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(Short version of the Swedish report)

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Summary

To estimate the natural protection around the coast of Scania, a survey was conducted, estimating the amount of sand between the coastline and infrastructure for the sandy beaches of Scania. Out of the almost 200 km long sandy coast of Scania, more than half of the coastline had more than 300 m^3 sand per meter coastline in front of the infrastructure, constituting a good protection. Out of the remaining sandy coast of Scania, 23 % had between 150 to 300 m^3 sand per meter coastline, while only 22 % of the coast had less than 150 m^3 sand per meter coastline.

Furthermore, parts of the coast where infrastructure was lacking at least 300 meters inland from the coastline were identified. These parts of the coast could likely be left to fluctuate naturally, and serve as retreat areas. Out of the almost 200 km long sandy coast of Scania, around 70 km lacked infrastructure within 300 meters from the coast, and another 30 km of the coast partly lacked infrastructure. It is of great importance to keep the coastal areas without infrastructure close to the coastline free of infrastructure, so that the coastline can be left to fluctuate naturally.

Introduction

Discussions on how and where to build, and how to protect existing buildings and other infrastructure in a changing climate are ongoing, particularly regarding sea level rise. A high exploitation pressure and high nature values along the coast results in opposing interests. Extreme weather the last couple of years, and climate scenarios predicting sea level rise highlights the importance of how to administer the coast now and in the future.

Sandy beaches are dynamic and the coastline fluctuates over time. These processes, with erosion and accumulation of sediments along sandy beaches, are natural processes. Erosion is not a problem in itself, but can become so if infrastructure or buildings are located too close to the coast. However, sand dunes or other larger sandy areas along the coast can act as a natural protection for the infrastructure.

Sea level rise will in several places increase the erosion, resulting in a more severe retreat of the coast than the sea level rise itself causes. These collaborating effects on sandy parts of the coastline could lead to major problems in areas where infrastructure is located close to the coastline. Due to the latest years storms and extreme weather events, in combination with sea level rise, the costal municipalities and property owners plan for different arrangements to protect properties and infrastructure. To be able to make legitimate decisions about how to handle, and if to handle, erosion we need more knowledge about the processes influencing erosion, and how the processes will change with climate change. Within Building with Nature Work Package 3, the County administrative board of Scania (Länsstyrelsen Skåne), developed a planning material aiming to support physical planning of exploitation near the coast and planning of shore protection to avoid effects of erosion along the coast.

In this project we aimed to investigate the coast to find locations suitable for planned retreat and ecosystem based solutions to handle the problems with erosion. We have quantified the volume of sand present between the coastline and buildings or infrastructure along sandy beaches in Scania. A large volume of sand between the coastline and buildings and infrastructure could work as a natural protection for the buildings and infrastructure, and with quantification of the volumes of sand, protection by the sand could be estimated. Further on, we identified parts of the sandy coast where buildings and infrastructure were lacking at least 300 meters inland from the coastline. These areas lacking infrastructure could potentially serve as retreat areas where the coastline could fluctuate naturally.

The results of the project are presented in a report, and in a map feature that is available through our webpage http://www.lansstyrelsen.se/skane (both in Swedish, Länsstyrelsen Skåne, 2018).

Methods

A previous study of the coast of Scania by the Geological Survey of Sweden (Sveriges Geologiska Undersökning, SGU) mapped the areas around the coast to get a geological basis of the land. Based on the soil type of the land and sea, sediment dynamics and terrain conditions, the erosion, present and future, around the coast was estimated (Malmberg Persson et al. 2016). Based on the material by SGU, we focused on the coastline classified as sand or gravel beaches. Along these parts, we defined areas between the coast and buildings or other infrastructure on land, that consisted of sand. Rarely, buildings connected to camping sites, conference or golf establishments were included in the areas defined as sandy areas, if they are remote from populated areas. Sandy areas were identified for the entire coast of Scania, and resulted in 130 sandy areas.

The volume of sand between the sea and buildings and other infrastructure can serve as a protection. Several factors impact how good of a protection the sand constitute, the most direct being the volume of sand. Hence, we estimated the volume of sand in the areas between the sea and infrastructure. Estimations of sand volume is based on elevation data from the year of 2010. As sand moves rapidly, a 50 meters buffer into the sea was included in the sandy areas to avoid missing sand present when the elevation data was collected. Using ArcGIS 10.3, the volume of all sand zero meters above sea level was calculated. To get a regional comparable measure of the amount of sand, we report the volume of sand per meter coast. The coast can be of different length depending on how detailed it is measured. To get a comparable length we used an outstretched coastline.

