

# Development of vegetation and human activities on the new emergent coastal areas of northwestern Estonia

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The development of vegetation and agriculture on the uplifting coastal areas of northwestern Estonia was studied with palaeobotanical methods. On the basis of the land-uplift curves the dynamics of new land appearance was reconstructed. From these reconstructions, we could better understand the pollen and macrofossil records, though some taxa often interpreted as anthropogenic indicators (*Ranunculus*, *Rumex*, Chenopodiaceae) are in this case the indicators of pioneer vegetation. The comparison of historical, archaeological and palaeogeographical data from coastal northwestern Estonia demonstrate that the first strong signals about agricultural activity appear in different sections at different time: about AD 292 ± 55 in the northern area and about AD 1080 in the vicinity of Paslepa village.

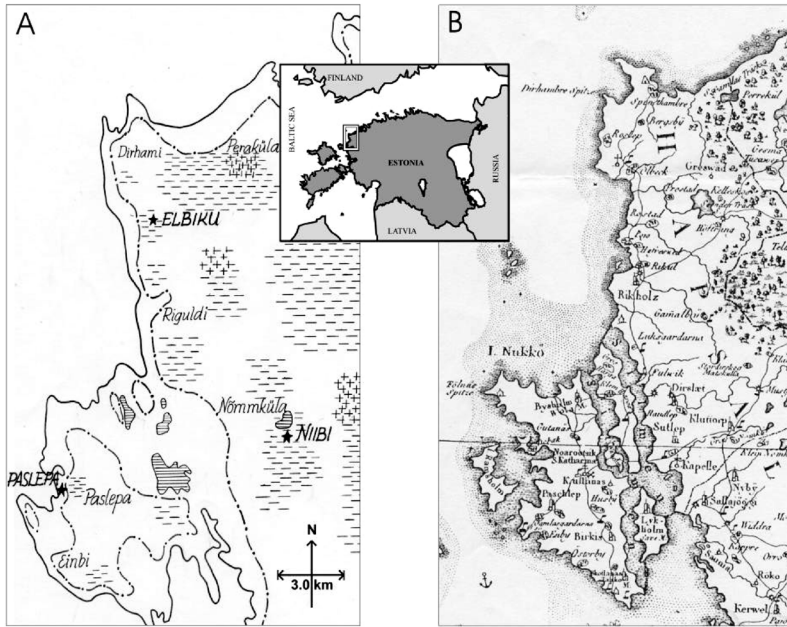
**Key words:** pollen analysis, vegetation history, land uplift, land use history, northwestern Estonia

## Introduction

Palaeobotanical analysis of sediments are widely used in order to reconstruct the development of vegetation and through that detect first traces of human activity in a certain region (Behre 1986, Berglund 1985, 1991, Hicks 1992, Vuorela & Hicks 1995, Poska & Saarse 2003, Zolitschka *et al.* 2003). As a rule the obtained records reflect the evolution of the integrated state of ecosystems that is influenced by both natural biogeophysical and human-induced processes (Koff 1995, Behre 2002, Hannon *et al.* 2005). Recently a new direction of historical ecology has developed that encompasses all the data, techniques and perspectives from palaeoecology, land-use

history from archival and documentary research, long-term ecological research and monitoring. Multiple, comparative histories from many locations can help evaluate both cultural and natural causes of variability and characterize the overall dynamic properties of ecosystems (Swetnam *et al.* 1999, Pärtel *et al.* 1999).

In Estonia, where the prehistoric human impact on landscapes was relatively weak (Poska *et al.* 2004) the findings of reliable traces in palaeoecological data are rare and must be interpreted with caution, especially so on coastal areas where new land is formed due to postglacial uplift. It has previously been pointed out in our investigations on the island of Naissaar (Nargö) in the Gulf of Finland that an important



**Fig. 1.** — **A:** Schematic map showing the location of Estonia and the location of the study area. \* = Location of sampling sites; - - - = coastal line 700 years ago; — = present-day coastal line; ··· = mires; ++ = ancient water bodies. — **B:** Historical map of the study area in 1798 (Mellin Atlas von Liefland oder von den beyden Gouvernemenren und Herzogthümern Lief- und Ehtland und der Provinz Oesel. Riga und Leipzig, 1782–1810).

role in the establishment of pioneer vegetation in new coastal areas was played by edaphic conditions (Punning *et al.* 1998). Also investigations on contemporary islets and coastlines of different stages of development showed this. Colonization of emerging islands by terrestrial biota depends on several factors, among which the most important are distance from the mainland or larger islands; area available for colonization, topography of the nearshore and substrate characteristics (Ratas & Nilson 1997).

