Implications of Accelerated Sea-Level Rise (ASLR) for Estonia:
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Sea-level rise is one of the key problems that should be taken into consideration in climate change impact assessments for Estonia. Accelerated sea-level rise may strongly affect the territory of Estonia because it has a relatively long coastline of 3,794 km (total country size comprises only 45,227 km²) and extensive low-lying coastal areas. Due to isostatic land uplift, the coastal zone has constantly been emerging during the whole Holocene period. At present, the annual rate of uplift ranges from 1.0 to 2.8 mm with the maximum uplift occurring on the north-western coast (Vallner et al., 1988). Consequently, a possible sea-level rise would be partly mitigated by land uplift in Estonia but still remains a serious potential hazard worthy of attention (Kont et al., 1996a, 1996b, 1997).

According to the MAGICC climate change scenario (Model for the Assessment of Greenhouse-gas Induced Climate Change) results, projected values of sea-level rise for the year 2100 are range between 32 and 56 cm on average with a maximum projection of 95 cm (Hulme et al., 1995). The potential consequences of a 1.0 m sea-level rise scenario have been analysed for Estonia. This value was chosen for two reasons: 1) to include the effect of possible biases of the model, and 2) the lower scenarios would not have a noticeable effect in Estonia because of the current isostatic land uplift. The projection of the sea-level rise by 1.0 m for the present century was also recommended by the U.S. Country Studies Program (Benioff et al., 1996) in which Estonia participated. The coastal zone vulnerability and adaptation assessment using the IPCC Common Methodology recommended by the US Country Studies Program was carried out in four case study areas in different parts of Estonia in 1995/96. Later, within the framework of local climate change programs, the study areas were subjected to more detailed analysis. Three sites were added for a better representation of the whole coastal zone of Estonia. To achieve comparable results, the same methodology was applied for all seven study areas.

Estonia is rich in different geomorphic types of coasts. According to the tilt of the primary relief, the geology, and prevailing shore processes, eight shore types have been distinguished by Orviku (1992): cliff shore, scarp shore, rocky shore, till shore, gravel shore, sandy shore, silty shore, and artificial shore. The seven study areas (Hiiumaa, Pärnu-Ikla, Matsalu, Tallinn, and 3 sites in northeast Estonia) contain all the listed shore types and the different types of ecosystems characteristic of the coastal zone of Estonia. The study sites are used by man in different ways and represent all kinds of coastal settlements. Thus on the basis of detailed analysis of the study areas, it is possible to generalise the results over the whole territory of the country.

Detailed measurements were made using large-scale (1:25000) topographic and geomorphic maps and calculations according to the Bruun Rule along the coastline at 200 m intervals. There were two major problems in using the Bruun Rule: (1) the Estonian coasts are too shoaly to apply the method without corrections, and (2) the overfill ratio which is 1.0 for sandy shores had to be approximated for the other shore types. Based on the measurements, calculations, and field observations, new coastline positions were drawn on topographic maps. Field observations were used to compare possible coastline changes obtained by the Bruun Rule with existing situations, and to make corrections where necessary. Two different coastline positions were drawn, depending on either normal weather conditions or potential storm surges. Both zones were subjected to inventories of land loss and temporary damages. Data on water-level fluctuations and storm surges were obtained from the meteorological and sea-level observation stations, which were located in the study areas. Tides are negligible in the Baltic Sea. The data from isostatic land uplift measurements were taken into account in land loss estimates, i.e., in every study area.

All of the potential loss from inundation and storm surge zones was calculated according to average prices in Estonia in 1996. Three different types of losses were accounted in monetary values: cost of submerged and temporarily damaged land; cost of actual existing properties in these two zones; and profit, theoretically missed from the damaged meadows and forests. The overall price of potential loss for the whole coastal zone of Estonia was calculated by multiplying the prices of study areas by four (the coastline length of the study areas provides 25% of the total coastline length of Estonia), and adding the prices of losses in the coastal cities. Loss estimates for Hiiumaa indicate that 100% of reed beds and 80% of coastal meadows including rare saline plant communities are in direct danger. The very unusual ecosystems of numerous lagoons and calcareous meadows, rich in orchids, on the northwestern coast of Hiiumaa would completely disappear.