It is neither reasonable nor possible to keep the entire coastline intact. Therefore, we need to make a priority on which parts of the coastline to protect and which parts we can leave, and let develop freely. As an early study of which parts of the beach that could be left for free development, we looked at areas of possible retreat. We identified areas without villages or other populated areas with several buildings aggregated, or other important infrastructure, within 300 meters from the coast.

For 24 out of the 130 areas defined in this study, the erosion was defined as severe in the study by SGU (Malmberg Persson et al. 2016). For those areas we did some further analysis to evaluate the protection for erosion that the sand present constituted for the buildings and infrastructure behind. We classified indications of protection measure index and vulnerability of the areas, based on table 1.

Table 1.

Assessment of an example beach			
Length (m)	750		
Volume (m^3)	240 000		
Protection measure index	High	Mean	Low
Sand volume per meter coast			
Width of the beach			
Width of dune			
Presence of sand bars			
Vulnerability	Low	Mean	High
Erosion index*			
Change in the coastline*			
Wave exposure**			
Obstacles for longshore drift			
Weaknesses			
Bathymetry			

*From Malmberg Persson et al., **From Länsstyrelsen Skåne, 2016.

The volume of sand per meter coast was classified as giving a high protection measure index when volumes were more than 300 $m^3 m^{-1}$, low protection measure index when the volumes were lower than 150 $m^3 m^{-1}$, and mean protection measure index in-between.

Width of the beach and sand dunes was estimated from orthophoto and elevation data. Width of the beach was defined as the flat part of the beach, without vegetation. If the beach was more than 35 meters wide, the protection measure index was classified as good, if it was less than 15 meters the protection measure index was classified as low, and in-between as mean. If the sandy area had sand dunes, the dunes were classified as giving a high protection measure index if the dunes were more than 40 meters wide, a low protection measure index if the dunes were less than 15 meters wide, and mean if the width was in-between.

The presence of sand bars was estimated from a scanning of the bathymetry conducted by SGU during the years 2012-2014. If several sand bars were present, parallel and in close connection to the shore, the protection measure index was classified as high, while if few and solitary sand bars were present, still covering the main part of the area, the protection measure index was classified as mean, and if sand bars were scares of absent the protection measure index was classified as low.

The erosion index and change of the coastline were presented in the SGU project (Malmberg Persson et al. 2016). Coast classified as beach with erosion were here classified as high vulnerability, while beaches with altering erosion and accumulation were classified as mean vulnerability and beaches with accumulation were classified as having low vulnerability.

Changes in the coastline between the years 1940 and 2010 were determined in the rapport by SGU (Malmberg Persson et al. 2016). If the coastline had retrieved between the years 1940 and 2010 we classified it as high vulnerability, no change was classified as mean vulnerability and low if the beach had increased.

Wave exposure was modelled by Aquabiota on behalf of Länsstyrelsen Skåne (2016) with Simplified Wave Model. Wave exposure was modeled in 7 classes, one being land, hence we used the remaining 6 classes and classified the two highest classes as giving a high vulnerability, the two lowest classes as giving low vulnerability and the two classes in-between as mean vulnerability. We looked at the wave exposure out to the depth of closure.

Longshore drift of sediment is important for many beaches. Anthropogenic constructions, such as ports and groins along the beach can hinder the longshore drift, and by visual analysis of bathymetry data and orthophotos we estimated if there were constructions disturbing the longshore drift to the sandy areas in our study. Areas were the longshore drift was negatively affected by constructions were given a high vulnerability, if the longshore drift was partly affected, or a construction affected different parts of the area differently, the vulnerability was classified as mean. For areas lacking constructions affecting the longshore drift, the vulnerability was classified as low, and for areas that had constructions, not affecting the specific area negatively, or even affecting it positively, nonetheless affecting another area negatively, were classified as low vulnerability but with effects on the surrounding.

Sand dunes can be damaged by high frequency of visits, and paths through the dunes increases the risk of overwash. Damages of the dunes can also increase the damages caused by sea flooding events. Low areas behind the dunes where the level of water can reach the dunes in case of flooding can damage the dunes from the landside. These kinds of weaknesses in the dunes were identified, and areas with several weaknesses were classed as having a high vulnerability, a few weaknesses classified as mean vulnerabilities, and no weaknesses classified as low vulnerability.

The angel of the slope of the seafloor close to shore is important for the energy in the waves when they reach the shore. With an angel was more than 1.7° (less than 200 meters to a depth of 6 meters) the vulnerability was classified as high, if the angel was less than 0.7° (500 meters or more to a depth of 6 meters) the vulnerability was classified as low, and in-between as mean.