In Finland, Hicks (1988) using pollen analysis traced the occupation history of Hailuoto island and found that the configuration of the shoreline and the distribution of new emerged land played an important role in determining the location of settlement. In Sweden, Segerström (1990) noted that an increase of apophytes need not always indicate human activity, as apophytes are typical of landscapes disturbed by flooding, land uplift or forest fires, which also occur in the natural environment. These findings are important to remember in interpreting the pollen diagrams from coastal areas.

Although in recent decades archaeological investigations have expanded in western Estonia, and many interesting artifacts, burial sites and even strongholds have been unearthed (Mandel 2003), these investigations have not until

recently reached coastal northwestern Estonia. Only a few buried finds and burial sites dating from the Early Iron Age have come to light there. During the last years a number of relevant field investigations have been undertaken in order to clarify the vegetation and settlement history and the earliest phase of the Estonian–Swedish colonization in coastal northwestern Estonia. The first archaeological field investigations were made in 1999–2001. Mapping, excavations and dating of landscape elements were carried out in Einbi village (Fig. 1) in order to gain information on the cultivation history, as well as the earliest development of the cultural landscape in terms of observable changes in the landscape use and field system (Markus 2002).

The aim of the present research is to reconstruct the palaeovegetation and agricultural history in northwestern Estonia using new pollen and macrofossil data.

## Geological development of the area and studied sites

The vegetation history and the spatial distribution of primary settlement in northwestern Estonia can to a large extent be understood by following the evolution of the physical landscape in the

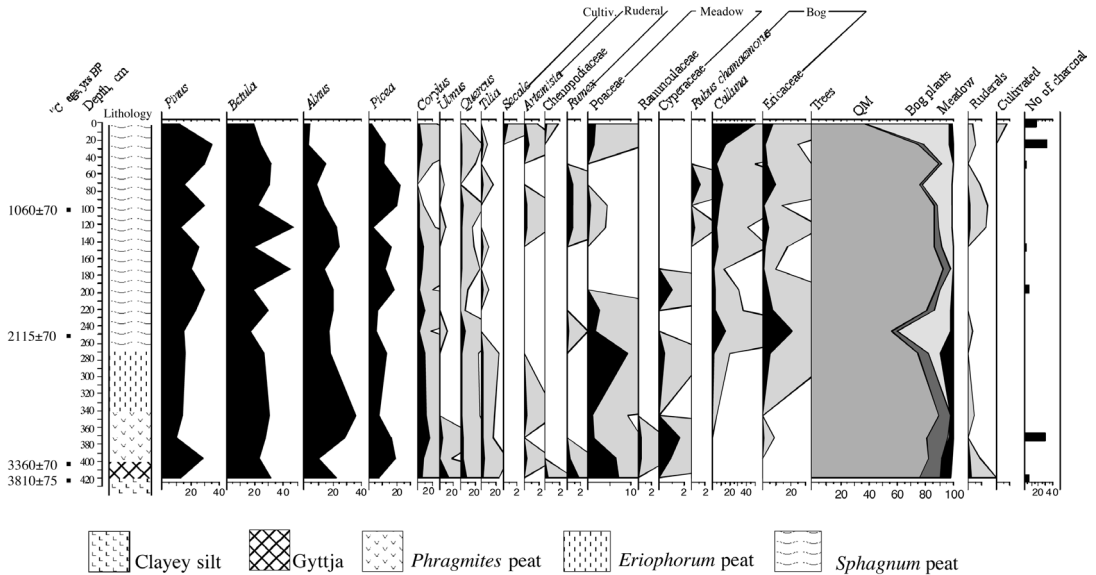


Fig. 2. Pollen percentage diagram from Niibi raised bog.

coastal zone. A wide spectrum of shoreline forms including beach ridges, sandy plains, sequences of lake and bog sediments on different elevations exists here, which tells about a complicated geological history of the area.

