Sea-level change and forestry in Northern Jutland, Denmark

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Abstract: The global climate is changing, and these changes will bring considerable changes to many aspects of nature. One of the consequences of a global warming is a eustatic sea level rise. This phenomenon will result in permanent flooding of some areas in the northern part of Jutland, a rising groundwater table in some parts of the region and finally higher temporary floods in the region. Together these consequences result in some areas being unusable for forestry, and other areas unsuitable for some specific tree species. The forestry in the region works with long time horizons, and therefore a risk exists, that if consequences of sea-level change aren’t incorporated into the planning of the forestry in the region, then maybe trees will be planted in areas where they are going to die because of the rising sea-level, before they have reached an age for harvest. To avoid this situation, knowledge is needed about which areas that are to be affected by the sea-level change. In this article it is calculated which areas that are going to be affected by permanent floods until year 2100, if the sea around the region rises either 0,48 m or 0,88 m (the predicted sea-level rise and the worst-case sea-level rise calculated by the Intergovernmental Panel on Climate Change). It is also calculated which part of the coastline in Northern Jutland is going too be exposed to erosion by the year 2100, if the sea rises 0,48m. Finally it is calculated which areas in the region that are in danger of being affected by temporary floods once a year in the year 2100, if the sea rises either 0,48m or 0,88m. Finally these results are presented on maps that can be used by forest owners in the region, and it is calculated how large areas that are going to be affected in the region.

Introduction

According to IPCC’s (Intergovernmental Panel on Climate Change) predictions in TAR (Third Assessment Report) from 2001, the global average temperature is going to rise between 1,4ºC and 5,8ºC until the year 2100 [Houghton et. al. 2001]. Globally this warming is going to have a range of different consequences for nature. Some of these include global changes in precipitation and vegetation, increased storminess, reduction of sea ice, thawing of frozen ground and rise of sea level [Skinner and Porter 1999].

It is estimated that the cost of protecting humans and investments from a global sea-level rise of only 0,5m will amount to more than 25 billion dollars annually [Haggett 2001]. This shows that sea-level rise is an important consequence of climate changes, and therefore it is necessary to develop knowledge about the future consequences of sea-level rise.

The main factor behind the coming sea level rise is the fact, that the mass of water expands when the temperature of the water rises. Therefore a global warming will cause water in the oceans of the world to expand, and subsequently the sea level to rise [Strahler and Strahler 1992]. Other factors such as thawing of ice also contribute to the sea-level rise, but the expanding water mass is the main factor [Hansen 2004].

It is estimated that the world has experienced a eustatic sea level rise of approximately 8cm in the period 1900 to 1980 [Strahler and Strahler 1992], and IPCC estimates that the rise will continue, resulting in a rise between 0,09m and 0,88m between 1990 and 2000 [Houghton et. al. 2001].

The sea-level rise is going to affect Denmark in different ways. The most obvious consequence is that some areas will be flooded permanently. Other consequences include a rising groundwater table and higher temporary floods during storm events [Bendsøe et. al. 2003].

It is necessary to incorporate these consequences in all the relevant planning processes in society [Bendsøe et. al. 2003]. One of the sectors in society that have to incorporate the consequences of sea-level rise in its planning is forestry.

Today forests cover approximately 11% of Denmark. According to the national
forestry programme in Denmark, which was commissioned in 2002, this area has to be expanded to cover 20% - 25% during the next 80 to 100 years, which is also the period in which the sea level around Denmark is estimated to rise between 0,09m and 0,88m. Therefore it is crucial to the success of the national forest programme, that new forest is not planted in areas where the sea level rise is going to affect the trees negatively.

The only way in which this can be accomplished is by creating knowledge about which areas will be affected by the sea-level rise, and then communicate this knowledge to people working in the forestry in Denmark. This will enable these people to incorporate the coming sea-level rise in their planning.

Regarding the mentioned consequences of the sea-level rise, it is certain that all trees situated in areas which are flooded permanently will be killed by the sea level rise, and apparently some tree species will be affected negatively by more frequent floods during storm floods [Andersen 2004].