For the areas with severe erosion according to SGU (Malmberg Persson et al. 2016) a new shoreline was estimated based on the theory of Bruun according to the following equation:

$$R = \frac{L}{B + h} * S$$

where *R* is the retreat of the shoreline, *L* is the cross-shore length of the active profile, which reaches from the closure depth, h, to B, which is the elevation of the beach of the maximum point to where sediment is transported from, and *S* is the sea level rise. We assumed a sea level rise of 1 meter, depth of closure varied between 2 to 7.2 meters along the coast of Scania. The active profile reached to the top of the dunes if dunes were present, and to the berm if no dunes were present. Input data in the analysis were elevation data and data from bathymetry scanning, using ArcGIS 10.3.

Results and Conclusion

A total of 130 areas with sand were identified along the coast of Scania. Out of the areas, more than 50 % of the total length of our areas had more than 300 m^3 sand per meter coastline, and around 20 % of the total length had less than 150 m^3 sand per meter coastline (figure 1). Areas with a large volume of sand, natural development of the beaches might be safe, although important buildings and infrastructure exists in close connection. Even if some sand is distributed from land to the sea bed close by, the sand still contributes to the protections of the infrastructure. The sand can also be brought back to land, and help the beach recover after storms.

More than 30 % of the length of sandy coasts were identified as potential areas of retreat of the coastline (figure 2). Additionally, 15 % of the sandy coast included segments where retreat could potential be possible, however, also parts where buildings or other infrastructure was present within 300 meters from the coastline. Most of the areas defined as potential retreat areas also contained large volumes of sand, 29 out of the 35 retreat areas had larger volumes of sand than 300 m^3 m^{-1}.

A few of the potential retreat areas were lowland and the volume sand lower. One such area was Falsterbonäset, an area at the southwest tip pf Scania. In this area the municipality is also planning for protective structures inland of the retreat area. Another interesting area suggested as retreat area is Hagestads nature reserve, one of the areas with severe erosion. However, the area lack buildings and infrastructure and erosion processes have been allowed undisturbed. This area could serve as a reference for erosions processes, and what could be expected in retreat areas.

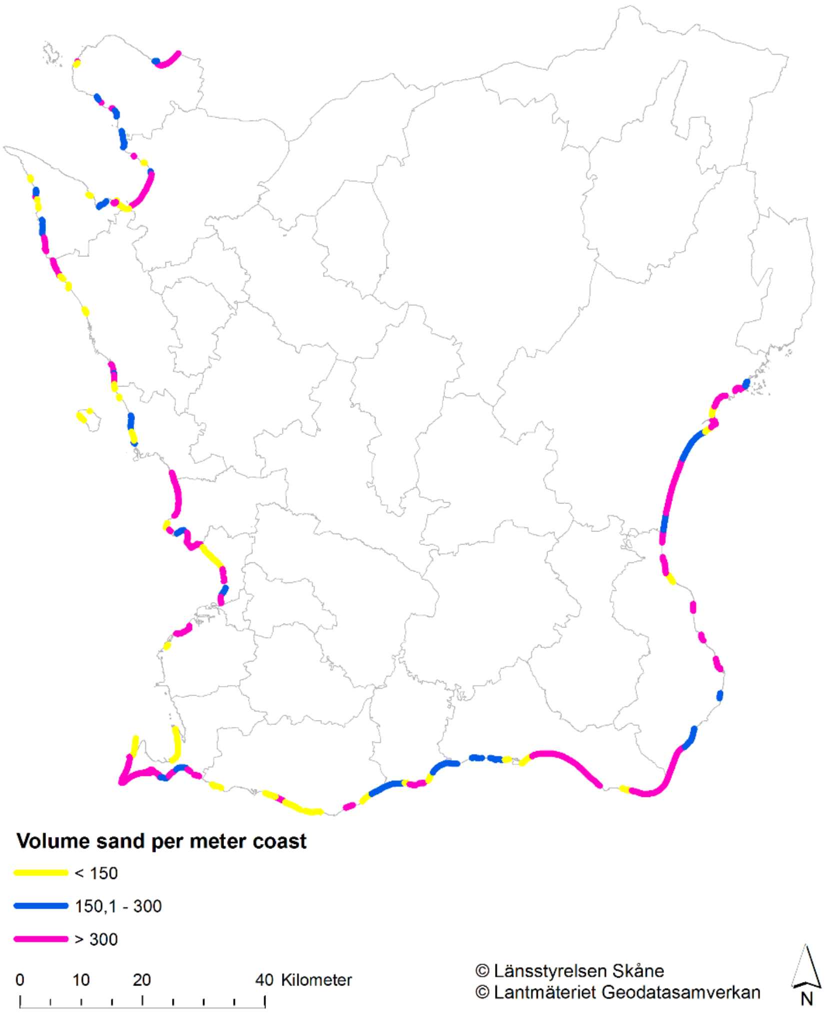

Figure 1. Sandy areas along the coast of Scania. The sandy beaches are colored based on the volume sand within the sandy areas per meter coast (m^3 m^{-1}).