Through the land uplift during the Holocene and the changing water level in the Baltic Sea the shoreline has gradually moved north- and westward (Kessel & Raukas 1979, Miidel 1995). As a result, large areas have been added to the mainland and new islands have appeared and continuously widened. The topography of the surface and spatial differences in the rate of vertical movement explain why the dynamics of land emergence in different regions along the coast has varied considerably. Recent studies (Punning & Miidel 2004) showed that the uplift of the last 4000 years consisted mainly of an inherited linear tectonic component and the average rates were close to the present being ca. 2.8–3.2 mm yr<sup>-1</sup>. On the basis of an estimated rate of land uplift, cartographic analysis and field work data, the corrected 2 m isobase was transferred to the digitized topographical map for the studied area (Hoppe *et al.* 2002). Using the land uplift rate of 2.8 mm yr<sup>-1</sup> the 2-m isobase marks the shoreline localisation about 700 years ago (AD 1300). In order to visualize the ancient settlement landscape the coastal line 700 year

ago is given on the bigger area map (Fig. 1A). It can be seen that the area was covered mainly by mires and ancient water bodies. The coastal line 700 years ago and the present-day coastal line differ to a great extent. Former islands and islets became peninsula quite recently as demonstrated by the historical map from 1798 (Fig. 1B).

The vegetation history was studied at three locations and at sites of different size. Pollen and macrofossils were analysed in sediment samples taken from the raised bog of Niibi (Nyby in Fig. 1B) (59°03'55'', 23°40'46''), in the minerotrophic mire of Elbiku (Olbeck) (59°09'40'', 23°32'47'') and an overgrown lagoon at Paslepa (Paschlep) (59°01'37'', 23°28'02'') (Fig. 1A).

The surface of Niibi raised bog (surface area around 1300 ha) (Fig. 1A) today lies 15.6 m above sea level. During the Litorina Sea stage (ca. 7000–4000 BP) of the Baltic Sea (Kessel & Punning 1979) a semiclosed bay existed in this area. In the course of land uplift it was separated from the sea. Traces of significant changes in the past environment are present in sediment stratigraphy: at a depth of 420 cm clayey silt changes into gyttja and at a depth of 400 cm into *Phragmites* peat (Fig. 2). Upward from a depth of 340 cm accumulation of *Eriophorum* peat started followed by *Sphagnum* peat from a depth of 270 cm. On the basis of the lithological composition

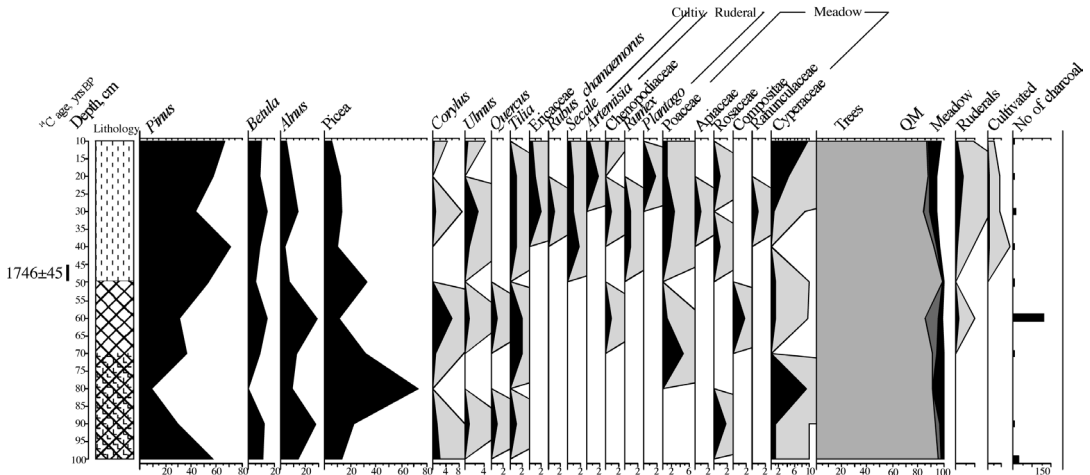


Fig. 3. Pollen percentage diagram from Elbiku mire. The description of lithology, see Fig. 2.

and the first appearance of freshwater diatoms at a depth of 420 cm we estimated the threshold altitude of 11.4 m above present sea level about 1680 BC (Hoppe *et al.* 2002). After that the connection with the open sea disappeared and ancient coastal lake or lagoon developed into a minerotrophic mire and later on into an ombrotrophic bog.