Because of this, the objective of this article is to identify which areas that are going to be affected by the sea-level rise until the year 2100. IPCC predicts, as mentioned earlier, that sea level is going to rise between 0,09m and 0,88m until the year 2100, with a rise of 0,48m as the most likely [Houghton et. al. 2001]. Therefore two scenarios have been modelled in this article, a rise of 0,48m (the most likely) and a rise of 0,88m (worst-case). Because of difficulties in handling large datasets in GIS (Geographical Information Systems), the analysis is only done for Northern Jutland.

Methods and Theory
When a phenomenon in the real world is going to be modelled in a GIS, some assumptions have to be made, simply because the real world is so complex that it is impossible to include all aspects of the phenomenon in the model [Longley et. al. 2001]. Therefore a crucial question regarding a GIS model of sea level rise is what to include in the model and what to exclude. The data available to this article ruled out the possibility of incorporating all scientific knowledge of coastal processes into the model, and therefore a simple modelling approach was used.

It can be said, that two ways of modelling sea-level rise exist, a simple method and an advanced method. In the simple method it is assumed, that all areas that have an elevation below the future sea level and adjacent to the sea will be flooded. The data needed to perform a “simple analysis” is an elevation model covering the area in focus and data about the coming sea-level rise [Titus and Richman 2000]. The weakness of the simple approach is the fact that coastal processes such as erosion and sedimentation are left out of the calculations [Edelvang 2004].

In advanced modelling of sea level rise, processes such as erosion and sedimentation, and information about waves, wind, sea-depth and coastal rock types is included in the model. These models are constructed in the same manner as atmosphere climate models, which are mathematical models relying on equations that describe the flows of energy and matter in the atmosphere. The advanced sea level models work in the same manner; the coastline in focus is participated into three dimensional boxes, and equations used to simulate the flows of energy and matter between these boxes [Edelvang 2004]. It is not possible to apply this method to large areas like Northern Jutland, because of two problems. The first problem is the fact that currently no advanced sea level model exists, that is able to calculate the consequences for Northern Jutland, and it would cost a lot to develop one and demand considerable scientific development work, which would be out of scope for this article. The second problem is the fact that precise advanced models need precise data to work. It would cost a lot of money to collect the data needed in advanced models for an area as large as Northern Jutland, and some data do not exists [Edelvang 2004].
Because erosion is left out of the model used in this article, a risk exists that the coastline in some areas will redraw further than predicted by the simple method. Therefore an erosion risk assessment has been made for the coastline predicted by the simple model. This can be used by the forestry in Northern Jutland in the following way: If the erosion risk on some parts of the future coastline are shown to be high, then it would be unwise to plant forest close to the predicted coastline in these high-risk areas. According to [Bryan et. al. 2001] the erosion on a given coast can be estimated by the exposure of the coast. Exposure is the length of open water in the direction of the prevailing wind [Bryan et. al. 2001]. In [Bryan et. al. 2001] the exposure of the coastline in focus is calculated so that the exposure value of the coast is awarded maximum points if there is 15km of open sea in the direction of the prevailing wind. Unfortunately [Bryan et. al. 2001] do not mention how exposure points are awarded precisely, for an example if there is a linear relationship between the length of open water and the exposure value or not. In this article exposure points are awarded by the following rules:

1 point: Not open sea up to 2,5km from the coast.

2 point: Open sea between 2,5km and 5km from the coast.

3 point: Open sea between 5km and 7,5km from the coast.

4 point: Open sea between 7,5km and 10km from the coast.

5 point: Open sea up to 10km from the coast.

There is a weakness in the method presented by [Bryan et. al. 2001], and that is the fact that only waves in the direction of the prevailing wind is seen as being responsible for erosion. Obviously wind coming from other directions will also create waves and therefore erosion. Calculating exposure values for eight directions, north, northwest, west, southwest, south, southeast, east and northeast has solved this problem. The eight different models have afterwards been summed together using information about how much time of the year the wind blows in each of the eight directions as weights. The result is a model that shows exposure values for the coastlines in Northern Jutland, in which all wind directions are implemented in the calculation. No precise knowledge exists about the future wind conditions in Northern Jutland and therefore existing wind data will be used, which will be a source of error.