To keep sandy beaches in Scania, it is important to keep the 300 meters free from buildings also in the future, particularly as the extension of the erosion is hard to predict, and the erosions will lead to larger withdraw of the shoreline than just the sea-level rise, according to Bruun.

Possible, single buildings within the retreat areas needs to be moved to allow undisturbed development of the shoreline. How to handle those sorts of actions needs to be discussed.

For the 24 areas defined to have severe erosion according to SGU, table 1 was filled out and discussed in our rapport, and presented in the map feature.

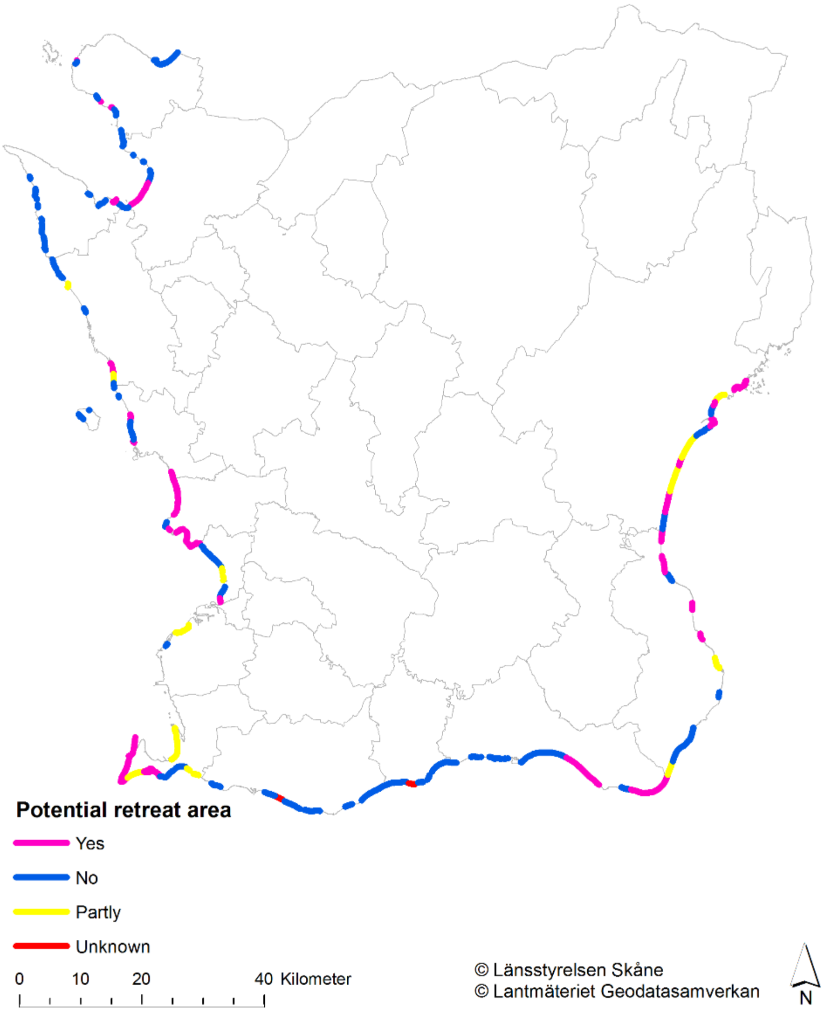

Figure 2. Sandy areas along the coast of Scania. The sandy beach is colored based on whether the area could potentially function as a retreat area, with no important infrastructure within 300 meters from the coast, partly with building or infrastructure within 300 meters from the coast, or not. A few could not be determined.

A major challenge is highly populated areas close to the coast located at low elevations. Not only the seawater is a threat, but also elevated groundwater. Moving the existing properties would be costly, and it is unlikely that the owners are willing to give up their properties unless the risks are evident. The Administrative board of Scania recently stopped new plans of constructions in such an area, as it is not reasonable to build in areas that will have severe problems in the near future.

Today we do not know how the area will progress, and as long as no longtime plan exist, to guarantee the persistence of the area, it is not wise to allow for more houses. However, we need to start discussions on how to handle areas like this, while we still have time to make changes. Sand nourishment is one possible action, however, sand is a limited resource, and also a demanded material for other purposes. An increase in the demand of a limited resource leads to higher costs of the material.

The theory of Bruun assumes the same elevation as the elevation where the active profile is measured on land, to continue further inland. If the elevation is higher inland – the estimated new shoreline is overestimated, and if the elevation is lower inland, sediment is "missing" from the redistribution according to Bruun, and the calculated shoreline will be an underestimation. A new shoreline according to Bruun was estimated for the areas with severe erosion, but only presented in the map feature when the assumption of equal elevation was met, more or less. We find that the assumptions for Bruun are rarely met along the coasts of Scania.

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