The surface of Elbiku mire (25 ha) (Fig. 1A), situated 14.0 m above sea level at the present, is covered by birch and pine trees. Previously there was an ancient lagoon that was surrounded from the west by a glaciofluvial delta and separated from the Baltic Sea by a spit during the Limnea stage (starting from ca. 4000 BP). In the present time, the depression is filled with lacustrine and peat sediments (Fig. 3). Elbiku mire was studied earlier by Kessel and Orviku (1969). They found that freshwater diatoms appear in the layers above clayey sediments. This transformation indicates the isolation of the lagoon from the Baltic Sea; according to  $^{14}\text{C}$  dating (Ilves *et al.* 1974) this happened  $3800 \pm 60$  BP (ca. 2250 BC) at the threshold altitude of 12.5 m. We studied only the upper part of the sequence accumulated in the depression isolated from the sea (Fig. 3). Basal layers consist of clayey gyttja, which at a depth of 70 cm changes into gyttja, and the uppermost 50 cm consists of *Eriophorum* peat.

Paslepa mire (surface 10 ha) lies ca 2.5 m above the present sea level and is an overgrown lagoon (Fig. 1A). The vegetation type around the

site is typical of shallow shore, consisting mainly of the reed *Phragmites australis*. In the studied sequence the bottom layers consist of clayey gyttja that changes into detritus gyttja at a depth of 75 cm. *Phragmites* peat makes up the uppermost 50 cm. The sediment stratigraphy (Fig. 4) indicates about a complicated evolution of the shoreline where the higher and lower water levels alternated forming a complex of lacustrine and paludified sediments. The water level of the coastal sea fluctuates nowadays on average  $\pm 1$  m. Taking into account the low and flat relief of this area it means that quite large areas on the coast are temporarily flooded.

## Methods

The samples for pollen and macrofossil analyses were taken from central parts of the studied sites with a sampler of Russian type. The sediment cores were wrapped in plastic and stored in a freezer. For pollen analysis 1 cm block samples were treated with 10% KOH followed by standard acetolysis according to Moore *et al.* (1991). In general, at least 500 arboreal pollen grains were determined under a microscope. The percentage pollen diagrams were constructed with the Tilia, Tiliagraph and TGView programs on the basis of total terrestrial pollen, using the sum of arboreal and non-arboreal pollen (Grimm 1990). Charcoal pieces longer than  $100 \mu\text{m}$  were counted from the

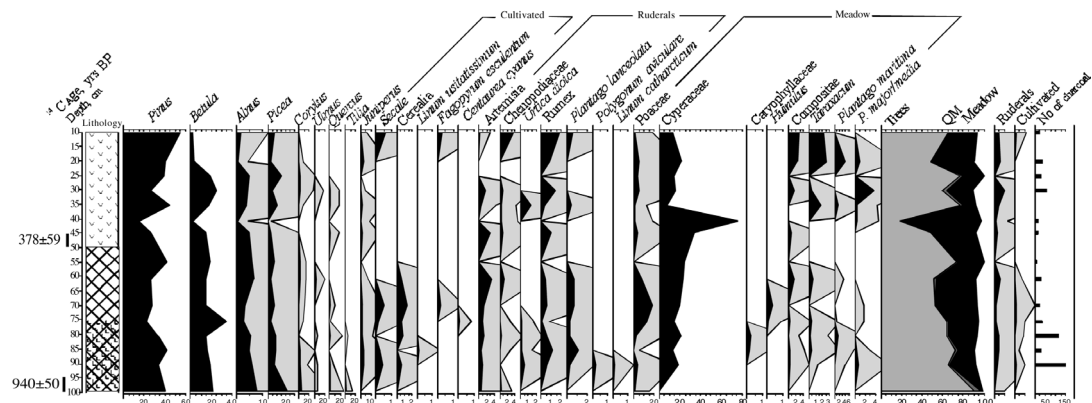


Fig. 4. Pollen percentage diagram from Paslepa mire. The description of lithology see Fig. 2.

pollen slides and are presented on the diagram as the number of charcoal. Pollen and spore nomenclature follows Moore *et al.* (1991).

The land-use indicator taxa were grouped on the basis of pollen into three main categories following Behre (1981), Berglund (1991), Berglund and Ralska-Jasiewiczowa (1986) and Koff (1995). Pollen of *Secale cereale*, Cerealia (which includes *Triticum*, *Avena* and *Hordeum* types), *Fagopyrum esculentum*, *Linum usitatissimum* and the weed *Centaurea cyanus* belong to the group indicating cultivated land.