A see-level rise will also cause future flood events to be more severe. A flood is defined as an extraordinary high sea level that rarely occurs and is caused by special wind- and weather conditions [Kystdirektoratet 2002]. A return period is the time between which two equal sea levels are reached in a given area, and the return level is the sea level that is reached once in a given return period [Kystdirektoratet 2002]. If the return level is 1,5m and the return period one year in a given area, this translates into the fact, that statistically the area will experience a flood once a year, where the water reaches a level 1,5m above normal sea-level. Sea level rises are going to affect flood events in a given area in two ways. Firstly if the return level of a one-year flood is 1m today, then it will be 1m + 0,48m = 1,48m after a sea level rise of 0,48m. Secondly climate change will most likely increase the amount of storms over Denmark, and also cause the storms over Denmark to be more powerful, thereby increasing the return level of floods [Fenger et. al. 2001]. A flood basically happens because a lot of water is forced into the coastal areas. Therefore information about sea-currents, wind, sea-depths and topography in the coastal areas is crucial to precise calculations of the extents of future floods. No precise data exist about future wind conditions above Denmark, and as a result this precise method cannot be used. A simpler method is therefore needed, and in this article the extent of a “minimum” one-year flood in Northern Jutland is predicted by adding the future sea level rise to the current return level.
of a one-year flood, and then identify which areas that have elevations beneath this level and contact to the sea. It is not known how powerful the storms above Denmark are going to be in the future, and therefore a range of scenarios are calculated in this article to show different scenarios:

1: Extend of a one-year “Minimum” flood calculated by adding 0.48m to the height of a currently one-year flood.
2: Extend of a one-year flood calculated by adding 0.48m to the height of flood 10% higher than a currently one-year flood.
3: Extend of a one-year flood calculated by adding 0.48m to the height of flood 20% higher than a currently one-year flood.
4: Extend of a one-year flood calculated by adding 0.48m to the height of flood 50% higher than a currently one-year flood.
5: Extend of a one-year “Minimum” flood calculated by adding 0.88m to the height of a currently one-year flood.

This section has now presented the theories and methods behind the analysis carried out in this article. The next section will now present the practical analysis, and how these were made in GIS.

Sea level rise in Northern Jutland

Data
This section will present the data needed for the analysis. The most important data model is a Digital Elevation Model (DEM) covering Northern Jutland. Currently two DEM’s covers Northern Jutland, one made by the firm COWI and one made by Kort og Matrikelstyrelsen (KMS), and therefore it’s important to use the DEM that is best suited for the challenge. Both models have accuracies around 2m, and therefore it was necessary to analyse how the models have been created to choose the one best fitted for the task. The analysis of the models showed that the DEM made by KMS was best suited for the task, because this model contained most details.

The next model that is needed is a vector model showing the extent of the sea around Northern Jutland. This model will be used in the selection of areas that have elevations beneath the future sea level and are adjacent to the sea. This model was made by using the DEM covering Northern Jutland, vector polygon models covering the two adjacent counties¹ and appropriate vector based calculations in ArcView 3.2a and ArcGIS 9.

The next input needed for the analysis are wind data for the weighting of the eight exposure models. A problem in this regard is the fact that the wind is blowing differently during the year on different locations in Northern Jutland. Therefore it was chosen to use data from one wind measure station located in the centre of the region, a station located in Aalborg run by Danish Meteorological Institute (DMI). The newest data from this station are from the period 1/1-1989 to 31/12-1998. In this period the wind measurements were divided in twelve different directions [Cappelen and Jørgensen 1999]. The exposure calculations in this article will be done using Map Algebra, and therefore it is only possible to calculate exposure for eight directions, and consequently the wind measurements made by DMI in Aalborg were converted to eight directions.