Although dikes protect 1/3 of the coastline of Tallinn, the capital city of Estonia, the possible damages here would be greatest compared to the other study areas. The Paljassaare Peninsula would represent over one half of the potentially submerged area of Tallinn. It has no significance as a dwelling district. Most damage comes from industrial enterprises and land loss.
There are two most vulnerable areas in northeast Estonia. One is the easternmost part of the study area between Narva-Jõesuu and Meriküla that is an important recreation site with excellent sandy beaches. The other site of great risk is Sillamäe, an important industrial centre where the dumping basin of the former uranium enrichment plant is still the greatest threat to the environment of the coastal plain and the Gulf of Finland.

The Matsalu Bay study area is the most vulnerable to sea-level rise in Estonia. A 1.0 m sea-level rise would inundate over 76 km$^2$ of the territory including the whole reed bed and most of the flooded meadows. This coastline recession is the longest (6.4 km) in Estonia. Several plant communities and biotopes of rare species, including unique orchid species, would disappear. At the same time new wetlands would be created as a result of elevated groundwater tables. The primary problems of the Pärnu-Ikla study area are the socio-economic impacts, particularly the protection of recreational areas. Pärnu is the most vulnerable city to the rising sea. During the most recent strong storms, the waves have reached many dwellings up to 300 m inland.

Generally, the climate change scenarios predict the same kind of climatic conditions that have been observed in Estonia during the Holocene climatic optimum. The Atlantic climatic stage 4800-7800 years ago can be observed as an analogue for the future climate (Punning and Koff, 1996; Kont et al., 1996a). During that time, vast coastal areas of contemporary Estonia were below sea-level. Therefore, flooding will be very probable in the conditions of significant climate warming. At the same time no future scenario can be directly taken over from the past.

The season most vulnerable to climate warming will be the winter. Temporal variability of winter temperature is more than two times higher than during the other seasons. The increase in temperature and precipitation in winter are the most probable changes caused by climate warming. Mild winters are connected with the increase in intensity of cyclonic activity and frequent winter storms. Due to a lesser extent of sea ice, the stronger erosion of seashores can be predicted in Estonia. It is easy to presume that mild winters will be followed also by earlier springs.

Although a slow uplift of the earth’s crust is occurring, there has been erosion of sandy beaches almost everywhere in Estonia in recent decades and in some places the sea is advancing again. In autumn and winter, the westerly and south-westerly storm winds raise the sea level up to 2.0 m above its summer level. As there is little evidence of a rising sea over this period, beach erosion appears to be largely due to the recent increased storminess in the eastern Baltic Sea.

Fig. 1. Location of study areas (a) and isobases (b) of annual rates (mm/year) of vertical land movements in Estonia (Vallner et al., 1988). Study areas: 1 = Hiiumaa; 2 = Tallinn; 3 = Kaesmu - Vergi; 4 = Toolse - Aseri; 5 = Sillamaee - Narva-Jõesuu; 6 = Matsalu Bay; 7 = Pärnu - Ikla.
To prevent coastal land loss, some options, which could be applied in Estonia, are the construction of seawalls and beach nourishment. These are well known techniques and have been extensively discussed in the context of sea-level rise (Nicholls et al., 1995). It is obvious that the cities at risk, such as Tallinn, Pärnu, Kuressaare, Haapsalu, Kärdla, Sillamäe, and Narva-Jõesuu would need to be protected by seawalls and dikes. Most of the harbours need upgrading. As for the West Estonian Archipelago and the West Estonian Plain, the most useful option to preserve unique and valuable natural ecosystems would be the hardening of headlands to avoid coastline straightening. This method can be applied in the areas where we have nothing to lose on the shores of bays behind the headlands. Hardening of headlands will result in much stronger erosion of bays. In the areas where this option is not applicable losses of unique ecosystems seem to be inevitable.

As the coastal villages in Estonia are usually located at a distance from the shoreline today, there are only a few areas where retreat would be the most reasonable adaptation option.

For conclusions and future plans the following should be added: Relatively long coastline and predominance of low-lying coastal areas full of shoals make the territory of Estonia highly vulnerable to accelerated sea-level rise. Although isostatic land uplift partly mitigates possible consequences of the rising sea, it still remains an area with potential hazard worthy of serious attention. The diverse structure of Estonia's coasts, quickly changing shoreline positions, and great number of small islands extremely complicates reliable predictions in the case of climate warming and sea-level rise. For that purpose, a new original methodology applicable to the pointed out conditions must be elaborated and verified in the study sites of different types of coasts. Integrated coastal zone management that should be started in the nearest future in our country can be based on trustful forecast of coastal zone responses to the rising sea.

References