The second group consists of Chenopodiaceae, *Artemisia*, *Plantago* (*P. major/media*), *P. lanceolata*, *Urtica dioica*, *Rumex* (*R. acetosa/acetosella* type) *Polygonum aviculare* and *Linum catharticum* pollen. Many of these plants are usually included in the group of ruderals but they are also common in natural communities (Behre 1981, Vorren 1986). Especially seashore vegetation and its relative indication value can be different in different situations. Botanist H.-E. Rebassoo (1975) studied vegetation on 600 small Estonian islands and found that Chenopodiaceae, *Artemisia*, *Plantago lanceolata*, *Urtica dioica* and *Rumex acetosa* are the most widely distributed plants on newly emerged islands.

The third group of taxa indicates pastureland and meadows and contains Cyperaceae, Poaceae, Caryophyllaceae, Compositae (Asteraceae + Cichoriaceae), Apiaceae, Ranunculaceae, Fabaceae, *Trifolium*, Rosaceae, *Melampyrum*, *Galium* type and *Saxifraga*. Pollen of Cyperaceae might indicate also the minerotrophic phase of bog evolution.

Samples from the Paslepa site were also subjected to macrofossil analysis. Samples were dispersed in water and washed gently through a sieve of mesh aperture of 0.25 mm. Residues were dispersed in water and examined on a white plate under a stereomicroscope. All seeds and fruit and other remains were picked up and identified with a reference collection and manuals for seed descriptions (Beijerinck 1947, Katz *et al.* 1977, Birks 1980, Grosse-Brauckmann & Streitz 1992). The results are presented as the number of macrofossils per 100 cm<sup>3</sup>.

The dating of the bulk samples (Table 1) was done in the radiocarbon laboratory of the Institute of Geology at Tallinn University of Technology using the standard scintillation technique. The Niibi and Paslepa cores were dated by macrofossils on the AMS device in the Ångström Laboratory, Uppsala University. Calibration of the radiocarbon ages to calendar years BP was done using the age calibration program of Stuiver *et al.* (1998). As <sup>14</sup>C data from the Paslepa and Elbiku sites were made earlier using a conventional method without isotope fractionation corrections their calibrated ages might be incorrect (Table 1).

## Results

According to the radiocarbon dating the pollen diagram from the Niibi site (Fig. 2) covers the time interval since 3810 BP (2250 BC) (Table 1). During the initial stage of the formation of lacustrine sediments at a depth of 420 cm *Pinus*



and *Betula* pollen dominate (up to 30%). *Picea* pollen is represented in lower values (up to 20%). The content pollen of *Alnus* and of broad-leaved trees is around 2% in the samples from depths of 420–400 cm.

From a depth of 400 cm upward the lagoon started to overgrow as evidenced by *Phragmites* peat and *Eriophorum* peat in layers up to a depth of 270 cm (Fig. 2). At a depth of 270 cm (about 130 BC) the transition of the minerotrophic fen to an ombrotrophic bog took place as testified by the formation of *Sphagnum* peat and appearance of *Calluna* and Ericaceae pollen in the sediments (Fig. 2). The content of cultivated and ruderal plant pollen was very low through most of the sequence. A certain increase occurred in *Rumex* and *Artemisia* pollen in the layers from 80 to 120 cm. *Secale* pollen appeared only in the uppermost layers accumulated during the last 100 years. Chenopodiaceae pollen appears at the early stage of the development of the ancient lagoon, indicating the appearance of plant associations connected with sea-shore vegetation (Laasimer 1965, Rebasoo 1987). In the upper part of sequence, Chenopodiaceae pollen occur together with the appearance of Cerealia pollen characteristic of plant associations connected with human activities (Kukk 1999).

In the Elbiku pollen diagram (Fig. 3) the maximum of *Picea* pollen is well expressed at a depth of 80 cm where it reaches up to 70%. There is a sharp depletion in the content of *Picea* pollen at a depth of 60 cm (Fig. 3). At the same

depth also the highest numbers of microscopic charcoal were found. This leads to the assumption that the forest in the surroundings burned, maybe due to human activities. Spruce is a rather demanding tree species with respect to soil fertility, and so many ancient fields were established instead of spruce forests. This assumption is supported by the appearance of *Secale* in sediments at a depth of 45 cm accompanied by an increase in the diversity of other pollen types and an increase of pollen of the ruderal group of plants. This all supports the conclusion about the presence of permanent human settlement and indicates the beginning of agricultural activity in the area around 1745 BP (cal AD 292 ± 55) (Fig. 3 and Table 1).