The final input needed for the analysis is a vector model showing the height of a contemporary one-year flood in the existing sea level measurement stations in Northern Jutland². In the publication [Kystdirektoratet 2002] information about the height of a one-year flood in each measurement station in Northern Jutland is available and it is specified which city each station is situated in. By finding the coordinates of a point on the coastline by the mentioned cities and digitalise these coordinates as points, a vector point model showing the locations of each

¹ The county’s of Viborg and Aarhus.
² 9 stations exist in Northern Jutland, but because a lack of stations on the west coast, one station in Viborg county was also included in the model (this station is situated on the west coast of Jutland but outside North Jutland county) to give a more realistic picture.
measurement station were created. In the attribute table of this model, information about the height of a contemporary one-year flood in each station was saved. This point model will act as input to the interpolation of a raster model showing the height of a one-year flood all over Northern Jutland.

This section has now presented the input data needed for the analysis of how sea level rise is going to affect Northern Jutland. The next section will now present how the analysis was carried out in praxis.

**Analysis – Permanent flooded areas**

All calculations in this section have been carried out in ESRI’s ArcGIS 9.0 and ArcView 3.2a with Spatial Analyst and 3D Analyst extensions.

Firstly KMS’s DEM was converted to a raster model. Thereafter the cells with elevations beneath 0.48m and 0.88m were identified using Map Algebra expressions, and these cells were then converted to polygons. This conversion is problematic because cells are defined as one polygon if they are neighbours at a “long side” and defined as two different polygons if they are neighbours “by the corners”. Therefore it is not possible to identify all the areas that will be flooded by using the “Select by Location” function in ArcGIS 9.0 to select the polygons that have contact to the sea-polygon, and the error that occurs if this is tried is shown at figure 1.

The solution to the error described in figure 1 is to apply a buffer of 10m to each polygon (the cell size in the original raster were 25m). Thereafter all the buffer polygons that have contact to the sea are identified, and finally all the original polygons showing areas beneath the futures sea level that have contact to the selected buffer polygons are identified. This method solves the problem mentioned in figure 1, and the method is illustrated in figure 2.
Figure 3: The maps show the same area as figure 1. On the first map the red areas are the areas beneath the future sea level onto which a buffer of 10m has been applied. On the second map the buffer polygons with contact to the sea have been identified (red areas). On the third map all the areas with elevations beneath the future sea level and contact to the red polygons on the second map have been identified. As can be seen on the third map, this calculation method solves the problem mentioned in figure 1.

By using the mentioned method it has been identified which areas in Northern Jutland that will be flooded if the sea level rises either 0.48m or 0.88m.

The next step in the analysis is to convert the DEM covering Northern Jutland into a vector polygon model, and subtract the polygons showing which areas that are going to be flooded from this model. The result is a polygon model that shows the extent of Northern Jutland in 2100, and thereby also the future coastlines.

**Analysis – Exposure on future coastlines**

Firstly the model showing the future extent of Northern Jutland is merged with a model showing the extent of the adjacent counties, because areas in these regions will provide shade for some coastlines in Northern Jutland, and therefore affect the exposure values on these coastlines. Preferably models showing the extent of the adjacent regions in 2100 should be used, but it was not possible to obtain DEM’s over these areas and calculate these, and therefore models showing these areas as they are today are used in the analysis, which is a source of error. The next step was to convert the vector model to a raster model called “nj2100r” with a cell size of 100x100m. In the conversion the cells were awarded the following values 1 (land) and 0 (sea). The exposure for a given wind direction were then calculated by using the following Map Algebra expression in ArcGIS 9.0’s Spatial Analyst extension:

\[
\text{Con (}\text{nj2100r} > 0, \\
\text{Con (focalsum(}\text{nj2100r}, \text{wedge, 25, 359.714, 0.286}) > 1, 1, \\
\text{(Con (focalsum(}\text{nj2100r}, \text{wedge, 50, 359.714, 0.286}) > 1, 2, \\
\text{Con (focalsum(}\text{nj2100r}, \text{wedge, 75, 359.714, 0.286}) > 1, 3, \\
\text{Con (focalsum(}\text{nj2100r}, \text{wedge,}
\]

