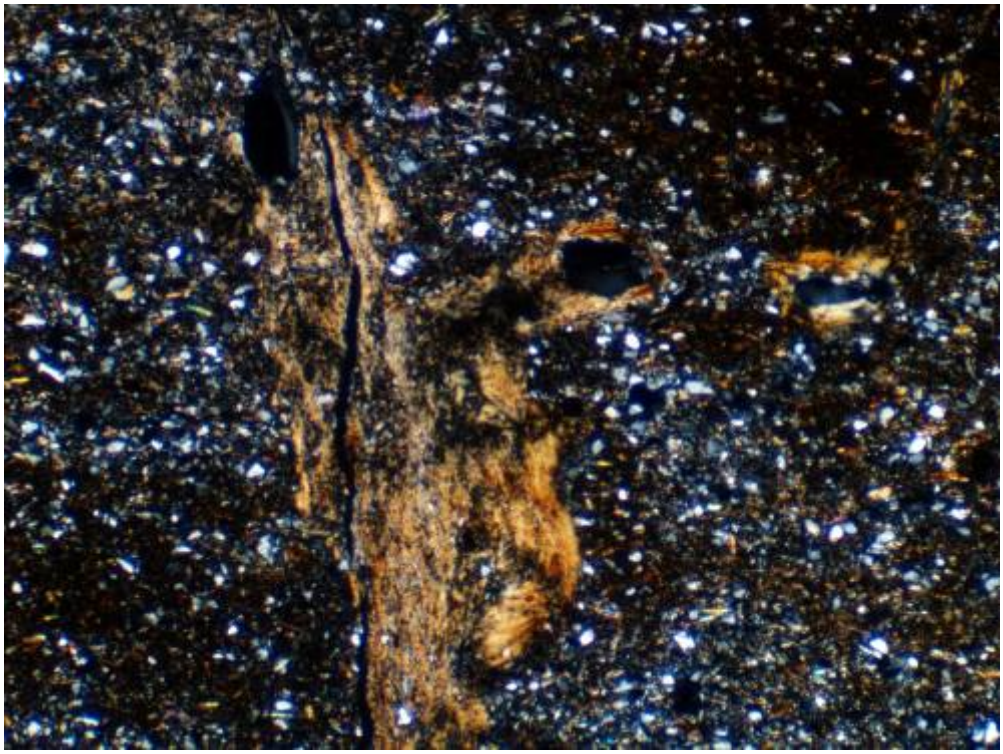
Site 2: Båstad (ØF11: age 11050 +/- 150 years): Btg horizon: Strong clay illuviation around a crack and several channels. Width of photograph: 2.15 mm, plane polarised light (photo and text: Daniela Sauer).



Site 2: Båstad (ØF11: age 11050 +/- 150 years): Btg horizon: Strong clay illuviation around a crack and several channels. Width of photograph: 2.15 mm, crossed polarisers (photo and text: Daniela Sauer).



Site 2: Båstad (ØF11: age 11050 +/- 150 years): Btg horizon: Most (but not all) pores have thick clay coatings. The sediment is clearly laminated. Width of photograph: 2.15 mm, plane polarised light (photo and text: Daniela Sauer).



Site 2: Båstad (ØF11: age 11050 +/- 150 years): Btg horizon: Most (but not all) pores have thick clay coatings. The sediment is clearly laminated. Width of photograph: 2.15 mm, crossed polarisers (photo and text: Daniela Sauer).

3.4. List of participants

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