The Paslepa pollen and macrofossil diagrams cover the last 1000 years (Fig. 4). *Pinus* pollen dominated over the whole sequence with up to 60%. The *Betula* pollen maximum is 40% in samples from a depth of 78 cm. *Alnus* and *Picea* had values around 10%. The content of different types of herbaceous pollen is high. Poaceae pollen has a maximum of 20% at a depth of 70 cm. The content of Cyperaceae pollen is highest at a depth of 40 cm where *Phragmites* peat was formed. The first indicators of human impact — *Secale* and Cerealia pollen — were found at a depth of 90 cm (layer accumulated about AD 1080) while at a depth of 85 cm pollen of *Linum usitatissimum* appeared. The number of charcoal particles also increased in samples from a depth of 85–80 cm. At a depth of 90 cm pollen

**Table 1.** Radiocarbon dates from the Niibi, Elbiku and Paslepa sequences. The radiocarbon dates obtained by the AMS method were calibrated using CALIB 4.3.

Site	Sample depth (cm)	Lab. number	Macrofossils dated	<sup>14</sup> C age (yr. BP)	δ <sup>13</sup> C (‰ PDB)	Cal AD/BC
Niibi	103	Ua-16570	<i>Pinus sylvestris</i> (TR)	1060 ± 70	-29.5	AD 980
Niibi	253	Ua-16571	<i>Betula pubescens</i> (F&CS)	2115 ± 70	-27.4	130 BC
Niibi	403	Ua-16572	<i>Betula pubescens</i> (F&CS), <i>Picea abies</i> (N)	3360 ± 70	-28.0	1680 BC
Niibi	423	Ua-16573	<i>Betula pubescens</i> (F&CS), <i>Pinus sylvestris</i> (TR)	3810 ± 75	-28.7	2250 BC
Paslepa <sup>1</sup>	45–50	TIn-2619	<i>Phragmites</i> peat	378 ± 59	–	AD 1537 ± 60
Paslepa	98	Ua-19021	<i>Potamogeton</i> seeds	940 ± 50	28.1	AD 1080
Elbiku <sup>1</sup>	45–50	TIn-2569	Wooden peat	1746 ± 45	–	AD 292 ± 55

N = needles, F&CS = fruit and catkin scales, TR = tissue remains.

<sup>1</sup> Note that <sup>14</sup>C data were obtained by the conventional method without isotope fractionation corrections and therefore their calibration is not correct.



coastal north-western Estonia numerous bays and lagoons became isolated, and terrestrialized. In some of them accumulation of gyttja and peat started already about 2300 BC. Depending on the emergence of land and formation of suitable edaphic conditions the development of natural vegetation as well as permanent human settlement became possible. In the interpretation of pollen data it is necessary to take into account that the establishment of plant associations on the newly formed coastal areas has some specific features and many plants that are regarded as ruderals or pastureland indicators are also recognized as pioneer species on the shore.

For example, comparison of the pollen diagrams from the Niibi and Elbiku sites reveals that the development of the mires and the local topography play an important role in the formation of the vegetation and pollen spectra. Niibi is a large bog and the pollen diagram reflects the vegetation history on a broader regional scale as seen from the stable values of pollen of the main tree species (Fig. 2). The contents of *Ranunculus*, *Rumex* and *Chenopodiaceae* pollen in the samples from depths of 420–400 cm indicate the development of shore vegetation around the isolated lagoon in the course of land uplift. The wide distribution of minerotrophic fens in the studied area and regular flooding of the newly emerged lands (Fig. 1) are reflected in the pollen diagram as the increase in *Cyperaceae* pollen while the increase in *Calluna* is connected with the change to an ombrotrophic bog (Fig. 2). The appearance of cultivated herbs in the upper layers indicates that intensive agricultural activities were pursued in the area only during the last centuries.

In the studied area the fields are distributed as small patches in topographically higher places and are mostly surrounded by forest even at present (Leet 1998). Extensive spread of pollen of cultural herbs from such patches was limited as shown earlier (Koff & Punning 2000). Thus to prove traces of primary agriculture in this area is complicated. An indirect proof of human presence at the Elbiku site is the decrease in the *Picea* pollen content at a depth of 60–70 cm and the increase in the number of charcoal particles at a depth of 60 cm together with the appearance of *Chenopodiaceae* and *Compositae* pollen (Fig. 3). This may refer to a fire and an

opening in the forest due to human activity in the area. In layers accumulated around AD 292 ± 55 (depth 45–50 cm) a strong signal of agricultural activity documented as appearance of *Secale* was found. According to the archaeological time scale (Jaanits *et al.* 1982, Lang & Kriiska 2001) it might be related to the Roman Iron Age. That is the period when all over Estonia agricultural activities started to expand together with the growth of human population and expansion of settlement areas, which took place also in north-western Estonia (Mandel 2003).