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2005
The expression above uses the three functions Con, Wedge and Focalsum to apply an exposure value to each cell in the grid. Con is used as a conditions expression: Con (“condition”, “to do if true”, “to do if false”) [McCoy 2002]. The first Con expression tests whether the raster cell in focus is a sea-cell or not, if it is a sea-cell (has the value 0) then it is given the value 0 again. If not the second Con expression is tested. The second Con expression uses a combination of focalsum and wedge to calculate the sum of 25 cells due east of the cell in focus. Focalsum defines that it is the sum of the cells that is going to be calculated and wedge, 25, 359.714, 0.286 defines that it is the sum of the cells in the direction between 359.714 and 0.286 degrees (0 degrees is due east) from the main cell in a range of 25 cells (equals 2.5 km) that are going to be calculated [McCoy 2002]. If there is land in this area the sum will be larger than one (one land cell (value 1) plus 24 sea-cells (value 0) equals 1), and therefore the cell will be assigned the value 1. If the Con expression is false, then the next Con expression will be tested. The next Con expression tests whether there is land between 2.5km and 5km from the cell in focus and so forth.

The Map Algebra expression presented above is used to calculate “exposure raster models” for the eight direction mentioned earlier by changing the angels in the wedge formula to the following values:
Northeast (44.714, 45.286), East (359.714, 0.286), Southeast (314.714, 315.286), South (269.714, 270.286), Southwest (224.714, 225.286), Vest (179.714, 180.286), Northwest (134.714, 135.286), North (89.714, 90.286)

The eight rasters resulting from these calculations are finally summed together, and the wind data presented in the past section is used as weights. The result is a raster model where the cell value 0 symbolises water, 1 symbolises land without exposure (erosion) and cells with values above 1 are affected by erosion, the higher the number, the more powerful the erosion.

Analysis – Temporary floods
The final thing that had to be calculated is the extent of one-year floods in Northern Jutland in 2100. The point vector model showing the location of 10 sea level measurement stations was interpolated to a raster by using the Inversed Distance Weighting function. The surface created by the interpolation can be seen as a theoretically sea surface during an event in which all the measurements stations reach a one-year flood simultaneously, on the assumption that Northern Jutland does not exists! Of course it’s unlikely that all stations would experience a one-year flood simultaneously, but the raster surface should be seen as a theoretically worst-case scenario. By adding 0.48m to the cell values in the raster a surface is created that shows the extent of a “minimum” one year flood in the year 2100, if the sea rises 0.48m until then. Finally this surface is subtracted from the DEM made by KMS, and all areas in the resultant model with elevations below 0m and contact to the sea are the areas that are going to be flooded during a one year “minimum” flood in the year 2100. These areas are identified using the same method as was presented earlier in this section to identify all the areas that are to be flooded permanently in KMS’s DEM model. This method was used to identify the extent of the five different one-year flood sceneries presented in the method and theory section.

This and the last two sections have now presented the analysis carried out in GIS to identify the areas in Northern Jutland that are going to be affected by sea-level rise until 2100. Next section will now focus on the results, the uncertainties in these and the possible use of these results.

Sea level rise in Northern Jutland: Results and uncertainties
The results of the analysis are quite difficult to show as maps in an article printed in this
size (A4). Therefore 6 maps presenting the consequences for only a small area of Northern Jutland will be presented. These maps will illustrate how the consequences of sea level rise can be illustrated on a map, which can be used in the forestry planning in Northern Jutland. The maps can be seen on supplement one in the end of this article. Exposure is divided into three classes on the map showing erosion risk, because after the summing of the eight exposure rasters only exposure values up to 4 points existed, and therefore three exposure classes were created: 1-2 = low erosion, 2-3 = medium erosion and 3-4 = high erosion. In the real world these maps could be presented on a webpage.

Because of the difficulties in showing the consequences of sea level rise in Northern Jutland using maps alone a quantitative examination was also carried out, in which it has been identified how much land that is going to be affected by permanent floods, and also the land use of the affected areas. The data used for this examination was the two models showing the extent of permanent floods after sea level rise of either 0,48m or 0,88m and a land use model. The land use model used is the Danish “Areal Informations System (AIS) Arealanvendelseskort”. This model was created with the specific task of being a land use model that could be used for statistically and geographical analysis on a regional level [Nielsen et. al. 2000]. Therefore the model is well suited for the use described above. The land use model is a vector model, and the models showing the extent of the permanent floods are also vector models. Therefore it was possible to determine the size of the areas affected by the floods and the types of land use affected, by applying appropriate vector and raster based calculation techniques in ArcGIS. The results will be presented and discussed in the conclusion.

Because of the important role the results from this article can play in society, it is necessary to discuss the sources of error in the results. Obviously there are some weak points, firstly the fact that a simple modelling approach was used to simulate sea level rise. But at the time the models were created no better methods existed that would work on a area as large as Northern Jutland, and as discussed earlier the data existing is not good enough to form the input in advanced models. Actually the question of missing data is the core in a discussion on the uncertainties in the results. For an example the DEM used was relatively imprecise with an accuracy of 2m, but the best one existing, and precise data about winds above Northern Jutland in the year 2100 does not exists. Therefore it can be said, that there is no point in making more precise models regarding coastal processes or temporary floods, before better data about the contemporary situation has been collected, for an example a better DEM. Therefore it must be concluded that the results reached in this article is not likely to be 100% correct, but it is impossible to estimate how precise they are, because no key exists. The models applied are the best currently existing and the data used are the best currently existing. Therefore it must be up to forest owners and society in general to decide whether they want to use the results or not. One way in which planners for example could use the results is as a source of knowledge about which areas in the region that should undergo further and more detailed local studies, for an example build up areas with risk of being flooded. Next section will now present the conclusion and a brief discussion about further work with this subject.

**Conclusion and Further work**

The objective of this article was to identify which areas in Northern Jutland that are going to be affected by the sea-level rise until the year 2100. In the article a method was presented to calculate which areas in a given region that will be flooded permanently because of the coming sea level rise, which part of the new coastline that will be subject to erosion and which areas in the region that will experience temporary floods during
storms. Finally this method was applied to Northern Jutland, and the practically aspects of the calculations were presented. Table 1 shows what types of land use that are going to be affected if the sea rises either 0,48m or 0,88m, and how large areas that will be affected. It shows, that if the sea level rises 0,48m around Northern Jutland then approximately 17737 hectares will be flooded permanently, and if the sea level rises 0,88m then the area will be around 24530 hectares. Of these areas only 340,4 and 730,2 hectares is currently forest, which is a relatively small area compared to other posts in the table such as agricultural lands. Therefore it is tempting to conclude that information about the coming sea level rise is unnecessary to the planning in the forestry in the region, but that conclusion would be a mistake. As mentioned earlier a Danish national forestry programme exists, and one goal of that is to approximately double the area of forest in Denmark before the year 2100. Therefore it is crucial that the forest owners and other people who wish to plant forest know which areas that are going to be affected by sea level rise, so that they do not plant forest on for an example some of the areas of contemporary agricultural land that will be flooded in the future. The conclusion must therefore be, that it is very important that the knowledge produced in this article is used in the planning of the forestry in North Jutland.

Finally a couple of words should be said about possible further work on this subject. The results reached in this article can help to prepare Northern Jutland for the coming sea level rise, but currently only one person actually has the data models presented in this article, and that is the author of this article. This situation does not help to create a better future for Northern Jutland. It is necessary that the models and thereby the knowledge presented is spread out to the public so that people in society can act after this knowledge. Therefore I am currently working on a project about how the results from this article could be shown on a webpage designed for gymnasium students in Denmark, so that this group understands the results and can thereby use them in their further work.