The sedimentation at the Paslepa site started around AD 1000 (Fig. 4). In pollen and macrofossil records ruderal plants are represented indicating both the establishment of coastal vegetation and influences of human activities. Appearance of the indicators of human impact *Secale*, *Cerealia*, *Linum usitatissimum* and *Plantago lanceolata* testifies local and small-scale cultivation, possible slash and burn cultivation and extensive animal husbandry during the last 1000 years. The first sign of the beginning of agriculture is the appearance of rye and flax pollen AD 900–1300 (Fig. 4 and Table 2). The finding of single pollen grains may refer to long-distance transportation, but here the presence of seeds of the weeds such as *Polygonum aviculare* and *P. lapathifolium* as well as of *Ranunculus flammula* and *Ranunculus* spp., confirms the closeness of the farming area to the study site. Pollen and macrofossil analysis also clearly demonstrates the period when the fields were abandoned as pollen of cultivated plants and other ruderals decreased.

As a result of archaeological investigations it has been concluded that a clear cultivation period, manifested as an intensive phase of clearing and settlement, occurred in the 10th–13th centuries (Markus 2002). Hoppe (2001), judging from the oldest map material from the end of the 17th century, pointed out that many villages were laid waste during the Livonian wars in the 16th century and were later rebuilt. After this interception another period where traces of land cultivation occur again in the upper layers of sediments started a few centuries ago. However, the abundance of indicators was much lower than during the first period, though relatively intensive agricultural activities were taking place in the vicinity.



**Table 2.** Historical, archaeological and palaeogeographical data from coastal northwestern Estonia.

Time	Historical data (Markus 2002)	Archaeological data (Mandel 1993, Hoppe 2001)	Palaeoecological data (this study)
2000 BC	–	–	Isolation of Niibi and Elbiku sites from the Baltic Sea
AD 200		Roman Iron Age burial sites and artefacts	First rye pollen grains in Elbiku site
AD 900–1300	First written records about Swedes in area, 1294	AD 890–1290 — intensive phase of clearing and settlement in a forested environment dominated by spruce and pine	Appearance of rye and flax pollen at the Paslepa site. Increase in charcoal content
AD 1300–1500	Nucke (Nukkö) island first mentioned in 1391	Two records from AD 1300–1490 of Einbi indicate that the village was constantly inhabited	Appearance of rye, barley and buckwheat pollen together with weed seeds at the Paslepa site
AD 1500–1600	According to the register of holdings and taxes Einbi had 11.5 ploughland units in 1550	Farms were abandoned during the Livonian War (1558–1583)	Decrease in cultivated plant pollen and other ruderals, also in the amount and variety of other herbs at the Paslepa site
AD 1600–1900	Paslepa's population in 1850 was 493		Appearance of pollen of cultivated plants in Paslepa and Niibi sites

## Conclusions

The obtained results of palaeoecological studies on the coastal areas with a permanent uplift demonstrate that topographical data combined with landscape studies and archaeological investigations are important for understanding the development of the vegetation and evaluating both cultural and natural causes of variability and characterizing the overall dynamic properties of ecosystems.

Comprehensive methodology of historical geographical research allowed us to reconstruct topographic maps for different time slices and so to better understand the temporal changes of the landscapes. In the interpretation of pollen data, it is necessary to take into account that the plant associations formed on the newly emerged coastal areas have some specific features, and many plants that are regarded as ruderals or pastureland indicators are also recognized as pioneer species on the shore. Especially the contents of *Ranunculus*, *Rumex* and *Chenopodiaceae* pollen indicate the development of shore vegetation around an isolated lagoon.

The first strong signals about agricultural activity in the northwestern coastal area in Esto-

nia appear in different sections during different time: about AD 292 ± 55 in the northern area and about AD 1080 in the vicinity of Paslepa village. Landscape characters, caused by land uplift, made intensification of agricultural activity possible.

## Acknowledgements

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