Other things could also be done to enhance the results from this article, as mentioned earlier better data could be collected, such as a better DEM, and the models and calculations methods could be enhanced.

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Table 1

<table>
<thead>
<tr>
<th></th>
<th>Area 0,48m rise (hectare)</th>
<th>Area 0,88m rise (hectare)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Open built up area</td>
<td>258,7</td>
<td>431,9</td>
</tr>
<tr>
<td>Buildings in open country</td>
<td>105,1</td>
<td>166,0</td>
</tr>
<tr>
<td>Bridge</td>
<td>7,7</td>
<td>11,9</td>
</tr>
<tr>
<td>Highway</td>
<td>0,8</td>
<td>1,2</td>
</tr>
<tr>
<td>Road &gt; 6m</td>
<td>15,0</td>
<td>22,2</td>
</tr>
<tr>
<td>Road 3-6m</td>
<td>34,3</td>
<td>61,4</td>
</tr>
<tr>
<td>Railroad</td>
<td>1,5</td>
<td>8,4</td>
</tr>
<tr>
<td>Agriculture</td>
<td>9429,3</td>
<td>13358,4</td>
</tr>
<tr>
<td>Grass-grown areas</td>
<td>22,2</td>
<td>35,1</td>
</tr>
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<td>Grass in build up areas</td>
<td>1,2</td>
<td>3,4</td>
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<td>Deciduous forest</td>
<td>164,2</td>
<td>326,2</td>
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<tr>
<td>Coniferous forest</td>
<td>174,0</td>
<td>400,4</td>
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<tr>
<td>Mixed forest</td>
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<td>Common</td>
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<tr>
<td>Moor</td>
<td>283,4</td>
<td>531,3</td>
</tr>
<tr>
<td>Sand / Dune</td>
<td>235,4</td>
<td>331,3</td>
</tr>
<tr>
<td>Other surface with sparse vegetation</td>
<td>24,8</td>
<td>32,3</td>
</tr>
<tr>
<td>Meadow</td>
<td>213,9</td>
<td>291,4</td>
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<tr>
<td>Wet areas</td>
<td>1061,5</td>
<td>1436,3</td>
</tr>
<tr>
<td>Bog</td>
<td>610,3</td>
<td>778,2</td>
</tr>
<tr>
<td>Marshland and tidal meadow</td>
<td>4084,9</td>
<td>4918,0</td>
</tr>
<tr>
<td>Lake</td>
<td>821,9</td>
<td>1119,6</td>
</tr>
<tr>
<td>Stream &gt; 8-12m</td>
<td>112,0</td>
<td>154,0</td>
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<tr>
<td>Unclassified</td>
<td>44,4</td>
<td>60,9</td>
</tr>
<tr>
<td>Total area</td>
<td>17737,8</td>
<td>24530,6</td>
</tr>
</tbody>
</table>

Acknowledgement
This article has been written over a project the author made at 7. semester at the Spatial Information Management specialisation at Geography at Aalborg University in the fall of 2004. The full project (125 pages in Danish) can be downloaded from the following address: www.plan.aau.dk/~khre02/. The author is grateful to all the people who helped create that project and this article, and therefore a big thank you shall go to the following people: Henning Sten Hansen, Lars Bodum and Lars Brodersen who helped create the project and this article; Bent Egede Andersen, Claus Riber Knudsen, Jan Kloster Staunstrup, Karen Edelvang, Ole Gregor, Peter Ilsoe, Peter Momme, Poul Frederiksen, Rune Andersen, Anne Buch-Larsen, Esben Norby Clemens, Ian Berg Sonne, Jørgen Bierdings, Thomas Hunter Eriksen and Thorben Brigsteds Hansen.

References
[Andersen 2004]: Interview of forest supervisor at Buderupholm Statsskovdistrikt in Denmark Bent Egede Andersen 19/11-2004.


Supplement One
The following maps show how different sea-level sceneries will affect a small area of Northern Jutland near Mariager Fjord.